Lunar Librarian Newsletter
July 2006

LRO News

Meet the team: Mark Beckman

If you were to pass him in the hallway, you would most likely think that Mark Beckman is just like any other NASA aerospace engineer. After all, on the day he was interviewed Mark was wearing a t-shirt, shorts, and sandals. But as ordinary as Mark may seem, he has a very extraordinary job to do – especially for those interested in seeing the Lunar Reconnaissance Orbiter (LRO) succeed. Mark's job as the Flight Dynamics Lead for LRO is to ensure the spacecraft's safe delivery to our nearest neighbor. When he was asked how he first decided to become an aerospace engineer, Mark responded by saying it was something he always knew he wanted to do. When he was in fourth grade, Mark was voted "Most likely to become an astronaut," so you could say that his interest started at a very young age. Now after 16 years at NASA's Goddard Space Flight Center (GSFC), that interest has paid off. In his tenure at GSFC, Mark has worked on NASA's past two lunar missions, Clementine and Lunar Prospector. Mark's experience on the lunar missions makes him the only person to be involved in all three of NASA's most recent missions to the Moon.

At first you might think to yourself, "How hard can it be to get a spacecraft to the Moon?" Indeed, when compared with our other celestial neighbors, getting to the Moon seems like a walk in the park. However, even getting to our closest neighbor takes lots of planning and preparation. In order to send LRO to the Moon, Mark must carefully plan the path the spacecraft will take to get to the Moon (the mission trajectory), the moves the spacecraft will make on its way (maneuvers), and once the spacecraft arrives, the orbit around the Moon. Keeping the spacecraft in proper orbit around the Moon will be no easy task, either. The Moon's gravity will have an effect on the orbital path LRO takes, and in order to understand the scientific data, that path must be closely monitored. The Moon's gravitational field varies widely depending on location, and little is currently known about the gravitational field of the far side of the Moon. In order to keep track of the Moon's gravity, the gravitational model that is currently used contains 20,000 variables. According to Mark, LRO will be tracked from Earth and the ground tracking data will be combined with the data from LRO to better constrain the Moon's gravity model.

Mark enjoys spending time with his wife, Yael, and their two daughters: Maya (2 ½ yrs) and Julia (7 mos.). When he's not at work or with his family, Mark spends his free time running and playing poker. In addition to LRO, Mark is also the Flight Dynamics Lead for the James Webb Space Telescope. When he was asked about the most rewarding part of his job, Mark replied "watching the spacecraft launch after years of planning." We agree, Mark. We'll see you at the launch in 2008.

NASA News

Science On a Sphere (SOS) at Goddard's Visitor Center.

Hovering three feet above the floor, six feet in diameter, white sphere hangs in the middle of the Goddard's Visitor Center auditorium. *Science On a Sphere (SOS)*, developed by the National Oceanic and Atmospheric Administration (NOAA), is a visualization system consisting of computers and four video projectors working together to display animated data. Most of the presented data sets, such as "3-D Surface on the Earth and Nighttime Lights," "Moon and Mars," and "X-Ray Sun," are silent animations that could accompany a lecture. Recently, the media team at Goddard created the first movie, "Footprints," to be displayed on SOS. This movie will be distributed to several of the other SOS exhibits, including the Maryland Science Center in Baltimore. Besides displaying Earth science data sets, SOS displays many of the planets and moons found in the Solar System. This includes several icy bodies, such as Jupiter's Galilean moons, Titan, Triton, and Enceladus.
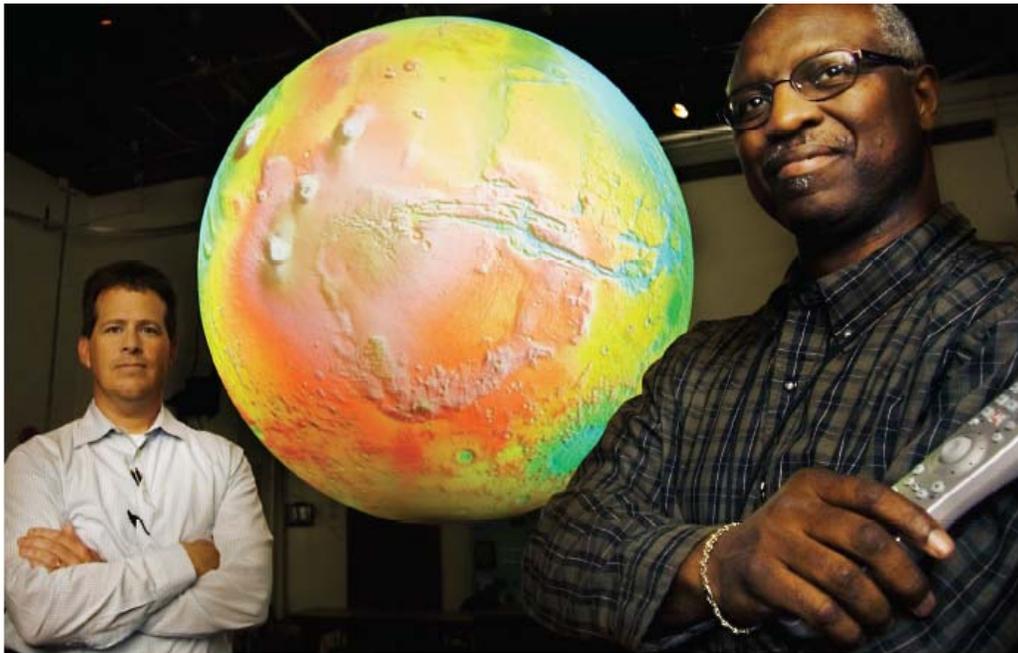
Caption: Dave Himes, NOAA forecast systems software developer for SOS and Maurice Henderson, science Manager of SOS.

