



SBAG Meeting  
28-30 June 2016

## **SSERVI / Lunar Mapping and Modeling Portal**

Greg Schmidt  
*Deputy Director*



# SSERVI Overview



***SSERVI is a virtual institute established to advance basic and applied lunar and planetary science research and to advance human exploration of the solar system through scientific discovery.***



# SSERVI Overview



***SSERVI is a virtual institute established to advance basic and applied lunar and planetary science research and to advance human exploration of the solar system through scientific discovery.***

***Many opportunities exist to connect with and help the small bodies community***



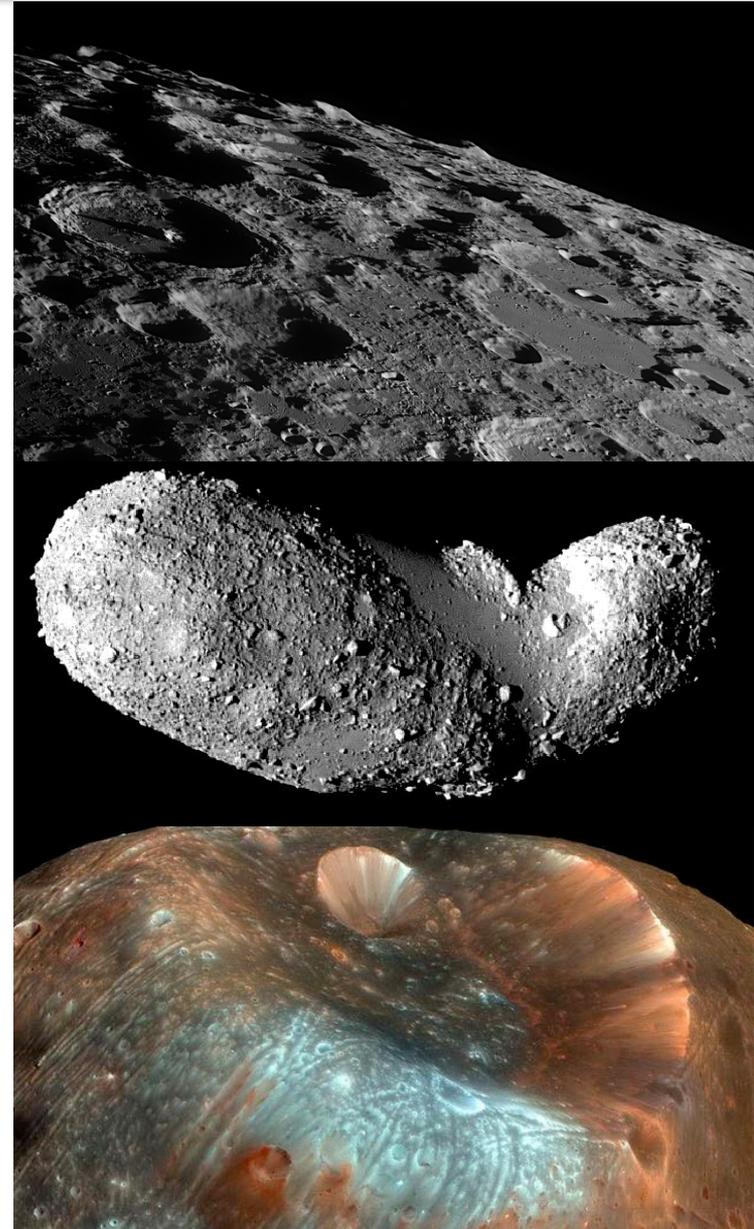
# SSERVI Science and Exploration Research



**SSERVI is a virtual institute established to advance basic and applied lunar and planetary science research and to advance human exploration of the solar system through scientific discovery, jointly funded by SMD and HEOMD (JRPA program) Focus areas include:**

- The Moon, Near Earth Asteroids (NEAs), Phobos & Deimos
  - origin and evolution of the inner Solar System
  - planetary differentiation processes
  - potential human destinations
  - structure and composition
  - regolith, dust and plasma interactions
  - volatiles and other potential resources

**[sservi.nasa.gov](http://sservi.nasa.gov)**





# SSERVI Domestic Teams



NINE TEAMS FUNDED IN MARCH of 2014, EACH FOR FIVE YEARS



**Bill Bottke**, *Southwest Research Institute*  
Institute for the Science of Exploration Targets: Origin, Evolution and Discovery (ISET)



**Dan Britt**, *University of Central Florida*  
Center for Lunar and Asteroid Surface Science (CLASS)



**Bill Farrell**, *Goddard Space Flight Center*  
Dynamic Response of Environments at Asteroids, the Moon, and moons of Mars (DREAM2)



**Tim Glotch**, *Stony Brook University*  
Remote, In Situ and Synchrotron Studies for Science and Exploration (RIS<sup>4</sup>E)



**Jennifer Heldmann**, *Ames Research Center*  
Field Investigations to Enable Solar System Science & Exploration (FINESSE)



**Mihaly Horanyi**, *University of Colorado*  
Institute for Modeling Plasma, Atmospheres and Cosmic Dust (IMPACT)



**David Kring**, *Lunar and Planetary Institute*  
Inner Solar System Impact Processes



**Carle Pieters**, *Brown University*  
Evolution and Environment of Exploration Destinations: Science and Engineering Synergism (SEED)



**Andy Rivkin**, *Applied Physics Lab, Johns Hopkins University*  
Volatiles, Regolith and Thermal Investigations Consortium For Exploration and Science (VORTICES)



