Team Executive Summary

The Dynamic Response of the Environments at Asteroids, the Moon, and moons of Mars (DREAM2) team led by Dr. Bill Farrell at Goddard Space Flight Center (GSFC) examines the complex three-way interaction between the harsh space environment, the exposed surfaces of airless bodies, and human systems near these affected surfaces. During its fifth program year the team produced/published over 25 papers on the space environment at airless bodies, including the Moon. The team also was recently awarded the prestigious Robert H. Goddard Award for excellence in science, being specifically cited *'For excellence in the application of space environmental science to exploration applications'.* In the area of surface interactions, the team presented a new model of the solar wind implantation, OH creation, H diffusion and exospheric H_2 creation that fits the current surface and exospheric observational sets. They also performed new laboratory experiments in the GSFC Radiation Facility of proton implantation and hydroxyl creation in mineral samples and lunar samples, showing a change in the 3 micron OH feature in the more complex lunar sample mineralogy. In the area of exospheric research, the team published a generalized model of exosphere creation that examines the potential development of a bounded surface exosphere across all body sizes. They also modeled exospheric water liberated at the lunar surface by impacts in support of LADEE mission results. In the area of space plasma, team members used ARTEMIS data to detect the tenuous lunar ionosphere about the Moon. In radiation research, the team continues to monitor galactic cosmic ray flux and allowable astronaut flight days during this unusual period of weakening solar cycles. They also published a review paper on space weathering from deep dielectric discharge that can occur at cold regions at the Moon. In an intermural effort, team members performed research in support of the now-canceled Resource Prospector (RP) mission, including modeling the landing plume and its effect on the near-rover volatile environment, the effect of Earthshine on polar volatiles, and rover charging in shadowed regions near the poles. Many of these studies were presented at the SSERVI Forum in mid-summer of 2018 and apply not just to RP but to any rover mission to the lunar polar regions. To assist in enabling this array of exciting research, DREAM2 continues to support an outstanding intern program— with many students from a Howard University-DREAM2 collaboration established in 2013. The team continues to integrate many post-doctoral fellows and graduate students at Goddard and at partnering institutions. DREAM2 also works in close coordination with our SSERVI partnering teams (eg. VORTICES, IMPACTS and REVEALS), especially in the areas of surface interactions and exospheric research. The expertise is intimately connected across teams triggering many new joint research projects.

1.0 DREAM2 Team Project Report

DREAM2 has 4 space environmental themes in the area of space plasma interactions at airless bodies (1.1), collisionless atmospheres or exospheres formed at airless bodies (1.2), radiation environment (1.3), and surface interactions (1.4). DREAM2 also has 2 derived themes: one being team intermural studies, like that recently performed in support of Resource Prospector (1.5) and the other being DREAM2's footprint into mission activities (5.0).

1.1. Plasma Environment

The DREAM2 plasma team continued its successful campaign to understand the impact of the space environment on airless body surfaces and exospheres of all scales. Airless bodies likely represent the most common type of object in our Solar System and beyond, and they interact directly with the space environment, which consists in large part of plasma. By most estimates, more than 99% of the visible matter in the universe is ionized and therefore classified as plasma. The plasma-surface and plasma-exosphere interactions that the DREAM2 plasma team investigates are therefore of fundamental importance in our universe, and have implications for airless bodies of all sizes both within and outside of our Solar System.

The DREAM2 plasma team conducted fundamental data analysis and theoretical investigations focused on the Earth's Moon and other small bodies. Highlights include fundamental investigations of the physics of the interaction of the solar wind protons with unmagnetized areas of lunar regolith, and the characteristics of the resulting scattered/reflected protons [Lue et al., 2018]. This work is a companion paper to the work by Poppe et al. [2017], which studied the reflection of protons from magnetized regions of the Moon. DREAM2 plasma team members also studied the effects of these reflected protons on the near-Moon plasma environment, with an oral presentation on this topic at AGU by Ms. Stephanie Howard. The DREAM2 team also studied the trailing wake downstream from the Moon, utilizing a novel technique to infer wake electric fields from electron measurements, and comparing to a theoretical treatment of an asymmetric wake. This work was presented by Dr. Shaosui Xu at AGU, and will be submitted to GRL this month.

DREAM2 members were also active in planning the next steps in lunar exploration, participating in the Lunar Gateway workshop, making presentations on the use of the platform to study solar wind and geomagnetic tail plasma and the use of a patch plate onboard the platform to examine solar wind implantation, diffusion and hydroxylation.