For more information on Science On a Sphere:

Goddard View, Vol. 2 Issue 8, page 4.
http://www.nasa.gov/centers/goddard/pdf/148605main_GV2_8_Web.pdf

"Video Projections on a Globe Make Planetary Data Click" by Warren E. Leary
http://www.nytimes.com/2006/06/13/science/13sphe.html

Science News

NASA Science News has published several articles last month. Please follow the links to read the full stories.

Droids on the ISS
A little droid is roaming the corridors of the International Space Station, and more are on the way.
http://science.nasa.gov/headlines/y2006/01jun_spheres.htm?list199364

Huge Storms Converge
The two biggest storms in the solar system are about to go bump in the night, in plain view of backyard telescopes. http://science.nasa.gov/headlines/y2006/05jun_redperil.htm?list199364

Corkscrew Asteroid
A tiny asteroid corkscrewing around Earth for the past seven years is about to leave the neighborhood.
http://science.nasa.gov/headlines/y2006/09jun_moonlets.htm?list199364

Cool video: A Meteoroid Hits the Moon
Last month, astronomers watched a meteoroid blast a hole in the lunar Sea of Clouds. Their video of the event is a must-see. http://science.nasa.gov/headlines/y2006/13jun_lunarsporadic.htm?list199364

Lunar Swirls

Pale swirls on the surface of the Moon have been puzzling researchers for decades. Fresh clues are in the offing as NASA prepares a new round of lunar exploration.
http://science.nasa.gov/headlines/y2006/26jun_lunarswirls.htm?list199364

A Heavenly Sky Show on the 4th of July

Who needs fireworks? As night falls on the 4th of July, a moon, a giant planet and a spaceship will emerge from the twilight for a sky show of their own.
http://science.nasa.gov/headlines/y2006/29jun_july4th.htm?list199364

Librarian News

Here's what's going with some of the librarians who participated in the workshops

Pennsylvania:

Pittston Memorial Library will be holding a Scavenger Hunt

Easttown Library & Information Center will be holding a Moon Camp July 31- August 3, 2006. They are planning on having several hands on activities. On Tuesday night, they are hosting a family night of sky watching with an amateur with real telescopes. There will be 14-16 kids, 4th – 6th grades, enrolled in our Moon Camp and the time is 10:00 – 11:15 each day. Brooke and Heather will be attending on August 3.

Dillsburg Area Public Library held their first program June 15, 2006. It was attended by 26 children and 13 adults.

What's going on at your library??

Email Heather, heather_weir@ssaihq.com, with your library's space program activities by July 24, and it will be included in the next Lunar Librarian Newsletter. Feel free to send along pictures from your workshops.

Did you know?? Where can I find??

Need a NASA scientist or a speaker to come and talk at your library?

Please feel free to contact either Brooke Carter (brooke_carter@ssaihq.com 301-867-2057) or Heather Weir (heather_weir@ssaihq.com 301-867-2083) with details on what you are looking for and what you want to cover. Also, if you could provide a schedule of when you want to plan your event, this would be helpful.

So you want to have an astronaut come and speak…..

Astronaut Appearance Request Guidelines

NASA astronauts appear before a variety of groups to inform the general public about the U.S. Space program. Typically, presentations are made to high schools and universities, community organizations, businesses and associations or military organizations.

Unfortunately, due to the extensive training requirements for astronauts and the high demand for astronaut appearances, we can respond favorably to only a limited number of appearance requests and many valid requests must be declined.