*“More than the sum of its parts, SSERVI’s distributed network of U.S. Teams leverage government, academic, and industry capabilities and investments to advance science and engineering technologies for multiple target bodies and communities.”*



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*“More than the sum of its parts, SSERVI’s distributed network of U.S. Teams leverage government, academic, and industry capabilities and investments to advance science and engineering technologies for multiple target bodies and communities.”*



# Science/Exploration Balance in SSERVI Teams



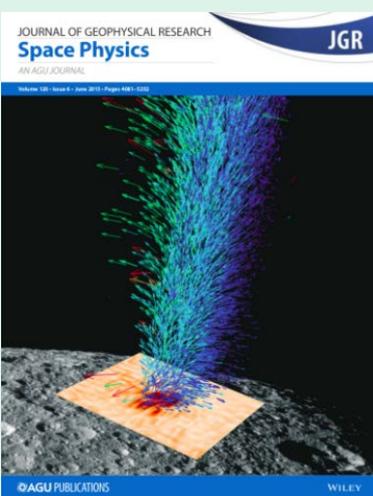
					Britt		Heldmann							
	Heldmann				Farrell	Heldmann	Britt							
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Kring	Kring	Farrell	Kring	Farrell	Horanyi	Horanyi	Horanyi	Horanyi	Bussey	Horanyi			Kring	
Horanyi	Glotch	Horanyi	Glotch	Horanyi	Glotch	Glotch	Glotch	Glotch	Glotch	Glotch	Glotch	Britt	Glotch	Glotch
Role of Target Body(s) in revealing the origin and evolution of the inner Solar System	Target Body structure and composition	Innovative observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe	Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes	Dust and plasma interactions on Target Body(s)	Near-Earth asteroid characterization (including NEAs that are potential human destinations)	Geotechnical properties (Moon, NEAs, Mars)	Regolith of Target Bodies	Radiation	Volatiles (in its broad sense) and other potential resources on Target Body(s)	In-Situ Resource Utilization (ISRU)/ Prospecting (Moon, NEAs, Mars)	Propulsion-induced ejecta (Moon, NEAs, Mars)	Operations/Operability (all destinations, including transit)	Human health and performance (all destinations, including transit)	

Science emphasis

Exploration emphasis (SKGs)



- 72 published refereed journal articles in 2016 and 455 publications since SSERVI started 25 months ago (data as of April 2016)
  - Does not include conference publications and other scientific products
- Annual report due in August (online)
- Growing portion of research stimulated by interactions between teams, unlike typical R&A program



## Rover Wheel Charging in Polar Regolith

DREAM2 team (PI Farrell): provided models of volatile transport and redistribution that identify locations where RP might prospect. Models of rover wheel charging are also applicable to the RP rover system (Jackson et al., ASR, 2015).

## Orion-NEA Gas Interactions

Water may be retained on an asteroid surface, depending upon the defect character, maturity, and composition of the asteroid. Estimates of the Orion water retention levels were provided (paper in submission).

## Solar Wind – Magnetic Anomaly Interaction

DREAM2 modeled the solar wind interaction with the Gerasimovich magnetic anomaly via a hybrid plasma simulation (Fatemi et al. 2015)

### Moon SKGs:

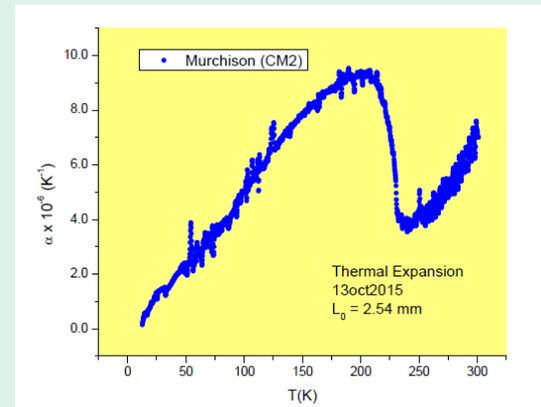
- II-D: Human Health and Performance...
- III-D: Lunar Dust Remediation
- III-E: Plasma Environ & Charging

### Mars Themes: (feed forward)

- B3: Crew Health and Performance
- C1: P/D Surface Science
- C2: P/D Surface Ops

### NEO/P/D Themes: (feed forward)

- II-A: Biohazards and mitigation
- II-B: Hazards to equipment and mitigation
- II-D: Interaction w/ surface
- III-B: Ionizing radiation environ.
- III-C: Mitigation strategies for health



The temperature dependent coefficient of thermal expansion of the CM carbonaceous chondrite Murchison measured by CLASS Co-I Dr. Cy Opeil.

## Regolith Simulant

CLASS (PI Britt) provides the scientific leadership in partnership with Deep Space Industries to develop a family of asteroid simulants to support NASA exploration goals. This work has been selected for Phase II funding (SBIR).

## Health Hazards of Carbonaceous Chondrites

CLASS (PI Britt) has taken the lead on research to characterize the potential health effects of PAHs in carbonaceous chondrites. This is a joint collaboration between CLASS and RIS4E SSERVI teams.