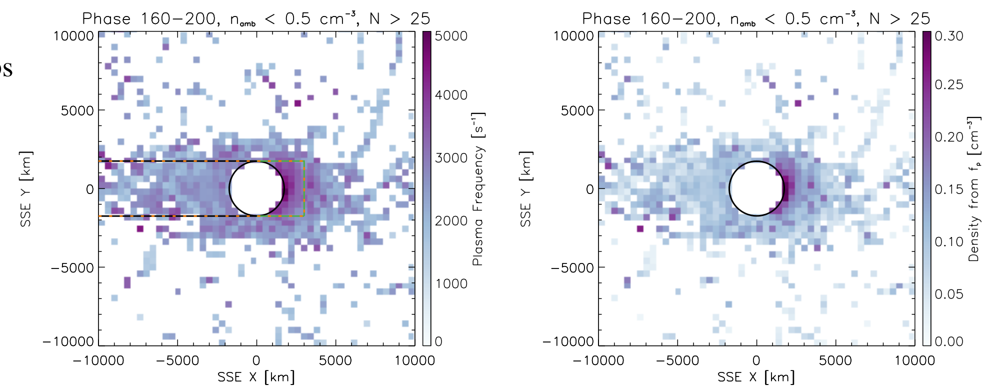

Figure 1.1.1. Frequency of narrowband plasma oscillations (left), and the resulting inferred ionospheric density (right) near the Moon in the lunar geomagnetic tail.

Another highlight of the DREAM2 plasma team's 2018 research was a comprehensive investigation of the lunar ionosphere in the geomagnetic tail (Figure 1.1.1) [Halekas et al., 2018]. In the solar wind, ionized constituents of the Moon's exosphere do not comprise a significant portion of the charged particle density, and do not appreciably perturb the local plasma environment. However, in the tenuous environment of the Earth's magnetic tail, the Moon is often the dominant source of plasma, and this plasma can significantly affect the local environment. Halekas et al. [2018] used ARTEMIS measurements of electric field oscillations to probe this tenuous ionosphere and determine its properties and dynamics.

1.2 Exospheres at Airless Bodies

Exospheres, or collisionless atmospheres, form as a direct result of space weathering of the surfaces at airless bodies. Solar radiation, space plasmas, and meteor impacts all create outgassing in the form of thermal, photonic, and electron desorption, plasma sputtering and impact vaporization. Depending upon the species released, the ejection velocity, and the gravity of the body, the material can remain in the local space environment to form a surface bounded exosphere.

DREAM2 team members continue to contribute to knowledge of the lunar volatile and exosphere environment from observations, Monte Carlo models, and laboratory studies. Highlights include:

Hurley and Benna [2018] simulated lunar exospheric water events from meteoroid impacts. Their model calculates the probability of measuring any given density from the water vapor released, given a meteoroid impact mass distribution and water content. They calculate the mission profile required to measure the water released by meteoroid impacts on the Moon for >1% mass fraction of water. Figure 1.2.1 illustrates the model results of a 1 gram water release at 5000K at a time 30 seconds after impact.

Prem et al. [2018] performed Monte Carlo simulations of volatile transport on the Moon and other airless bodies with and without a surface roughness model. They conclude that small scale temperature variations and shadowing lead to a slight increase in cold trapping at the lunar poles accompanied by a slight decrease in photo-destruction.

Killen et al. continue to observe the lunar sodium exosphere remotely using their coronagraph situated at the Winer Observatory in Sonoita, Arizona. They reported results featuring possible north/south asymmetries in the lunar sodium exosphere [Killen et al., paper under review, Icarus, 2019].

Sarantos provided modeling support for ground-based Fabry-Perot observations of the lunar sodium exosphere. They reported that the sodium effective temperature distribution of the sodium exosphere to be approximately a symmetric-function of lunar phase with respect to full Moon. Within magnetotail passage they found temperatures in the range of 2500 – 9000 K [Kuruppuaratchi et al., 2018], consistent with the Killen et al. results.

Hodges [2018] performed a time-dependent simulation of the argon-40 exosphere of the Moon that spans 4 draconic years. He shows that the semiannual oscillation of argon identified by the neutral mass spectrometer on the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft is consistent with adsorptive respiration in seasonal cold traps near the lunar poles. The magnitude of the oscillation requires that high energy adsorption sites on soil grain surfaces at polar latitudes be free of water contamination.