Incoming requests are evaluated carefully to ensure that astronauts appear at events organized to educate a large audience. Sponsors are advised that unforeseen events, mission priorities or operational commitments can cause the cancellation of a confirmed appearance.

1. Requests for astronaut appearances should be submitted in writing.
2. Requests should be submitted to the Astronaut Appearances Office no earlier than six months before the event.
3. Lead times for domestic (continental United States) requests is 8 weeks
4. The request letter must be written or typed on the letterhead of the sponsoring organization and must be signed by an official representative of that organization.

Contact and more guideline information is available here:
http://www.nasa.gov/about/speakers/astronautappearances.html

Ice in the Shadows

ESSENTIAL QUESTION

What Does Ice in the Shadowed Craters of Mercury and the Moon Tell Us About the Solar System?
How can ice remain stable in the shadowed craters? Where does the ice come from? What can we learn by detecting and comparing the ice on Mercury and the Moon?

ACTIVITY QUESTION

***Why Is There Ice at the Poles of Mars, Earth, Mercury, and the Moon?***
Why are polar regions colder than the rest of the planet? What role does the angle of sunlight play? How can ice be on a planet so close to the Sun (Mercury)? How can we detect the presence of ice on places like the Moon and Mercury?

BACKGROUND

Earth's 23.5º Axial Tilt and Sphericity
In our era the Earth tilts at an angle of about 23.5º and aligns with the North Pole pointing toward Polaris, the North Star. In its orbital path around the Sun, the tilt of the Earth remains the same: always close to 23.5º pointing toward Polaris.

Generally the equatorial region of the Earth receives the most direct sunlight. The light at the poles varies within more or less grazing angles. (The angle of sunlight is only part of the story: Earth's atmosphere also influences how solar radiation is distributed with its resulting weather and climate conditions.)
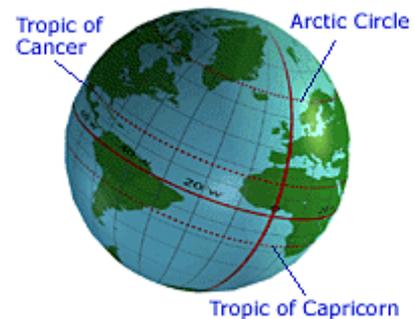
The Tropic of Cancer marks the northernmost latitude (23.5º N) of direct sunlight, which occurs on the June solstice. On that day, the North Pole receives 24 hours of sunlight and the South Pole receives 24 hours of darkness.

The Tropic of Capricorn marks the southernmost latitude (23.5º S) of direct sunlight, which occurs on the December solstice. On that day, the South Pole receives 24 hours of sunlight and the North Pole receives 24 hours of darkness.

The position of the Earth in relation to the directness of the sunlight changes a bit each day, marked by four familiar transition points:

- The summer solstice—summer in the northern hemisphere, when sunlight is most direct at the Tropic of Cancer (23.5º N latitude); winter in the southern hemisphere.
- The fall equinox—autumn in the northern hemisphere, spring in the southern, when sunlight is most direct at the Equator;

- The winter solstice—winter in the northern hemisphere, when sunlight is most direct at the tropic of Capricorn (23.5º S latitude); summer in the southern hemisphere;
- The spring equinox—spring in the northern hemisphere, autumn in the southern hemisphere, when sunlight is again most direct at the Equator.

It's not surprising that this is hard to visualize. Our everyday experience on the surface of the Earth is a sensation of a flat expanse more than an expansive curvature. Only when we get a glimpse from space or project our knowledge of the Earth's curvature onto a model, like a globe, does our mind begin to cope with the meaning of living on a spinning, spherical, and tilted planet.

Depending on the time of year, the latitudes between 23.5º N and 23.5º S receive the most direct sunlight. As you move north or south toward the poles, the sunlight is less direct because the Earth's surface curves away from the direct sunlight. As the sunlight becomes less direct, the solar radiation and the heat it produces are proportionally less intense. So it is warmer in the tropics and colder at the poles. In between regions experience more seasonal variations.
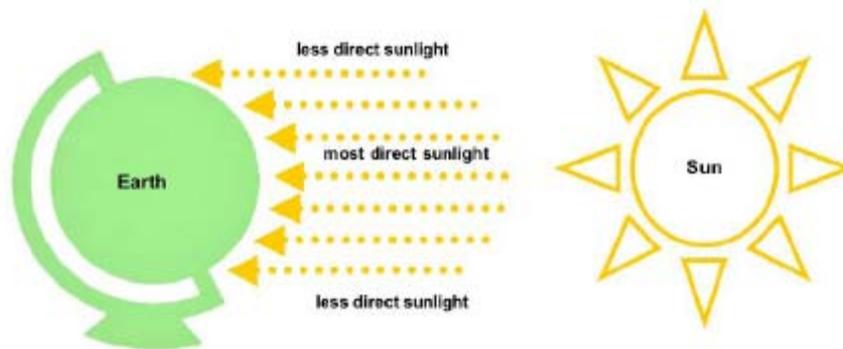
Likewise, depending on the time of day the angle of sunlight changes as the world turns: at midday, when the Sun appears highest in the sky, we receive the most direct sunlight, and that is usually the warmest part of the day. Sunlight is less direct in the morning and evening, also usually cooler times of day.