### Moon SKGs:

- II-C: Biological effects of dust
- II-D: Human health and performance

### Mars Themes: (feed forward)

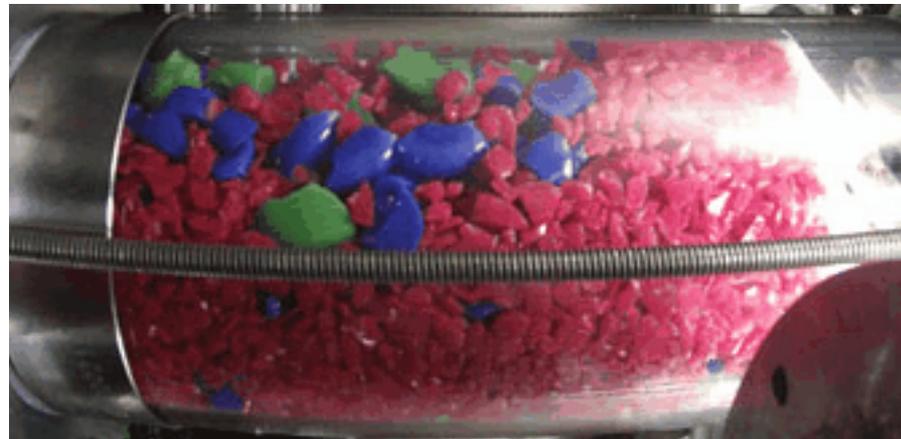
- C1: P/D surface science

### NEO/P/D Themes:

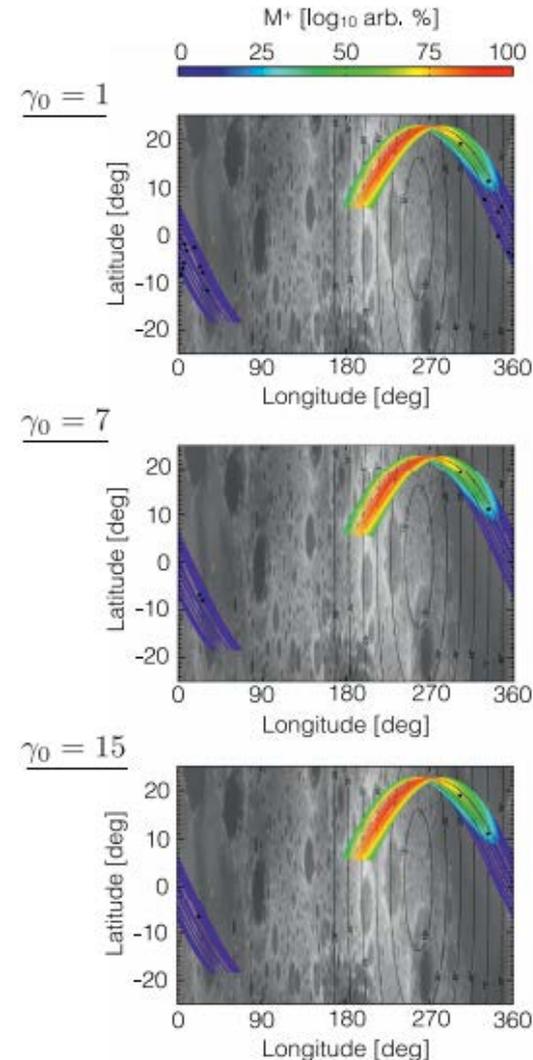
- I-C: NEO composition and phys. properties
- II-A: Biohazards and mitigation
- II-C: SB surface mechanical properties
- II-D: Mobility and interaction with surface
- III-A: Particulate environ. of small bodies
- III-C: Mitigation strategies for health
- IV-A: NEO resources
- IV-B: P/D resources



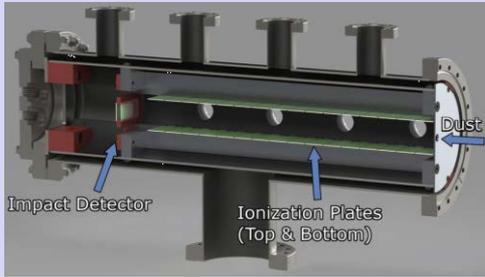
# Research Highlights: SSERVI CLASS ISS flight experiment



- LDEX instrument on LADEE was used to map the dust density distribution over the lunar surface up to an altitude of ~250 km
- Researchers measured the lunar dust cloud during intense meteoroid showers and derived properties of those streams
- SSERVI's IMPACT team at the U. of Colorado correctly measured parameters for four known meteor streams, and potentially discovered an unidentified meteoroid stream that peaked on March 25, 2014
- Future longer duration missions with in-situ dust detectors like LDEX, could be used to characterize meteoroid streams bombarding *any* airless body in the solar system
- The novel method of measuring the local meteoroid environment using the Moon itself as a large surface area dust detector was detailed in their paper "*Detecting meteoroid streams with an in-situ dust detector above an airless body*" published in the April Issue of Icarus. For more info: <http://sservi.nasa.gov/?p=11316>

