GOOD MORNING. Welcome to our first SSERVI series at headquarters. I am welcoming you on behalf of that director. Today's speaker will be Dr. Bill Farrell. It is the DREAM2 team. Bill was born in upstate New York. With his dad he was influenced and inspired by the Apollo mission. He received his PhD at the University of Iowa in 1987. His advisor was also Jim Green's advisor. I am hoping we get bits of information. Bill sees his work has a strong exploration influence. He was on the electron beam admission in the vicinity of the space shuttle. Bill is involved in various NASA projects and missions. He even did work with US Air Force. His research is around electrification of dust [Indiscernible] on Mars. This work has taken him out in the field of dust devils. In 2008 he joined our lunar science institutes for the dream Center for lunar studies. That is part of our former incarnation. In 2013, he competed for our [Indiscernible] and placed as one of our 19 with his DREAM2 center. Today he will be talking about his research as one of the PI's of the SSERVI solar system exploration research Institute.

Thank you, Doris. The title of the talk today is DREAM2 space environmental studies. There is probably 20 or 25 ongoing science related tasks. I have tried to pick some that focus a lot on the exploration side.

I would like to talk about what is SSERVI and DREAM2 . I would like to give for good examples of how the space environment ties into exploration. I will provide the new science we are doing and showed the exploration perspective and follow up with conclusions.

It goes back to 2007. NASA's planetary division worked with exploration to form a virtual Institute dedicated to integrating science and exploration. It is not a brick and mortar building where we go. It is because of modern technology, you can form coherent groups using the modern comment system. DREAM2 is one of seven selected teams.

In 2013, and LSI changed to -- it was renamed to solar system exploration research Institute this SSERVI. We are a group called Dynamic Response of the Environments at Asteroids, the Moon, and moons of Mars. We will talk about our work on the space environment.

We are a theory modeling and data center emphasizing space environment connection. We want to go after the question, "how does the highly variable environmental energy from the sun affect airless bodies". We love extreme events like solar storms. It is like dialing the knob up to the maximum level to get at these interconnections that might be more subtle in normal times. Human interaction is another form of an extreme events. These small bodies have been out there for humans of years. Humans come by with spacecraft. That is an extreme events.

We also provide science support and exploration support for missions like LADEE.

We studied the excess fear, plasma, surface interaction, radiation. A key ingredient that makes DREAM2 work so well is that we understand they are merged. Plasma hits the surface and you get sputtering. Radiation comes in, hits the surface and allows plasma to absorb into those defects. All of this is interrelated. We are going after were those bubbles merge.

These are common processes occurring at all of the target bodies. Not just the moon.

Here is our team. In the lower left-hand quarter, -- I list our institutions. Here is a big picture view of what we think of on this team. You have surfaces that hold the history of the solar system. The space environment has energy and matter that goes up the -- up against the services and drive a response. Things like solar, went, plasma, solar x-rays and micro meteoroids are bomb bombing the moon. In a response, these small bodies outcast. Some of those are defined as a collision a list atmosphere. They will interact with the services. These Adamczyk will get ionized. You have an ionosphere at these bodies. The solar wind plasma is an electrical cast. You look at surface electrical field that you don't get in a body with an atmosphere. The moon and small body should have a these surface electric fields.

Dust gets lofted with impactors. You get dust kicked off that way. Maybe there is a possibility the dust may be charged and levitated in the electric fields. This is the environmental we look at. It is very dynamic. As of the sons energies increases these small bodies directly exposed will have their surface reaction wax and wane.

This is a gallery of types of models we have. We have over 20 models part of DREAM2. For lab facilities and eight data sets. Solar wind plasma interactions with airless bodies -- we will talk about that. We have impactors and a vapor models of how a vapor is emitted. This is applied for the L cross impact. Human systems like astronauts as they walk around on the moon and touch airless bodies are an electrical connection. We have models of the excess fear -- spacecraft and small body interactions. And models of radiation. Predictions of how solar energetic particles will propagate out.

We have 20 various models that are part of DREAM2. A key theme that we walk away from with DREAM2 is that every component of the space environment that we study has a science and exploration manifestation. It is like polarized glasses. It is the same components. If you look at it from one polarization it is science. If you tilt your head, you view it differently with an exploration flavor. For example, and science radiation surface chemistry -- that works into the exploration interest of radiation shielding and surface charging. Plasma expansion in the polar crater. How plasma expand in. They are really basic science modeling efforts. As we solve those problems, we are understand during -- understanding polar grounding.