Moon's Axial Tilt is 1.5º and There is No Atmosphere to Distribute Solar Radiation
Although the plane of the Moon's orbit around the Earth is inclined about 5º, it's equator is inclined about 6.5º, resulting in a 1.5º tilt of the Moon's spin axis to the orbital plane around the Sun. This means that sunlight always just grazes the poles of the Moon. Some craters in the lunar polar regions are permanently in the shadows and never receive any sunlight. At temperatures of 40 to 50 Kelvin, craters could act as "cold traps" that could keep ice so solidly frozen that almost none of it escapes into space.

Mercury Axial Tilt is 0º and There is No Atmosphere to Distribute Solar Radiation

Similarly, Mercury's axis of rotation is oriented nearly perpendicular to its orbit, so that in the polar regions sunlight strikes the surface at a constant grazing angle. Its poles have been pointing in the same direction ever since the planet was formed.

The interiors of large craters at the poles are permanently shadowed and remain perpetually cold, below -350° F (60 K). Below 80 K, the molecular motion of ice is nearly nonexistent. Ice is stable at that temperature even in a near vacuum and does not sublimate as vapor into space. *Possibly*, the tiny influx of ice from infalling comets and meteorites could be cold-trapped in these Mercurian polar caps over billions of years. Or water vapor might originate from the planet's interior and be frozen out at the poles.
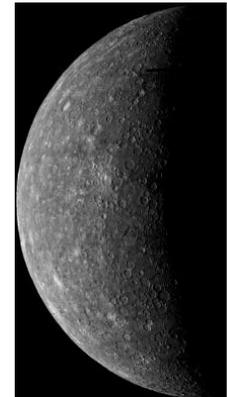
Alternatively, it has been suggested that the polar caps consist of a different material, perhaps sulfur sublimated over the eons from minerals in the surface rocks.

So which is it? How can water ice be coldtrapped in craters of polar regions even on small worlds, even close to the Sun, such as Mercury and the Moon?

Hmmm, How Could the Ice Get There?

Is there water that outgasses from the planet's interior that then freezes at the surface?

Could comets deliver ice? Such impacts might be so powerful (several megatons) that any ice would be obliterated by the energy of the impact, and could destroy any ice that might already be there.

Micrometeorite? Ice is traveling in abundance in interplanetary space. Over billions of years, perhaps many micrometeorite hits brought in the ice.

How Could the Ice Stay There?

After impact, ice molecules would hop around in the exosphere. Some might be lost over time due to photodissociation, solar wind, sputtering, and micrometeoroid gardening. Some jump straight out into space.

But some hop across the surface only to land and hop again, unable to escape the Moon's or Mercury's gravitational field. These molecules continue to move around in a process aptly called, a 'random walk', slowing down as they jump into cooler areas until they reach an area that is below 80 degrees Kelvin (80 K). Once inside these 'cold traps', the molecules are so cold they stop hopping altogether and could lie trapped for billions of years.

Recapping the Evidence

In 1994, the Clementine mission confirmed that conditions for a cold trap that could support lunar ice existed by bouncing radar and receiving highly reflective signals, indicating the likely presence of ice. In 1999, the Lunar Prospector mission found somewhere between 10 to 300 million tons of water ice scattered inside the craters of the lunar poles, based on data from its neutron spectrometer.

Radar echo images of Mercury's polar regions, first obtained from ground-based radar telescopes at Arecibo in 1991, show that the large craters' interiors are highly reflective at radar wavelengths suggesting the presence of ice.