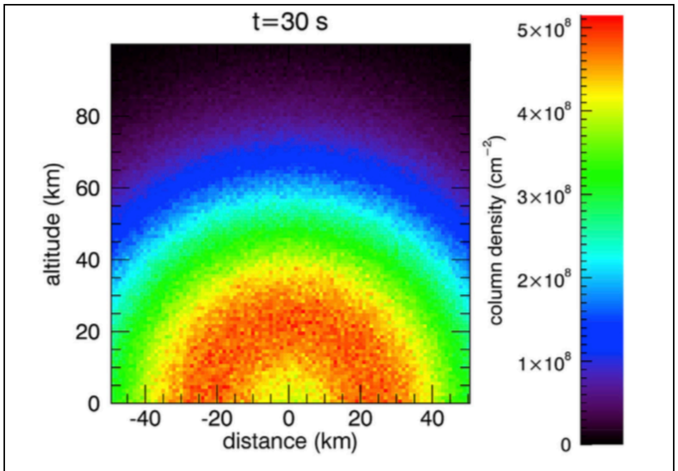

Figure 1.2.1 – The simulated water vapor cloud from a 1 g water release at 5000K (a temperature consistent with impact vaporization) [Hurley and Benna, 2018].

McLain and Keller continue to perform laboratory studies of gas sorption on regolith material at low temperatures to simulate the effects in lunar polar and nightside regions. These adsorption/desorption experiments are being performed in a separate UHV surface science chamber designed to measure laser-induced thermal desorption(LITD) from lunar soils. These LITD data indicate that the maturity of the lunar soil significantly increases the distribution of adsorption sites. Therefore, the temperature range at which volatiles like argon and carbon dioxide stick and desorb is significantly higher than that of less mature soils.

Killen and David Williams are continuing a study of the lunar exosphere using the recently archived LACE data from Apollo 17 [Killen et al., paper under review, Icarus, 2019]. In addition, Killen is collaborating with Prabal Saxena, Avi Mandell and Noah Petro on examining moderate volatile loss through lunar history [Saxena et al., paper under review, Nat. Geosci, 2019].

DREAM2 was the inspiration of two smallsat efforts funded under NASA's PSDS3 solicitation: Mike Collier led the PRISM (Phobos Regolith Ion Sample Mission) cubesat development and Tim Stubbs led the BOLAS (Bi-sat Observations of the Lunar Atmosphere above Swirls) tethered cubesat mission development.

1.3 Radiation Environment and Humans

The DREAM2 radiation team continued to explore the changing space radiation environment and how energetic charged particles affect the surface of the Moon. Unlike plasmas, which interact with the surfaces of airless bodies, galactic cosmic rays (GCRs) from outside the Solar System and solar energetic particles (SEPs) from solar flares and coronal mass ejections can penetrate regolith down to ~1 m. These penetrating particles can have significant effects on lunar regolith, and they create a radiation hazard for missions exploring the Moon, moons of Mars, and asteroids.

One highlight of this year's work is the continued investigation of how SEPs can cause dielectric breakdown in lunar regolith [Jordan et al., 2019]. Previously, the team showed that permanently shadowed regions (PSRs) are so cold that large SEP events can cause significant deep dielectric charging in the regolith; the charging can increase the subsurface electric field to the point of dielectric breakdown [Jordan et al., 2017]. The team also showed that breakdown could weather, (i.e., melt and vaporize), regolith in PSRs as much as meteoroid impacts. Building on this work, Jordan et al. [2019] found that the lunar nightside is also cold enough for breakdown to occur, and that breakdown weathering may have affected 3-10% of all gardened regolith on the Moon (Fig. 1.3.1). If so, breakdown-weathered material may be present in the Apollo samples—perhaps "masquerading" as the products of impact weathering. The team also conducted pilot experiments that lay the foundation for future laboratory explorations of how breakdown affects regolith grains.