Hydrogen implantation, solar wind made up of protons. As they hit these outside which services at the moon and small bodies, you can create new 08 chemistry. This is a whole new branch of science. It is also a resource for exploration. Same great science but a strong exploration manifestation.

Let's talk about solar wind interaction at airless a bodies. I will define what that is. The sun gives off tenuous ionized gas. Primarily protons and electrons. About five particles per cubic centimeter extremes out from the sun at about 400 km/s with a temperature of 100,000Â°. That may sound like a lot but that is cool believe it or not. And airless a body like the moon are obstacles in this conductive plasma fluid flow. We are seeing space is not a vacuum. It is a conductive medium.

Small bodies outside the spacecraft are part of the solar electrical circuit. They are getting currents and electrons and ions that traced back to the sun and are guided by magnetic field lines. There is a huge solar system electric field in these small bodies are in it.

This looks like a busy figure but it is actually not. When you think about under and LSI taking some of these views from the late 90s we realize there is a trailing plasma wake behind the move that may go out as far as 30 moon radii. The densities are very low. It is really a place the plasma drops out. Under NLSI we modernized this of you. We added other elements of the space environment around the moon including reflective protons.

We also recognize these weeks our self similar. Of these weeks scale. We look at plasma many weeks that formed in polar craters. Solar wind plasma can migrate in but at lower density levels.

Bottom line, once we got done with NLSI we realize you can divide the moon up into a conducting region and an insulating region. The moon is not a great conductor. It has low conductivity. On the lunar surface the conductivity maybe as well as paraffin. Where you get conduction is the plasma. The medium itself is a conducting medium. You are not granted to the surface. You are grounded to the plasma.

Were plasma drops out in of these weak regions, it becomes less of a conductor and more of an insulator. Exploration would be interested in this because if you have an ashen not on the moon or driving around that ashen not is a capacitor. They will tribal chargebacks capacitor. To dissipate that, you will not dissipate into the ground. You will dissipate it into the plasma. How quickly you dissipate has to do with plasma conditions. On the lunar, dayside you did not see much of an electrical effect. In lunar night side with the plasma density drops to 1/1000 of the plasma, you have to worry about losing access to electrical ground. That capacitor will stay charged for a long time.

As you come into contact you have to worry about dissipation. We took on models of the plasma and put in a small body. A body of one -- couple hundred meters in size. There is a contrasting nature. You can see the contrasting nature were ions have a difficult time flowing in behind the object. You get Amber polar electrical field that deflect the ions in. Because you have this little dimple you do not get a lot of photo electrons. This new tree code that similes this is awesome. Mike Zimmerman is working with dust levitation.

They are looking at dust often to explain dust ponding and congregation in craters that was observed by [Indiscernible] when it was landing on euros. They are using this model to dust transport. We have also asked ourselves the question, why haven't the human Explorer walked around this asteroid? We had this Zimmerman model and merged it with the Astro charging model. What would happen if an astronaut was touching the surface? You have a tribal electric source. On the region where you do not get a lot of plasma, you get a held up of charge. As soon as you get into the solar wind I flow, you dissipate that charge.

Your source turn on the hand exceeds the losses. When you get into the solar wind I flow and into daylight, you dissipate that.

The key take away from example 1 is we have a new basic science will tool. As we are doing new science about dust lofting and understanding electric fields, we are pursuing electrical grounding issues. Some ideas for consideration is maybe in untethered astronaut should explore the dayside of an asteroid first or make sure they are in a place where there is a high local plasma environments to avoid plasma starved locations.

Another radical idea published in 2011 is space suits should have metallic outer skin to obtain connectivity to plasma. Spacecraft in the solar wind have strict electrical conductivity requirements to avoid differential charging. Astronauts are grounded to the plasma just like spacecraft. You should need electrical conductivity requirements on these suits also.

For Apollo, they are in a plasma rich region on the dayside. When you head into exotic places in shadow and plasma is starved, you want to increase your return current collecting area.

XO fears and gas environments. XO fears are low density, coalition lists -- less atmosphere. The moon has a surface bounded XO sphere. Sodium is an ominously bright. Most of the other species you have to get in situ. We think about XO sphere from low mass, small bodies were grabbing will not hold the particles down. We also have four models of impact vapor release.

Gas releases from space cast if you warm it up. Photon and electron absorption kickoff gases. So what went plasma can sputter particles off of rocky bodies. Micro meteoroid impacts are a big source of gases.