We know that large craters in both polar regions of Mercury and the Moon are:
1. C-c-c-cold, below -350º F (40– 60 K)
2. In perpetual shadow
3. Highly reflective at the radar wavelength (an indicator of water ice)

But to know for sure whether it's ice or hydrogen sulfide we need new data:
- High flux of low-energy thermal neutrons—indicates hydrogen (H)
- Ultraviolet and gamma ray detectors— indicates sulfur or oxygen

MATERIALS

Main Activity
- Hair dryer or heat lamp
- Ice cubes
- Modeling Clay
- Toothpicks

PROCEDURES
PART 1.
Modeling the Sphericity of Mercury and the Moon

Have each student make a spherical "Mercury" or "Moon" out of modeling clay. Have students notice the different angles in relation to the "Sun," explicitly, by having them place toothpicks straight in and noticing that they point out in different directions (angles).

Have each student scratch a line to mark the Equator, where the Sun shines most directly; and to mark the north and south poles, the "top" and "bottom" of Mercury or the Moon, where the Sun shines least directly.

Optional: Make the spheres and position
them accordingly and then cool the clay
prior to the ice melting experiment.

PART 2.
Do Angles Make a Difference?
Have students work as partners, with two modeling clay worlds (a control and a variable). Have one student be ready with the heat source (hair dryer or heat lamp) to aim directly toward the Equator of the variable world. (This represents the thermal effect of solar radiation.)

The control sphere is off to the side to account for any effect of room temperature and the warmth of the clay itself.

Once the heat source is in position, ready to be turned on, embed ice cubes in modeling clay spheres, at 90º apart, representing an equatorial and a polar region. Push each ice cube in far enough so that it's top surface matches or sits below the clay surface.

Turn on the heat source and aim it directly at the Equator of the variable world.

Notice the effect on the ice cubes. Observe and time how quickly the ice cubes melt.

Write and illustrate new understandings that result from this activity.

Ask students: *Which ice cube is likely to melt faster?*

Have students switch roles and repeat:
Using one "world" as a control, do nothing. Toward the other, aim the heat source in such a way as to create warm air blowing toward it. Make sure the air current reaches the whole sphere from one direction.

The "equatorial ice" receives a more direct angle of warmth. The "polar ice" receives a less direct angle of warmth. Also, see what happens if the ice cube sits in a "crater" near the pole.

Be sure to compare the variable to the control. Because we are in a classroom on Earth and not in a laboratory or in space, the ice on the control is also melting. If the ice melts more rapidly with the hair dryer, can we infer that the hair dryer made the difference?

Does melting occur differently at different angles (that is, does a direct equatorial angle melt the ice more readily than the warmth moving over the top? What happens where you created a "crater," where the warmth rides over it altogether?
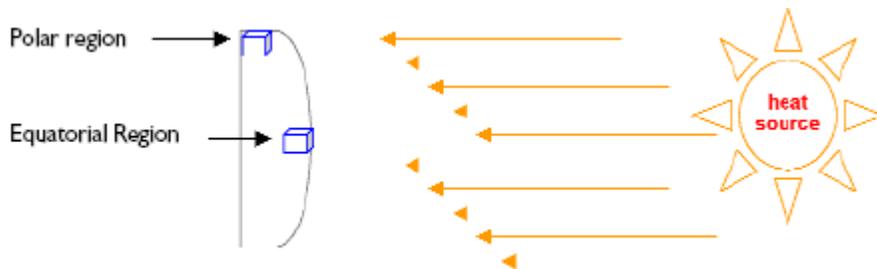
What happens?	Control World	Variable World
Ice Cube at Equator		
Ice Cube at the Pole		

Optional: Invite students to examine the situation in greater depth.

Subtracting the melting of the control world from the melting of the variable world might reveal that virtually *no melting* occurs due to the heat source when the ice cube is embedded in a shadowed crater. That is, if you could establish that the melting of the control and the variable at the pole is *the same*, then you can infer that the heat source had no effect because the heat did not reach the ice, *just as ice in the permanently shadowed craters of Mercury and the Moon can only remain stable if NO sunlight ever reaches it.*

This Table Connects the Model to the Phenomenon to guide discussion

Precursor Concept	Mercury and Moon Connection
Ice melts faster in direct sunlight than in the shade.	Ice melts or sublimates rapidly in direct sunlight; slowly in indirect light.
Compare angles with modeling clay worlds and toothpicks, in relation to a reference point.	Aimed at communicating that that a sphere presents different angles to a reference point (the Sun).
Ice cube placed at equatorial region melts faster than ice cube placed at polar region.	Directness of sunlight at equatorial regions versus grazing angle at the polar regions.
Ice cube at pole in variable world shows almost no difference in melting compared to ice cube at pole in control world.	Any ice that receives sunlight would sublimate very rapidly, evaporating into space; For ice to exist on an inner planetary world, it must be permanently shadowed in craters that craters allow NO sunlight or heat.