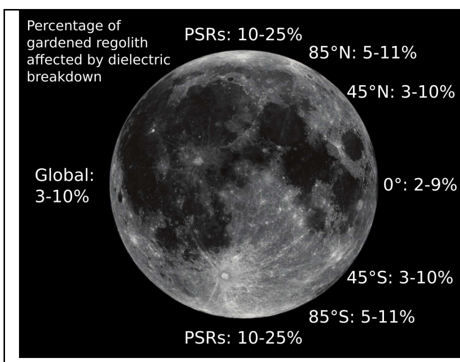

Fig. 1.3.1. Predictions for the percentage of gardened regolith that has been melted or vaporized by dielectric breakdown as a function of latitude and location. Breakdown-weathered material may be present in Apollo soil samples. (Figure from Jordan et al. [2019])

Another highlight is the team's work showing that the space radiation environment in the inner Solar System is worsening more than predicted—something that was not expected when DREAM2 began [Schwadron et al., 2018]. The solar minimum of cycle 23-24 was the longest in over 80 years, and cycle 24 continues to exhibit abnormally low activity. This enables GCRs to enter the inner Solar System more easily, and it has caused radiation dose rates on the lunar surface to be ~10% higher than the team had previously predicted [Schwadron et al., 2014]. This era of anomalously low solar activity suggests the Sun may be entering a new grand minimum, that is, an extended period of reduced activity. Yet although solar activity is low, large SEP events can occur with little warning: in September

2017, the largest event in almost a decade occurred after more than 1.5 years of quiet conditions. This work by the radiation team highlights the need to understand what the changing solar and radiation environment implies for the human and robotic exploration of the Moon, moons of Mars, and asteroids.

1.4 Surface Interactions

The harsh space environment—including impactors, energetic plasma, and radiation—creates damage within the regolith-rich surfaces at the Moon and other airless bodies. In PY 5, DREAM2 team members further examined the surface response to this environment.

Team members Tucker, Farrell, Killen, and Hurley [Tucker et al, 2019] published a new model of solar wind hydrogen implantation and expected surface hydroxylation, and the formation of the H_2 exosphere (Fig.1.4.1). The model assumes that solar wind protons implant into exposed surface and diffuse out of the surface by hopping from O to O in the regolith oxygen to form surficial metastable OH. The model uses diffusion rates from Fink et al. [1995] and Farrell et al., [2017], and tests modifications of these rates by changing the activation energy of the H diffusion. The model predicted the amount of retained hydrogen at the Moon—including the effects of H atom diffusion in damaged, irradiated silica surfaces. The model then included hydrogen surface loss by recombinative desorption of two H atoms in the top surface to exospheric molecular hydrogen (H_2) via $H + H = H_2$. The results suggest that the H_2 exosphere sensed by LRO/LAMP at 5000/cm^3 is controlled by the surface retention of H atoms – and a Fink-like diffusion is consistent with the H_2 exospheric values. If diffusion of H in the top surface was slower than the Fink et al. rates, the H_2 exosphere would be substantially less dense and the surface H content would be substantially higher. The model also predicts a lunation variation in OH content that was more recently confirmed in the IR observations.

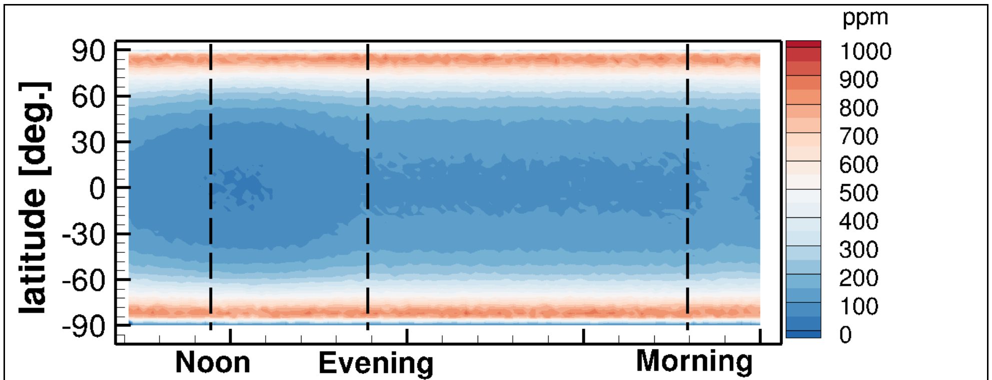

Figure 1.4.1: A new model of the hydrogen (in the form of metastable OH) buildup from solar wind proton implantation and subsequent Fink-like diffusion [from Tucker et al., 2019]. Surface loss of this hydrogen is via recombinative desorption of a pair of H atoms into exosphere H_2.

McLain, Farrell, Keller, and Hudson continue their laboratory investigation of proton implantation and associated hydroxylation using the unique Goddard Radiation Facility. In PY5, they compared the ion implantation and OH creation of fused silica to that found in lunar samples. They found that for the complex mix of oxides (SiO_2, FeO, etc) in an actual lunar sample that the 3 micron feature appears different from pure silica – with the maximum depth of the OH feature upshifted in wavelength. This work was presented at the 2018 SSERVI Forum.