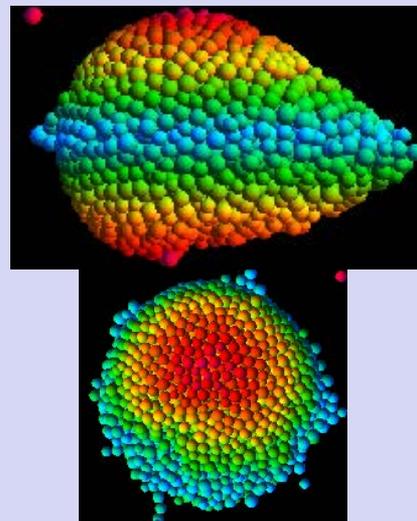
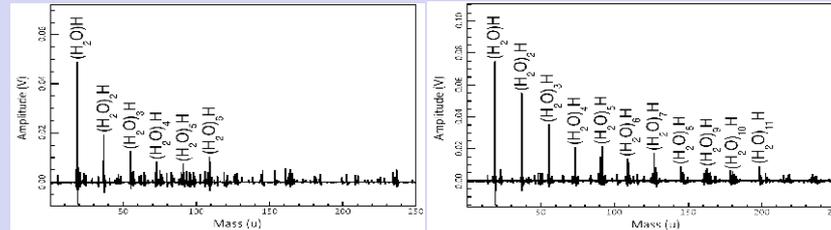
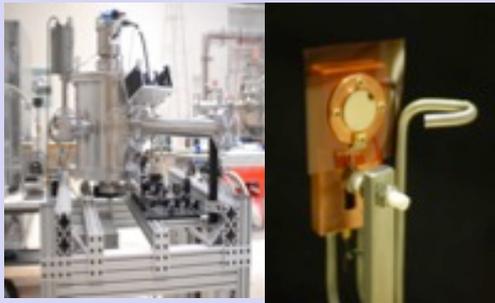


The burst distributions corresponding to the Northern Taurids. Credit: J. Szalay



## Improved Gas and Ice Targets for Impact Studies

IMPACT team (PI Horanyi) set a new speed record for dust accelerator; 117 Km/s. Additionally, improvements to their gas target facilities have shown that micrometeoroids are completely ablated within tens of centimeters.



## Mechanics of Weakly Bonded Asteroids

ISET/Bottke investigating the stress and failure analysis of observed active asteroids. His team has detailed predictions of how cohesive asteroids may evolve geophysically as a function of strength and friction. They are also focused on the dynamics of surface motion on small bodies, which has application to both exploration activities and to more detailed constraints on surface landslides on small bodies.

## Relevant SKGs:

### Moon SKGs:

- I-B: Regolith volatiles, Apollo samples
- I-C: Regolith volatiles, in-situ
- III-A: Excavation of lunar resources
- III-H: Micrometeorite shielding tech

### Mars Themes:

- A1: Upper Atmosphere
- A2: Atm. Modeling
- A3: Orbital Particulates
- B1: Lower atm.
- B4: Dust effects on surface systems
- B6: Atm. ISRU
- D1: Water resources

### NEO/P/D Themes:

- I-C: NEO composition and characteristics
- II-C: Surface mechanical properties
- III-A: Particulate environment

## Relevant SKGs:

### NEO/P/D Themes:

- I-C: NEO composition/physical character
- II-B: Hazards to equipment and mitigation
- II-C: SB surface mechanical properties
- III-A: Particulate environ. around SB
- III-D: Local and global stability of SB



# Current and Potential New International Partners



SSERVI currently has 10 International Partners including:

- Australia
- Canada
- France
- Germany
- Israel
- Italy
- South Korea
- Netherlands
- Saudi Arabia
- United Kingdom



Potential New Partners

- Mexico (*in progress*)
- United Arab Emirates (*in progress*)





# SSERVI Facilities

Available to the Science and Exploration Communities



## Relevant SKGs:

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- III-A: Particulate environment

### Moon SKGs:

- I-B: Regolith volatiles, Apollo samples
- I-C: Regolith volatiles, in-situ
- I-E: Pyroclastic deposit volatiles, in-situ

### Mars Themes:

- C1: P/D surface science
- C2: P/D P/D surface ops
- D1: Water resources

### NEO/P/D Themes:

- I-C: NEO composition and characteristics
- II-C: Surface mechanical properties
- IV-A: NEO resources
- IV-B: P/D resources

## Dust Accelerator Laboratory (DAL) (U. of Colorado)

A 3 MV linear electrostatic dust accelerator which is used for a variety of impact research activities as well as calibrating dust instruments for space application. The 3 MV Pelletron generator is capable of accelerating micron and submicron particles of various materials to velocities approaching 100 km/s.

Contact: <http://impact.colorado.edu/facilities.html>

## Ultra High Vacuum Chamber (UHV) & Ice and Gas Target Chambers (U. of Colorado)

Dedicated chambers that can be directly connected to the DAL for impact experiments requiring very clean conditions with exceptionally low background gas pressure, extreme cold temps, or various atmospheric gas pressures.

Contact: <http://impact.colorado.edu/facilities.html>

## Reflectance Experiment Lab (RELAB) (Brown University)

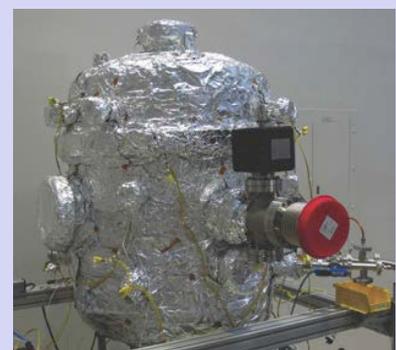
Spectroscopic data for compositional information about unexplored or unsampled planetary surfaces. Can obtain high precision, high spectral resolution, bidirectional reflectance spectra of earth and planetary materials.

Contact: <http://www.planetary.brown.edu/relab/>

## Vibrational Spectroscopy Lab (Stony Brook University)

Spectroscopic tools allow examination of geologic materials similar to those that are present on Mars, the Moon, or other solar system bodies for better interpretations of remote sensing data.