A recent paper by Andrew Poppe was to look at the XO sphere at Phobos. heavy ions from Mars atmosphere get accelerated down to detail and impacts Phobos. This is a sputtered mutual flux. They are predicting that at the orbit Phobos of there should be a neutral gas will will get ionized. We may be able to see this entire system. DREAM2 is making predictions that can get backed up.

I like this model because it is how to bodies worked to influence each other. Gas body Mars influencing a rocky body Phobos. A lot of people do not realize O'Ryan could be a source of water outgassing water -- these asteroids are fragile environments. Now we bring O'Ryan to it. How much outgassing is there from Orion.

The shuttle was incredibly gassy. Excuse the pun. The lunar atmosphere has 10-5 particles at the CC. The people who studied it during the Spacelab to mission referred to this as actually and artificial comments this comment -- comet.

This is a [Indiscernible] releasing 72 g of water. There is the shuttle doing its water dump.

You have water coming from Orion. Water absorbs onto the surface. It is a surface Adam interaction when you have potential wells that define molecular Adam, Adam interactions. The degree of trapping has a lot to do with how weathered your surface is. With more weathered surfaces having a deeper foundry. If you hadn't absorbs water it would stick to a defect site. Many have done a lot of work on these studies. We are looking for sticking times. They found their lab studies followed this equation where the residency or sticking time varied exponentially as a function of activation energy or how deep this well is divided by the temperature. More weathered material with larger crystal regularities the sticking times can be longer.

If you had a near-perfect crystal and lunar like temperatures, the water would stick for a nanosecond. If you have a defect rich crystal, the water can stay on for a day or longer. There is a strong exponential influence not just on temperature but vacancies and defects.

We built a model where we assumed we had an Orion spacecraft 1 km from our rocky body. In dynamic equilibrium, what does the water look like? It varies by a 10 to the eighth difference. If you have a space weathered body, you will get a healthy amount of water. This region is no longer quarter, water interactions. You are getting close to a monolayer. If you had a space weathered system with lunar like temperatures for your rocky body.

Water will stick. It depends on how weathered the asteroid is. Key takeaways from example number two. Any objects exposed Richler to the space environment will avgas -- outgas. these are energetic processes, especially sputtering. It's will erode away material Adam by Adam -- atom by atom.

The effect of that water absorption is a strong function of surface properties. It is fun from a science perspective. The group is having a good time testing. For exploration, I would argue don't flush near the body. If you are thinking about covering the asteroid, you might benefit from uncovering the asteroid in some of the images the small body appears covered in the a RM mission. I would suggest having a 3 Âμ IR monitoring system to see how much water is building up. This is an opportunity for great science. You can build a defect garden. Turn soil over that has not been weathered. You can have the astronauts impact to create satisfied bonds.

Example 3 our South polar crater surface interactions. Most people know polar craters are special, thermal environments. They are special volatile environments they hold the history of volatile influx to the moon. If a comment hit and the water bounced around it got trapped in the craters. It was suggested that polar created floors are thermally stable. The DREAM2 team of things while they are thermally stable they are not stable to other elements like plasma sputtering and impacts. This is from Mike Zimmerman who is now at APL. Here is the solar wind passing over and into a solar crater. It is normally a collision less gas. Electrons move into the crater ahead of ions and create an Amber polar electric field. That electric field diverge ions into the crater. They are not getting and by regular pressure but by electrical, static forces.

The ions hit the surface and what you see in green our sputtered waters. These water molecules are released to move up and out's of the crater. We talked about spillage. A polar crater volatiles onto adjacent terrains to both plasma sputtering and impact vaporization. If you have a polar crater floor with ice and impacts, there is enough energy in those impacts to transport that material to adjacent reasons around the crater. Here are the results with impacts with test water molecules. Highest density of material is on the crater lip.

To opportunities are present. One is prospecting. You do not have to get into the crater to understand volatile content. You can use a hopper lander to jump from crater lip to crater lip. Once you get into the craters that are really cold, you have technical problems. If you can get near it that could save your mission. The other thing is it suggests that there is a modern, ongoing process on these crater floors. It is not just Comet from the past. We are modeling the lost processes.

If that first is in dynamic equilibrium, there has to be an ongoing source. There is 10 to the eighth water lost about the size of this table on the polar floor. We don't know where that 10 to the eighth came from. It means it is a dynamic, modern process.