Team members Hartzell and Marshall published a paper on astronaut shaking as a means for removing adhered dust at small bodies like Phobos (see Section 1.6 also)– finding that shaking cannot remove small (<10 micron sized) grains due to the stronger cohesion forces. Team members Stubbs and Glenar have recently published a paper on the radiated power from sunlight reflected from the Earth (i.e., Earthshine) in support of the Lunar Prospector Mission (see Section 1.5).

1.5 DREAM2 Intramural Studies: The Space Environment affected by Resource Prospector

During PY4 and 5, the team initiated a set of studies in support of the now-cancelled Resource Prospector (RP) mission. The rover mission was meant to examine the surface and sub-surface volatile environment in the polar regions, including roving into regions of permanent shadow. A drill was included as part of the package. DREAM2 co-I Tony Colaprete was the instrument build lead of the RP Near IR and Visible sensing system (NIRVSS) and acted as a liaison between DREAM2 and the RP team.

Specifically, DREAM2 team members created models of RP rover wheel charging that define a limit to rover speeds in low plasma density PSR regions. If the wheel moves over the shadowed surface too fast, excess tribo-charging could occur in PSR regions (in the region of low plasma influx). Partial remedies include having any rover enter the PSR on the part of the crater facing into the solar wind inflow (or the wall facing into the sun) to ensure that deflected solar wind would continue to flow onto the rover to dissipate any charge build-up. In other words, the rover should stay in the electrical contact with the bulk plasma. This work was presented at the recent 2018 SSERVI Forum (Farrell and Colaprete, 2018, https://www.youtube.com/watch?v=HPJcp3oB0iU)

Prem and Hurley also examined the effect the landing craft exhaust plume has on the local volatile environment, especially near the RP rover. During the Chang'e-3 landing, over 100 kg of water was dumped onto the surface from the exhaust plume—in some locations possibly creating nearly a monolayer of water. This water was found to desorb and migrate over the surface. A similar exhaust plume from the RP lander could place a layer of volatiles adjacent to the survey site, which would also desorb and migrate poleward to contaminate the regions examined by RP. DREAM2 models can predict the impact of this process. Preliminary modeling of the landing plume gas merging collisional and collisionless models of the gas and the complex surface adsorption were presented at the recent SSERVI forum by Prem (Figure 1.5.1)

Stubbs and Glenar modeled Earthshine into polar regions where RP will rove and calculated the radiated power from an Earth-reflection to liberate volatiles. The reflected power was found to be relatively low. A paper on this Earthshine is in press in Icarus.

Jordan and Stubbs also have made some preliminary calculations of the possibility of active electrical events from radiation-induced deep dielectric discharge during solar energetic particle events and CME passes during the RP mission. The study was performed to consider whether RP's NIRVSS system would have the potential to directly observe the discharge event.

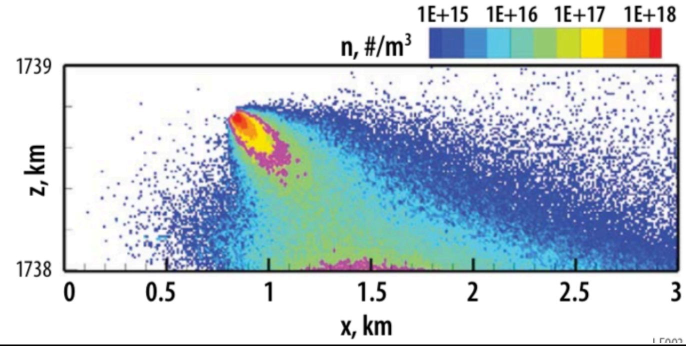

Figure 1.5.1 – A model by Prem et al., 2018 of a lunar lander exhaust plume including the collisional effects at the nozzle and surface. The release of the gas from the surface was modeled using a desorption model of the regolith. The desorbing and migrating plume volatiles represent a source contamination for any rover searching for surface volatiles.