Contact: <http://aram.ess.sunysb.edu/tglotch/>





# SSERVI Facilities

Available to the Science and Exploration Communities



## GSFC Radiation Facility (NASA GSFC)

A new dedicated 1 MeV proton beam line used to create radiation-stimulated defects in materials to help determine low energy H retention effects.

Contact: [william.m.farrell@nasa.gov](mailto:william.m.farrell@nasa.gov)

### Moon SKGs:

II-B: Radiation shielding of lunar material

### Mars Themes: (feed forward)

C1: P/D surface science

D1: Water resources

### NEO/P/D Themes: (feed forward)

I-C: NEO composition and characteristics



## Regolith Testbeds (NASA's Ames and Kennedy Space Center)

The 4m x 4m x 0.5m testbed at NASA Ames is filled with 8 tons of JSC-1A regolith simulant. The Swamp Works Regolith Bins at KSC are a 120 ton bin with BP-1 and ~4 ton bin of JSC-1A — both excellent for investigations in resource prospecting and regolith.

Contact: [joseph.minafra@nasa.gov](mailto:joseph.minafra@nasa.gov)

### Moon SKGs:

II-B: Radiation shielding of lunar material

III-A: Excavation of lunar resources

III-C: Trafficability: modeling

III-D: Lunar dust remediation

### Mars Themes: (feed forward)

B4: Dust effects on surface systems

C2: P/D surface ops

C3: Technology P/D



## Physical Properties Lab (U. Central Florida)

The density lab includes: (1) A Quantachrome Ultrapycnometer 1200. (2) A new custom-built pycnometer for larger samples. A special insert for thin slabs (up to 1/4 in.). Both pycnometers have uncertainties of better than 0.5%. (3) ZH Instruments SM-30 magnetic susceptibility meter. (4) A fieldspec reflectance spectrometer with a wavelength range of 0.4-2.5 microns.

Contact: [britt@physics.ucf.edu](mailto:britt@physics.ucf.edu)

### Moon SKGs:

III-G: Radiation shielding technology

### Mars Themes: (feed forward)

C1: P/D surface science

### NEO/P/D Themes: (feed forward)

I-C: NEO composition and physical prop.

II-C: SB surface mechanical properties



# SSERVI Facilities

Available to the Science and Exploration Communities



## Microgravity Drop Tower (U. Central Florida)

The drop tower provides a zero g experience with a high speed camera set up to fall along with the experiment (allows 0.7sec of freefall). An LED backlight makes it easy to track individual ejecta particles. Images are recorded with a high-resolution camera at 500 frames/second, which allows tracking of individual particles.

Contact: [josh@ucf.edu](mailto:josh@ucf.edu)

**Mars Themes:** (feed forward)

A3: Orbital particulates

C1: P/D surface science

C2: P/D surface ops

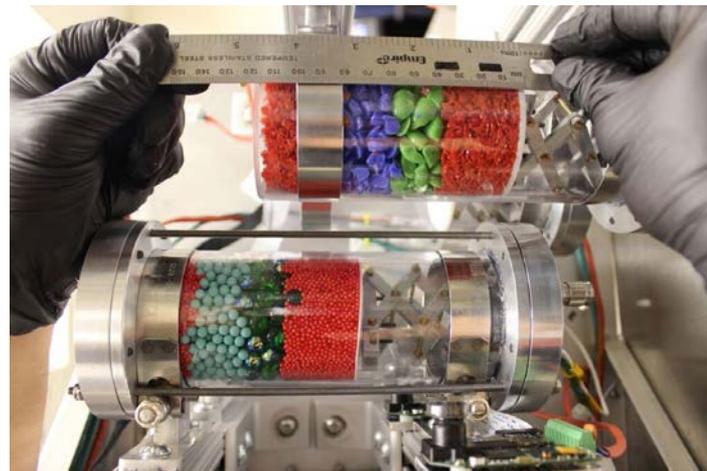
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II-C: SB surface mechanical properties

II-D: Mobility and interaction with surface

III-A: Particulate environ. around SB

III-D: Local and global stability of SB



*Strata-1 ISS experiment tested using the Microgravity Drop Tower Facility at UCF*





# Strategic Support to NASA



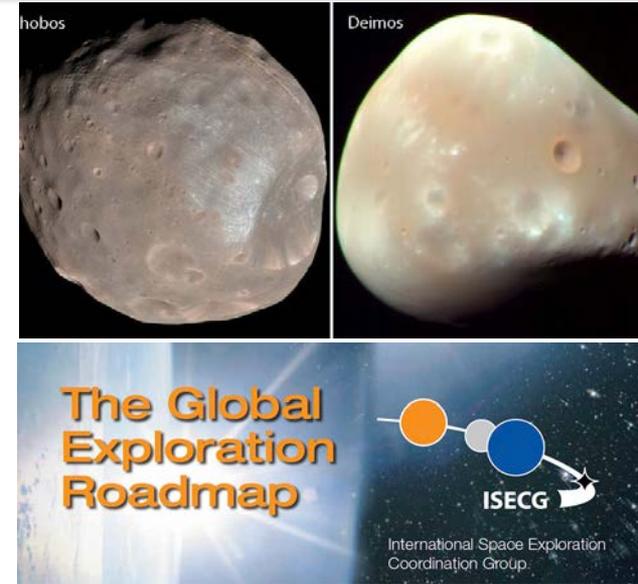
- **Phobos/Deimos SKG update (partnering with AGs)**
  - **SSERVI has organizational lead**
  - **Science co-chairs from MEPAG (Anderson) and SBAG (Rivkin)**
  - **Completion anticipated fall 2016**
  