Jumping from one crater to another.

Could be the source of the neutron suppress reasons -- regions that landed.

That is just surface water?

The impactor is getting deep as well. You are doing a little bit of subsurface as well. How that would translate we would have to look and see.

The other consequence has to do with roving. Imagine if you had a lunar rover on the date side. As we talked about and polar craters, I get in. The I flux can be lower than what it would be in the solar wind. Solar wind ions get in and create sputtering but there is not enough ions to offset a wheel charging. In this case, Jackson the built a wheel tribal charging model and drove it in different places. The dayside where there are lot of ions. You could develop a substantial charge on that tire that would last a long time. If you are drilling, roving, or driving, you don't want to pull wheelies in these shadowed regions because you will charge up.

It will eventually dissipate but the dissipation is over a long time. You don't want to hop out of the rover and then run back.

Key take away from example 3 -- lunar polar craters besides it being chemically and thermally complex, they are electrically complex also. This electrical complexity ties into the volatile picture particularly with plasma sputtering. The benefit with a greater understanding is you do not have to get into crater floor. The space environment is hurling the material out. Think of a parade with the firemen throwing candy out. You don't have to go to the candy store if it is being hurled at you. We should take advantage of that.

That could affect how RP affects its work. When you get into shadowed regions, where you are granted becomes an issue. You lose connection to your plasma since you are in a plasma start location. We recommend increasing metallic outer skin and increase current collecting area. As you drive around you have a piece of metal to counteract your charging. You may even consider within permanently shadowed craters a local plasma emitter to equalize things.

Can you charge a battery?

Not enough current to make it useful.

Is it true that there is not much time lag for granting between light and dark? You are often skirting or chasing shadow.

In plasma, there is not much tempo change. In regular, there might be. It might take 10,000 seconds -- ground conductivity is not that good. In plasma, it will do it quickly.

The understanding of how those horizontal field change in plasma is what we are getting at now.

Example number four has to do with radiation. We may be heading into a series of week solar cycles. This fax allowable safe days an astronaut can extend into space. We are talking about the lactic karmic raise. Highly energetic, charged particles are individual charged particles at 1000 MeV. these are at the opposite regime in terms of an agitation. There is a background level of galactic cosmic rays. You can see the modulation. This is a combination of models, ACE data and greater data. As you enter into solar maximum, you get more sunspots. You get a larger inner Helios feel it -- it it will drop by a factor or two. Are New Hampshire colleagues have found that the solar cycle is getting progressively weaker. The consequence is the dose rate of GCR are rising. Here you can see the trend. I have lined up the solar minima. They calculated dose rates for different shielding. It is tending to rise up over the last few solar cycles.

Given dose rates, we have a model of human system and how radiation influences a human system. They are finding this they do that model and calculate the allowable days -- 3% of the risk of exposure of induced death -- if you have 100% the likelihood of dying cancer associated with radiation is 95% statistical certainty. They are at 3% statistical level. The allowable days will drop out to about half a year in space flight during the next solar minimum if the trend continues.

The year 2020 the GCR flux is expected to get high and as a consequence will reduce allowable days. This might be a bad time to fly. As Nathan said there is always a positive. Because we are in a series of solar minimums over the next solar maximum near 2030, you will be back in the cycle where the GCR flux will drop out because of the 11 year modulation. Because of the solar cycle is weak, you will have a lower probability of a solar storm particle event. The best time to flight might be after the next solar minima during the next solar maxima. If you have a weakened son, the likelihood of getting a big SEP event is a lot lower.

We are also studying radiation safe havens. They are the combined VORTICES-RISE4-DREAM2. They are looking at GP our. They are getting three-dimensional views and feeding them into our models. They are getting these LIDAR measurements of plasma inflow and understanding how ground penetrating radar might work. Some people think the pits on the moon might form a tube. We asked, what is the magnetic signature of radar hitting a tube? We are trying to get data of pits from the rise for team into our models. I can see papers coming out on geologic stability, thermal properties, radar signature, plasma environment. This may be a great place for volatile reservoirs because it is a cold trap.

Is there certain publications that you find better support human exploration themes like these?

No. We are having a hard time. When she submitted her paper, they said it was a great paper.

We have a hard time finding a home for these kinds of things. [Indiscernible] did a special issue on volatile.

We build more connections in multidisciplinary. We have to entertain Journal support.

I agree.

[Indiscernible - low volume]

Lets see if we can get publishing to help us. A dedicated journal could come out of this.