1.6 Space Environment at Mars' moon Phobos

In late 2018, a set of four DREAM2 studies regarding the Phobos space environment were published in the journal Advances in Space Research (ASR). They are found in the ASR special issue on the 'Past, Present, and Future of Small Body Science and Exploration', Volume 62 (15 October, 2018). The studies were part of the intramural DREAM2 team effort that ran from PY3-4 on the targeted study of the space environment at Phobos which produced a total of 6 published works and a number of conference presentations. The ASR special issue includes DREAM2 articles:

'The possible contribution of dielectric breakdown to space weathering on Phobos' by Jordan et al.
https://www.sciencedirect.com/science/article/pii/S0273117718300759
"Anticipated electrical environment at Phobos: Nominal and solar storm conditions' by Farrell et al.
https://www.sciencedirect.com/science/article/pii/S0273117717305847
"Shaking as a means to detach adhered regolith for manned Phobos exploration' by Hartzell et al.
https://www.sciencedirect.com/science/article/pii/S0273117717306610
"Exospheric escape: A parameter study" by Killen et al.
https://www.sciencedirect.com/science/article/pii/S0273117717304222

1.7 Conclusions

At any given time, there are many 10's of DREAM2 scientific and outreach activities occurring during PY5, and we highlight a few of these herein. DREAM2 continues to make great strides in understanding the space environment's effect on the surfaces of airless bodies, and the three-way interaction between the surface response, environmental drivers, and human systems. As noted in the RP study, any rover sent to prospect for resources has to contend with the rover's own contaminating effect on the fragile environment- which may directly impact the prospecting process. Given our vast assets, DREAM2 remains poised to assist the commercial lander groups in evaluating these lander-surface-environmental effects in aiding in the defining of payload and mission requirements.

2 DREAM2 Inter-team and International Collaborations

DREAM2 team members are in continual contact and collaboration with other SSERVI teams, science mission teams, and Exploration architecture teams. Examples of DREAM2 interactions with other SSERVI teams include:

REVEALS: DREAM2 PI Farrell is part of the REVEALS Science Advisory Board and the team works together on modeling and lab efforts regarding solar wind implantation and surface hydroxylation at the Moon and other airless bodies. The two teams share an **NASA Post-doc position via a SSERVI-Central slot that funds early career scientist Micah Schaible** to perform lab work on the biochemistry and electrical passivity of irradiated surfaces.

NESS: DREAM2 and NESS share collaborators in understanding and assessing the space environmental effects on a sophisticated and sensitive radio astronomy system. We currently supported NESS colleagues on assessing the lunar dust and electrostatic environment, and how to better-ground the radio system.

TREX DREAM2 team members Hurley and Farrell are working with TREX lead Hendrix on the UV signature of surface water at the Moon. REVEALS team members are also involved.

VORTICES: Our team shared strong collaborating work on solar wind/airless body interactions, volatile interactions, and Orion/asteroid interactions and lunar pits. Our strongest collaborations are with individuals Zimmerman, Hurley, Prem, & Hibbitts.

RISE4: DREAM2 shared strong collaborating work on lunar pits, with the RISE4 field team providing lidar input to pit environment models shared by DREAM2 and VORTICES. We are working with RISE4 team to pursue opportunities to architect, design and build future exploration-oriented field instrumentation for astronaut use. DREAM2 team members also are collaborators on irradiated grain reactive chemistry that feeds into Rise4's grain cell survivability work.

IMPACT: DREAM2 maintains strong cross-team collaboration including post-doc opportunities for students, like A. Poppe who did his thesis work under CCLDAS and is now a key DREAM2 team member. **Currently, Anthony Rasca , a former CU grad student, is now a DREAM2 postdoc at GSFC.** DREAM2 modelers (Poppe, Zimmerman) are working with IMPACT team members (Daca, Wang) on magnetic anomaly and grain-grain surface charging studies.

FINESSE: DREAM2 share Co-Is Colaprete and Elphic, who under FINESSE perform field studies for the RP mission, while DREAM2 provides support with modeling studies on wheel-regolith interactions and volatile transport modeling (see Section 1.5).

<u>International Partners</u>

Sweden: DREAM2 team members continue close interactions with investigators at the Swedish Institute of Space Physics in Kiruna Sweden. DREAM2 Co-I Mike Collier took a 3-month NASA fellowship (sabbatical) to study with Mats Holmstrom, Stas Barabash, and Martin Wieser in Kiruna in 2012-2013. DREAM2 Co-I Shahab Fatemi relocated from UCB to Kiruna and is working closely with DREAM2 team members in modeling the plasma environment at asteroids, like 16 Psyche and the plasma flow about the Moon in the geomagnetic tail.