- **SKGs: overall support**
  - **Investigating development of new relational database; will allow multiple queries and easier updating of SKGs as well as easier use for mission concept development**
  
- **GER Science White Paper support**
  - **SSERVI has role of executive secretary and overall support to HEOMD chief scientist**
  - **White paper in final review following ISECG/COSPAR workshop in February**
  
- **Other strategic documents**
  - **Decadal survey: Partnered with LEAG to bring in large number of lunar-related white papers**



# Community Support and Leadership



- **SSERVI personnel serving on Phobos/Deimos SKG analysis group**
- **Provide scientific input and virtual meeting support for Global Exploration Roadmap (GER) and Science White Paper (SWP)**
- **SSERVI staff serve active roles in LEAG & SBAG (Executive/Steering Committees)**
- **SSERVI continues grass roots Focus Groups to bring together communities to share science and exploration strategies**
  - **As an example, the ALSEP Focus Group has brought back data previously thought lost**
  - **Most Focus Groups have lunar emphasis (started when we were NLSI); **great opportunity for small bodies FGs****
- **NASA Postdoctoral Program (NPP), with postdocs shared between teams to facilitate inter-team collaborations**





# Exploration Science Forum



- **The Exploration Science Forum (ESF) consists of**
  - **Parallel science/technical sessions**
  - **poster sessions**
  - **student lightning round talks**
  - **Award presentations (Shoemaker, Wargo, Niebur)**
  - **Focus Groups**
  - **Town Halls (LEAG/SBAG, NASA)**
- **In-person conference with virtual component**
- **All past Forum recordings are available on [sservi.nasa.gov](http://sservi.nasa.gov)**

National Aeronautics and Space Administration



# NASA EXPLORATION SCIENCE FORUM

JULY 20-22, 2016



NASA AMES RESEARCH CENTER  
MOFFETT FIELD, CALIFORNIA

[www.nasa.gov](http://www.nasa.gov)

[SSERVI.NASA.GOV/NESF2016](http://SSERVI.NASA.GOV/NESF2016)



# 3<sup>rd</sup> International Phobos-Deimos Conference



- **Jointly organized with SSERVI, SETI Institute and Mars Institute**
- **Oral/Poster Sessions on**
  - **Science**
  - **Robotic Reconnaissance**
  - **Human Exploration**
  - **Phobos-Deimos SKGs**
  - **Synthesis – to be presented at Forum**
- **SETI Institute sponsored space art exhibit**
  - **Featured painting by Chesley Bonestell**



NASA AMES RESEARCH CENTER  
MOFFETT FIELD, CALIFORNIA

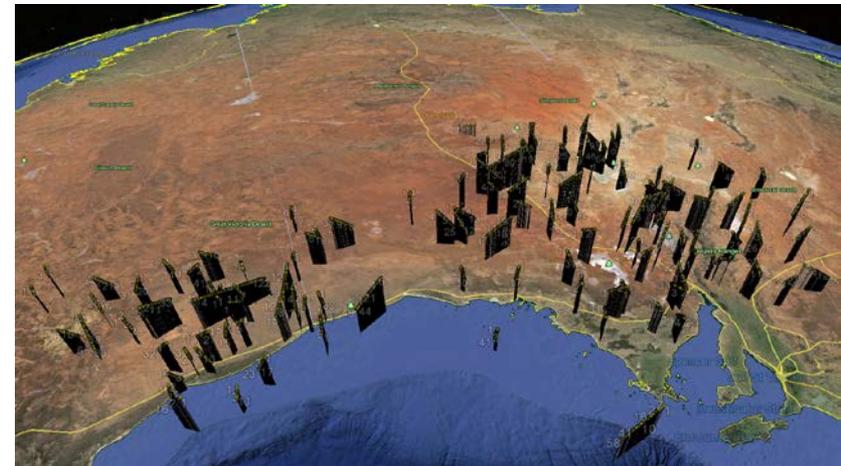
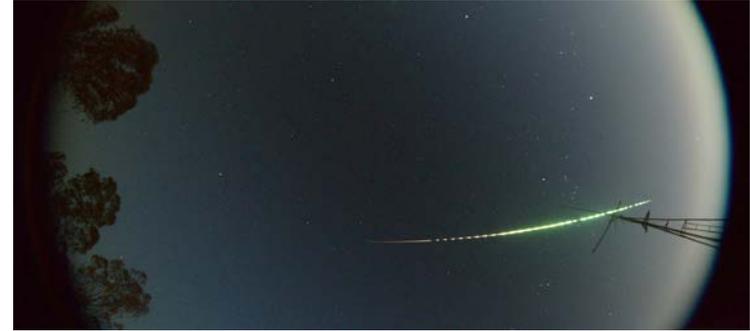
[www.nasa.gov](http://www.nasa.gov)



MARS INSTITUTE

# Desert Fireball Network

- **Developed by Australian SSERVI PI/partner Phil Bland, Curtin University**
- **Automated system for detection of bright meteors**
  - **Triangulation allows calculation of orbits**
  - **Can predict potential fall locations – several successes**
- **Total literature currently ~800 fireballs**
  - **DFN @ ~300 detections already**
- **Inexpensive hardware & automated data processing allow easy expansion**
  - **Currently expanding to other SSERVI partners/future partners**
- **Opportunity: Collection expeditions!** →

