The DREAM and ARTEMIS lunar plasma science connection


THEMIS/ARTEMIS SWG 091411
• What is DREAM?
  • Stands for: *Dynamic Response of the Environment at the Moon*
  • In 2007, NASA’s Planetary Division formed a **virtual institute** to pursue dedicated theme-based lunar science topics...analogous to NAI
  • In 2008, 7 science teams or ‘nodes’ were selected via a CAN under LSI central direction
  • DREAM is one of these teams picked to examine and advance understanding of solar-lunar connection
• “How does the highly-variable solar energy and matter incident at the surface interface affect the dynamics of lunar volatiles, ionosphere, plasma, and dust?”

• Model/data validation team

• Emphasize the dynamics – solar storms and impacts at the Moon

• Provide science support to missions like LADEE, LCROSS, LRO, Kaguya, Lunar Prospector
LSI TEAMs include

The Moon as Cornerstone to the Terrestrial Planets: The Formative Years; principal investigator Carle Pieters, Brown University in Providence, R.I.

Impact Processes in the Origin and Evolution of the Moon: New Sample-driven Perspectives; principal investigator David Kring, Lunar and Planetary Institute in Houston

Understanding the Formation and Bombardment History of the Moon; principal investigator William Bottke, Southwest Research Institute in Boulder, Colo.

Dynamic Response of the Environment at the Moon; principal investigator William Farrell, NASA Goddard Space Flight Center in Greenbelt, Md.

Scientific and Exploration Potential of the Lunar Poles; principal investigator Ben Bussey, Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

NASA Lunar Science Institute: Colorado Center for Lunar Dust and Atmospheric Studies; principal investigator Mihaly Horanyi, University of Colorado in Boulder

Lunar University Node for Astrophysics Research: Exploring the Cosmos from the Moon; principal investigator Jack Burns, University of Colorado in Boulder
“How does the highly-variable solar energy and matter incident at the surface interface affect the dynamics of lunar volatiles, ionosphere, plasma, and dust?”

*DREAM has four supporting themes that address this overarching question:*

1. Advance understanding of the surface release and loss of the **neutral gas exosphere** over small to large spatial scales and a broad range of driver intensities.

2. Advance understanding of the enveloping **plasma interaction region** over small to large spatial scales and over a broad range of driver intensities.

3. Identify **common links** between the neutral and plasma systems and test these linkages by modeling **extreme environmental events**.

4. **Apply** this new-found environmental knowledge to guide decision-making for future missions, assess the Moon as an observational platform, and aid in human exploration.

DREAMs first model: Na coma and wake
**DREAM Models**

CCMC MHD codes of solar wind/CMEs
Monte Carlo Exosphere (Crider/Killen)
Monte Carlo Regolith (Crider/Vondrak)
Ar-40 Monte Carlo Sims (Hodges)
Neutral/surface ejection (Sarantos/Killen)
Exo-ion pickup (Hartle)
Impact Model – LCROSS (Colaprete)
Impact Model – Snowball (Crider)

Hybrid/Kinetic plasma sims (Krauss-Varben)
Kinetic wake sim (Farrell)
Equivalent circuit model (Farrell/Jackson)
Surface charging model (Stubbs)
Dust Fountain model (Stubbs)
Mie scattering model (Glenar)

**DREAM Validation Sets**

Direct (public domain):
WIND (Lin/Bale)
GEOTAIL (Peterson)
SIDE ALSEP (Collier)
LP MAG/ER (Lin)
Apollo 15/16 subsat plasma

Indirect (access via co-i):
ARTEMIS (many)
Kaguya PACE (Saito, Elphic)
LRO (Vondrak, Keller, Stubbs, Spence)
LCROSS (Colaprete)
LADEE (Colaprete, Horanyi)
Constellation (Hyatt, Farrell, Dube)
<table>
<thead>
<tr>
<th>ARTEMIS Planetary Science Goals and Means</th>
<th>DREAM Goals</th>
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<tr>
<td>A. Sources and transport of exospheric and sputtered species, in relation to surface features, as revealed in the charged particle environment</td>
<td>Goal 1. Advance understanding of the surface release and loss of the neutral gas exosphere over small to large spatial scales and a broad range of driver intensities.</td>
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<td>B. Dust charging and circulation by electric fields.</td>
<td>Goal 2. Advance understanding of the enveloping plasma interaction region over small to large spatial scales and over a broad range of driver intensities.</td>
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<td>C. Structure and composition of lunar interior as revealed by electromagnetic sounding from orbit.</td>
<td>Goal 3. Identify common links between the neutral and plasma systems and test these linkages by modeling extreme environmental events.</td>
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<td>D. Surface properties and planetary evolution as revealed by crustal magnetism and space weathering.</td>
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DREAM Wake Model Studies

- Great example of cross-connection
  - DREAM very interested in trailing ion sonic wake, from large scale to near-surface wake features
- Try to validate models with LP and new ARTEMIS set

Zimmerman et al., 2011
Relaxing Plasma Expansion Quasi-neutrality

- Samir et al [1983] assumed $n_e = n_i$ throughout expansion
- Assumes ions nearly instantly catch up to electrons - convoluted argument
- But do they?
- Crow et al [1975] relaxes this constraint – finds electrons move in ahead of ions
Possible ARTEMIS Targets

- Proof of the formation of the electron cloud/ion depletion region
- Ambipolar E-field detection
- Wake replenishment (ion-ion vs electron beam instabilities)
- Inflow when B parallel to wake
- Solar storm affects

if we can understand the wake structure at the large scale, we can infer its structure on the small scale in craters, etc.
DREAM Exospheric Studies

- Great example of cross-connection
- DREAM very interested in neutral & exo-ion creation and their propagation in the near-Moon environment
- Try to validate models with LCROSS, Kaguya and new ARTEMIS set

LCROSS Support
Killen and Hurley

Exo-ion propagation
Hartle and Sarantos

Hybrid sims
of ion environment
Krauss Varben and Travnicek
Possible ARTEMIS Targets

- Cycloid motion of ions from quasi-localized source
- Get spatial enhancements that very as a function of ion mass
- ARTEMIS can use the Moon as a ‘poor man’s’ mass analyzer

Hartle at al, 2009, Fall AGU poster
Other Common Topics

- Dust exosphere detection during close passages
- Mag anomalies
- Solar Storms/CME passages by the Moon
- Precursor activity (see Jasper Halekas talk)
- Lunar surface charging (see Andrew Poppe talk)
- Moon as a platform to study deep m-tail plasma (see Tim Stubbs talk)

Stubbs et al., 2010
Conclusion

• DREAM Objective 4: Support ongoing missions
• ARTEMIS and DREAM share some objectives
• DREAM folks can provide community support to missions like ARTEMIS including run models, to consult, help out...but not usurp!
• E/PO: International Observe the Moon Night on Oct 8
• Want more information on DREAM and NLSI see http://ssed.gsfc.nasa.gov/dream/