3. Public Engagement (including EPO) Report

3.1 Undergraduate Internship Program

Summer 2018 marked a fifth successful DREAM2 Undergraduate Internship Program. Team members at GSFC (W. Farrell, R. Killen, M. Sarantos, M. Collier, J. Cooper, N. Whelley, P. Misra) hosted five students from DREAM2 Co-I institution, Howard University. Students gained experience in both doing and communicating science by participating in DREAM2 team meetings and by preparing and delivering poster and oral presentations attended by the greater GSFC community. Their families were also invited to attend the oral presentations.

Funding for five of the students was leveraged through a NASA Minority University Research and Education Project (MUREP) funding award to Howard University. The project pairs Howard students with GSFC mentors and engages them in cutting-edge Earth and Space Science research throughout their undergraduate tenure. The project takes a multi-faceted approach, with each year of the program specifically tailored to each student's strengths and addressing their weaknesses, so that they experience a wide array of enriching research and professional development activities that help them grow both academically and professionally. During the academic year, the students are at Howard taking a full load of courses towards satisfying their degree requirements and engaging in research with their GSFC mentors via regular telecons, e-mail exchanges, video chats and at least one visit per semester to GSFC for an in-person meeting with their mentor. The students extend their research with full-time summer internships at GSFC, culminating in a Capstone Project and Senior Thesis. As a result, these Early Opportunities Program students, who have undergone rigorous training in the Earth and Space Sciences, are expected to be well prepared to enter the NASA workforce.

3.2 DREAM2 support for Solar System Exploration Public Engagement Institute

The DREAM2 Education and Public Engagement Team supported the Solar System Exploration Public Engagement Institute that was led out of APL, which took place from July 23-July 27, 2018. 40 informal science educators from around the country, participated. The DREAM2 team welcomed the participants to Goddard for a day full of talks, tours, discussions, networking opportunities, and presentations by DREAM2 team members. Content focused on SSERVI target bodies–Earth's Moon, near-Earth asteroids, and the moons of Mars–including formation and evolution, the space environment, NASA's current plans to explore these objects, and the upcoming NASA's Apollo 50th Anniversary Celebrations. Participating DREAM2 team members included B. Farrell, J. Bleacher, R. Killen, A. Jones, and J. Cooper, and tours included GSFC integration and testing facilities. A lunch discussion invited participants to spend time talking individually or in small groups with scientists to talk, including learning about their work, how they became scientists, and what inspires them.

Figure 3.1 – The 2018 Solar System Exploration Public Engagement Institute hosted jointly by the VORTICES and DREAM2 teams.

The participants were asked to complete a survey at the conclusion of the workshop to gauge its success. The participants all agreed that they gained considerable knowledge about the Moon, objects in the Solar System, as well as current and future space research. Participants quotes about the talks, discussions and tours are: "*Being able to speak directly to the scientist is so valuable." "The interactions were phenomenal."* The participants found the tours *"Highly valuable. Great field trips. I learned so much and was so energized to plan new programs.*

4 Student/Early Career Participation

Undergraduate Students

DREAM2 co-I Prabhakar Misra at Howard University won a NASA award to fund a number of undergraduates for a 4-year internship with DREAM2 and others at GSFC. The Award is "NASA Early Opportunities Program for Underrepresented Minorities in Earth and Space Sciences" (PI: P. Misra, Howard University; Co-PIs: D. Venable, Howard University; B. Meeson, NASA Goddard; S. Hoban, UMBC; & B. Demoz, UMBC; 8/1/16-7/31/19). The HU students are:

Skylar Grammas (Mentor: Farrell)
Irima Ajang (Mentor: Killen)
Ajani Smith-Washington (Mentor: Sarantos)
Marla Brown (Mentor: Collier)
Robert Coleman (Mentor: Cooper)

Graduate Students

Stephanie Howard, Iowa, Solar wind magnetic anomaly plasma disturbances at the Moon
Philip Quinn, UNH, Radiation
Fatemeh Rahmanifard, UNH, Radiation

Postdoctoral Fellows

Charles Lue, Iowa, Space Plasma and ARTEMIS
Dov Rhodes, GSFC, Charging on human systems
Anthony Rasca, GSFC, Inner heliospheric plasma flow at small bodies
Parvathy Prem, APL, Exospheres and Collisional atmospheres
Micah Schaible, Ga Tech, DREAM2-REVEALS SSERVI NPP, biochemistry and passivity of irradiated grains