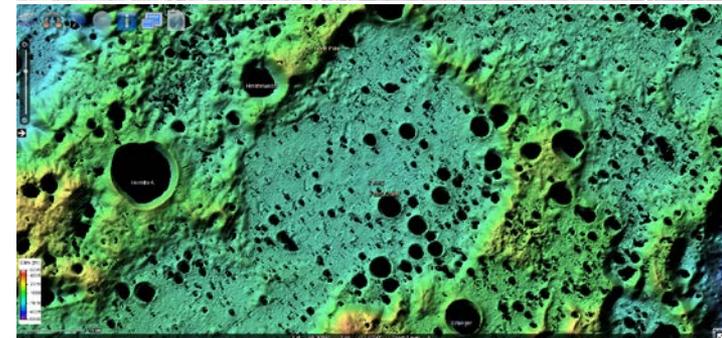


- International Observe the Moon Night – Oct 8, 2016
  - <http://observethemoonnight.org/>
- Jim Head (Brown Univ.), presented to UNAM students during the March 17 SSERVI video conference with several Mexico high schools.
- Partnered with Gemini Observatory in conducting *Journey through the Universe*, March 7-11, 2016, with over 8,000 students participating
- Frequent stories (3-4x/week) on [sservi.nasa.gov](http://sservi.nasa.gov)
- **Major social media presence: over 85K Twitter followers**
  - Will increase AES following via retweet bot put in place week of 4/4/16
- Many public presentations reaching thousands

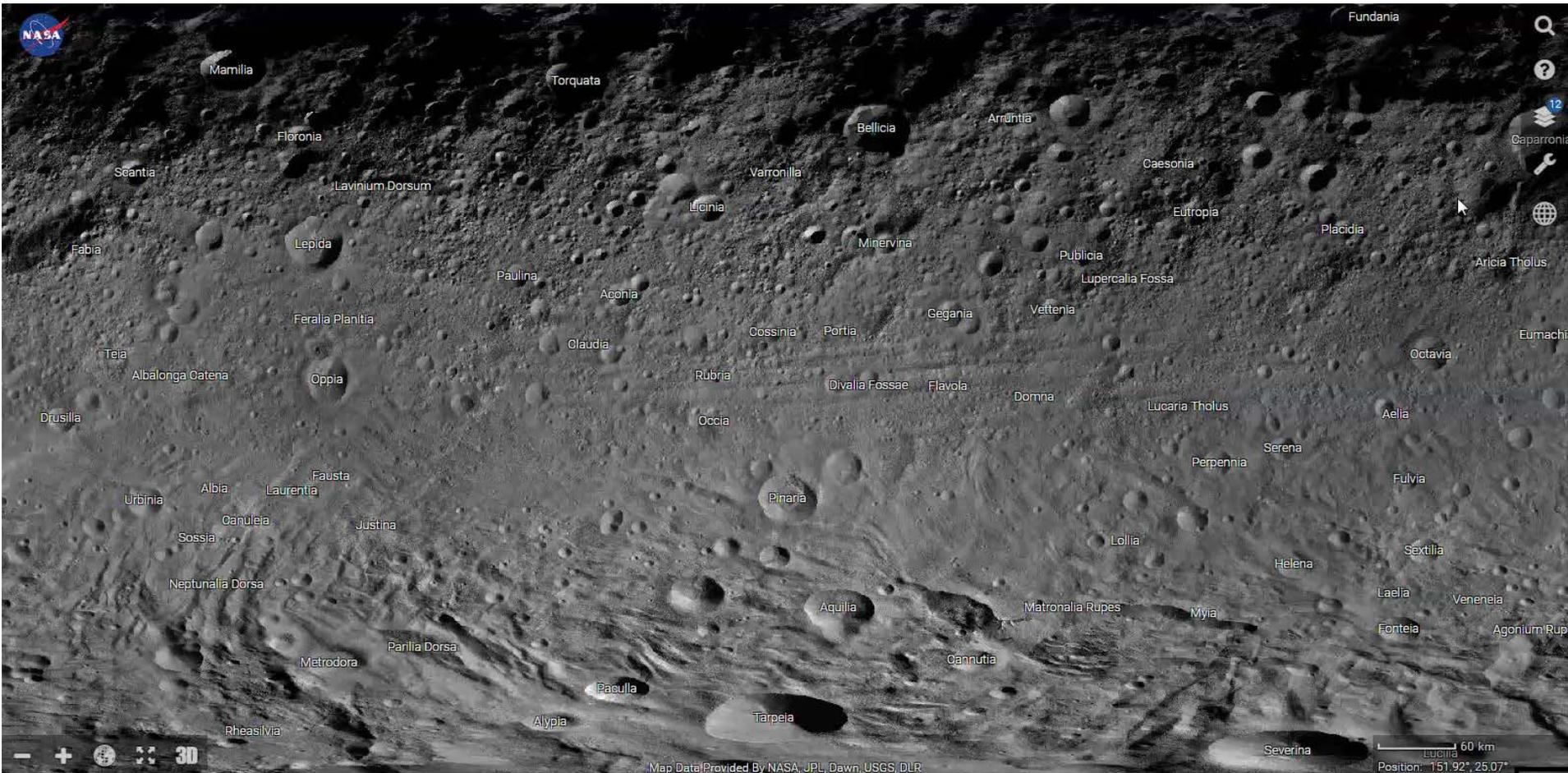


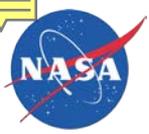
- **The Desert Fireball Network** is an end-to-end system that goes from seeing a shooting star, to holding it in your hand. The free Fireballs in the Sky app leverages **citizen science initiatives** and allows the public to report meteor sightings to scientists.