Speaking of Space Whether, they were interested but not suitable for their paper.

They are interacting bodies.

You think Space Whether what has welcomed its.

We need a dedicated journal.

Key take away is as we bring together data sets from history with the modern crater data sets we get into predictions about GCR levels and save times. We are looking at safe havens from the harsh radiation environment. For exploration consideration the allowable days occurring in 2020 is something to keep track of and think of in terms of human exploration.

As part of DREAM2 we will be doing deeper studies. It is an intramural team study. Sort of what we did with the solar storm at the Moon. We try to understand how the solar storm affects and NEA. And the space environment within Stickney Crater.

Those are great topics. You can't get them published.

Right. We will include at Howard University interns. There was a plate during DREAM2 we were doing our integrated model but did not have the support. We have integrated interns and have workshops at the end of the summer. Great way to get students involved and get a larger team thinking about this. We are already developing these polar crater models.

To conclude, we have four examples. We are contributing to questions like, what to wear? Were to touch? Went to flush? Where to rove? How fast to rove? What is the weather? When to fly and where to hide?

These a very interesting science problems like absorption of Wells -- as a we solve that problem we are making inroads in body body interactions. Hopefully we are true to the spirit of SSERVI. It is cool that we can do this. I want to thank everyone at headquarters in being supportive of this thinking.

I am having problems at Goddard. This is different from lab oriented things. I have 10 minutes of four questions.

[Applause]

Thank you. One of the reasons I am speaking for our director is that we have technical issues. Two speakers are not working well with each other. I would like to relate her thoughts. Please emphasize how pleased I am with this excellent talk.

When Earth's systems -- Earth science NASA wanted to foster a multidisciplined approach to Earth system science and break down the stovepipe of geologists not talking to geographers --

In order to overcome that resistance, you needed a place to publish, source of funding and source of students. They started funding classes to encourage undergraduates and graduate students. As well as working on the problem of where you publish and getting funding. You don't advance unless you can get funding and students and published. What else does and economic -- academic researcher need in order to move into a new area? Is something like that needed in this area to bring this integration?

That's what SSERVI is. They have a strong education program. They are putting money into this. Exploration and planetary talk -- it is the first step. I would say triple their budget.

Perhaps what is missing is the place to publish.

The community sees this. The geologists get this. They are talking about hand held instruments to do quick sample analysis. They are thinking -- gets these in the hands of astronauts. They are thinking exploration. SSERVI is a great place to do that kind of thinking. It is hard to break through those stovepipes. We are doing it as people see the value in it.

Helio physics Institute in Boulder Colorado has been supporting this concept. It is said that Space Weather wouldn't publish it. Space weather happens anywhere the sun interacts. Both of for graduate, undergraduate. What I am taking away from here is while we view the sun, the plasma -- we will pay attention to geology. That is the complement we are missing. If we integrate that, [Indiscernible - low volume]. Think about how to capture elements of this and leverage it into the space weather journal.

We should create one. Have a venue also for medical research or anything that has to do with humans.

There are opportunities. Of bringing this to the team especially since it is a safety factor is critical. There may be -- that is encouragement to the researcher and institution. This broadening, immediate application of this into plus Larry -- interdisciplinary research. [Indiscernible - low volume].

This is really interesting. When I look at these and think about plasmas and charging, it makes me wonder what are the time factors. Are these changes, dissipation something you immediately experience as you enter the shadow. Would routing the dark side of a rock be as serious as going into a mini crater? The temperature falls, but with the rover itself being partially in shadow, would it experiencing these problems?

What happens when you get into a polar crater that is smaller? We are trying to get into the smaller regions. It may not be as bad at the big rock level because plasma can get in quickly. Add to the polar craters, that is where it gets tricky. The solar wind doesn't get -- it can't turn the corner fast enough. You get a charge imbalance. The electrons can get in there fast. The ions don't have -- they can't dip into the crater fast enough. Some people predict you get an electron cloud region. That is a big question. Whether the plasma purposely will find a way to state neutral so that ions catch up with electrons. Or whether you will have to electrons separated from ions. If astronauts are roving in that electron cloud and they charge up, they will stay charged. There will not be ions to dissipate. They may discharge other ways.

As we have a meeting at 1 o'clock, we will formally finish the session. Thank you to everyone here. If you were not able to see this, go to the website to view the presentation. Thank you very much.

[Applause]

[Event Concluded]