New Faculty Members

Orenthal Tucker, NASA Civil Service, GSFC, Exospheres (a former DREAM2 NPP)
Wouter de Wet, UNH, Research Scientist

5. Mission Involvement

Shown are DREAM2 team member roles on current and planned missions. (PSD= NASA's Planetary Science Division, HSD= NASA's Heliophysics Science Division, AES=NASA's Advanced Exploration Systems Division)

PI, Co-I, and Guest Investigator roles (* = DREAM2 collaborator):

1. PSD/Lunar Reconnaissance Orbiter/Petro*/Project Scientist
2. PSD/Lunar Reconnaissance Orbiter/ Keller/Deputy Project Scientist
3. PSD/Lunar Reconnaissance Orbiter/Schwadron/CRaTER PI
4. PSD/Lunar Reconnaissance Orbiter/Spence/CRaTER Co-I and former PI
5. PSD/Lunar Reconnaissance Orbiter/Hurley/LAMP Co-I
6. PSD/ Lunar Reconnaissance Orbiter/Elphic/Diviner Co-I
7. PSD/Lunar Reconnaissance Orbiter/Stubbs/Participating Scientist
8. PSD/LADEE/Elphic/Project Scientist
9. PSD/LADEE/Delory/Deputy Project Scientist
10. PSD/LADEE/Colaprete/UVS PI
11. PSD/LADEE/Hodges/NMS Co-I
12. PSD/LADEE/Stubbs/Guest Investigator
13. PSD/LADEE/Glenar/Guest Investigator (named on the Stubbs GI proposal)
14. PSD/LADEE/Hurley/Guest Investigator
15. PSD/LADEE/Halekas/Guest Investigator
16. PSD/LADEE//Poppe/Guest Investigator (named on Halekas GI proposal)
17. PSD/LADEE/Sarantos/Guest Investigator
18. PSD/OSIRIS REx/Marshall/Co-I and former lead of Regolith Working Group
19. PSD/OSIRIS REx/Nuth*/Deputy Proj Sci
20. PSD/OSIRIS REx/Lim*/Co-I
21. PSD/OSIRIS REx/Hartzell*/Participating Scientist
22. PSD/Phoenix/Marshall/MECA Co-I
23. PSD/MAVEN/Delory/Co-I
24. PSD/MAVEN/Halekas/Co-I and lead build of ion spectrometer
25. PSD/MESSENGER/Killen/Co-I
26. PSD/Curiosity/L. Bleacher/Communications
27. PSD/Cassini/Farrell/RPWS/Co-I
28. AES/Lunar IceCube/Clark/Science PI
29. HSD/ARTEMIS/Halekas/Deputy PI
30. HSD/ARTEMIS/Delory/Co-I
31. HSD/WIND/Collier/Deputy PI
32. HSD/WIND/Farrell/WAVES and MFI Co-I
33. HSD/Parker Solar Probe/Farrell/Co-I
34. HSD/Parker Solar Probe/Schwadron/Co-I
35. HSD/IBEX/Schwadron/Co-I
36. HSD&ESA/Solar Orbiter/Collier/co-I Heavy Ion Sensor (GSFC lead)
37. HSD&ESA/SMILE/Collier/Co-I
38. HSD/CuPID cubesat/Collier/Co-I and instrument lead
39. ESA/BepiColumbo/Killen/Co-I
40. ISRO/Chandrayaan-1/Holmstorm*/Co-I
41. JAXA/MMX/Elphic/MEGANE Co-I
42. KARI/KPLO/Elphic/MEGANE Co-I
43. DoD (Space Test Program)/FASTSAT/Collier/Co-I and instrument lead
44. DoD (Space Test Program)/USAF DSX/Farrell/Co-I and Search coil build lead

Mission-recognized supporting roles includes:

45. PSD/Lunar Reconnaissance Orbiter/Glenar/LAMP data analysis
46. PSD/ Lunar Reconnaissance Orbiter/Prem/Diviner and Mini-RF data analysis
47. PSD/ Lunar Reconnaissance Orbiter/Wilson/CRaTER data analysis
48. PSD/ Lunar Reconnaissance Orbiter/Jordan/ CRaTER data analysis
49. PSD/LADEE/Marshall/UVS instrument calibration
50. PSD/Cassini/Cooper/CAPS team member, data analysis
51. PSD/Cassini/Hurley/Enceladus modeling
52. HSD/ARTEMIS/Poppe/plasma data analysis
53. HSD/ARTEMIS/Fatemi/plasma data analysis & modeling