- **Continuing support for Resource Prospector Site Selection and Analysis**
  - **Hosting and disseminating RP specific data products as well as a growing list of general polar data products**
  - **Committed to generate an additional DEM for RP**
  - **Working with mission to provide Taiwan nationals currently in a study agreement with NASA/RP with access to lunar surface DEMs especially in the proximity of the polar regions. Particular emphasis on use for Terrain Relative Navigation (TRN) studies.**
- **Lunar CubeSat Mission Support**
  - **Supporting mission planning and data management**
  - **Presented at 2015 International Workshop on Lunarcubes and are scheduled to present at 2016 workshop**
- **Lunar Mission 1 Collaboration**
  - **Participating in Landing Site Selection Working Group, with LMMP facilitating the team's work**
  - **Facilitating coordination between RP and LM1 Site Selection efforts**



- A web-based portal for exploration of Vesta
- Based on SSERVI-managed, JPL-developed LMMP platform – used for mission support
  - Extended LMMP to non-spherical objects & proved suitability for Phobos & others
- [vestatrek.jpl.nasa.gov](http://vestatrek.jpl.nasa.gov)

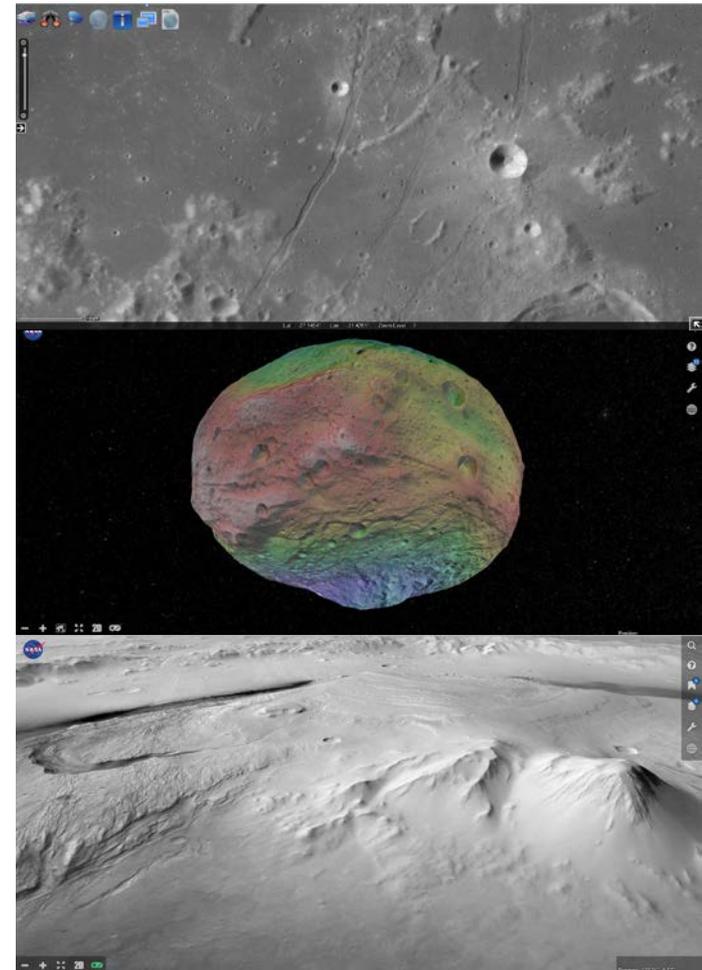




# Acquisition Innovation and Crowd-Sourced Development



- White House “ACQUISITION INNOVATION LABS & PILOT DIGITAL ACQUISITION INNOVATION LAB” memo of 3/9/16: *“This memorandum requests each Chief Financial Officer (CFO) Act agency to ensure it has an acquisition innovation lab, or similar mechanism, in place to help agency programs and their integrated project teams (IPTs) achieve better results for the taxpayer.”*
  - LMMP’s Image Processing Challenge through the NASA Tournament Lab is held up as the example for *“Applying Emerging and Best Practices – Procuring digital services and software through crowdsourcing”* (P9)
- Continuing support of NASA crowd-sourcing challenges
  - The “Vesta Revealed” 2016 NASA Space Apps Challenge, to *“Create a generic digital online tool to build Constant-Scale Natural Boundary (CSNB) maps of Vesta utilizing the Digital Elevation Model (DEM) found through Vesta Trek.”*
  - The “Open World Generation Using NASA Mars and Vesta Data” 2016 NASA Space Apps Challenge using data provided by Mars Trek and Vesta Trek.





# Online archives

- All past SSERVI events are archived at [sservi.nasa.gov](http://sservi.nasa.gov)
- SSERVI has hosted and maintains online an archive of classes & lecture series – examples include:
  - Asteroid Grand Challenge Seminar Series: <http://sservi.nasa.gov/agc-seminar-series/>
    - Morrison, Johnson, Chodas, Britt, etc..
  - Phobos-Deimos lecture series: <http://sservi.nasa.gov/event/planetary-evolution-phobos-and-deimos/>
    - Hosted by Britt and Pieters SSERVI teams



# Conclusions



- SSERVI is keenly interested in supporting the small bodies community
- Multiple potential methods exist right now to strengthen ties:
  - Workshops without walls
  - Focus groups
  - International partnerships
  - Support of Town Halls
- SSERVI to release CAN soon (most likely July)
  - Will include small bodies