Cooperative Scientific Opportunities: Recommendations

Facilitator: Alan Stern

Recorder: John Keller

Cooperative Scientific Opportunities

CORE TEAM MEMBERS

- Manabu Kato
- Keith Raney
- Carle Pieters
- Bernard Foing
- Sylvie Espinasse
- Igor Mitrofanov
- David Smith
- Martin Houghton
- Jerry Fishman
- Ben Bussey
- Stu Nozette
- Christian Veillet

Cooperative Scientific Opportunities

PARTICIPANTS

- Cherilynn Morrow
- Kurt Retherford
- Keith Raney
- Mary Reden
- Joe Mazur
- Justin Kasper
- Harlan Spence
- David Blewett
- Ben Bussey
- Jeffrey Gillis-Davis
- Josh Cahill

- Mark Nall
- Jerry Fishman
- Igor Mitrofanov
- Jacob Trombka
- Stephen Ballard
- Marc Foote
- Wayne Hartford
- Bruce Betts
- Manabu Kato
- Nori Namiki

Cooperative Scientific Opportunities

BACKGROUND PRESENTATIONS PROVIDED

- Selene ion mass analyzer observation of LCROSS impact, J. Keller
- Scientific operations and cooperation – Bernard Foing
- LRO orbit details – Martin Houghton

Cooperative Scientific Opportunities

- Coordinating for calibration AND for high coverage, need coordinated and large list of prime targets and potential landing sites
- Common language - terminology to describe landing sites
- Coordinate the mission terminations
- Understanding the lunar atmosphere – even orbiting instruments perturb the atmosphere. Common database for atmospheric measurements. Event Calendar
- Target of opportunity – Solar events. Planning for events to preserve data during safe mode, keep monitors on during events. High data rates for these instruments.   Be ready for anything. Preserve engineering data during energetic particle events.
- Mechanical coordination of the spacecraft – each spacecraft orbit is fixed inertially
- RF coordination – interference from spacecraft and Arecibo active interactions may damage instruments any other active assets including lasers.

Cooperative Scientific Opportunities

- Coordination of measurements between spacecraft LRO and Chandrayaan radar, imagers (glints).
- Measurements by other assets – Swift, Sodium measurements, Impact events and coordination of other assets. Use data from upstream monitors and magnetospheric measurements
- Laser Ranging from Earth – Tying of lunar and orbital coordinate systems.
- Comm relay mode for some spacecraft.
- Prepare for coordination for lander missions – active experiments.
- Coordination of lander missions – maximize return.

Coordination of Surface Study Sites and Coverage

- What is the optimal strategy for coverage of the moon by the entire constellation
- Adopt a split strategy--
  - Heavy mission to mission overlap on potential landing sites, calibration targets, scientific targets
  - But also coordinate to cover much of the moon
  - Optimize phase angle and lighting coverage between missions
  - Develop common terminology for site and site condition (e.g., lighting) designation

Coordination of Orbital Missions to Prevent Untoward Circumstances

- Orbital collision avoidance.
- RF interference avoidance
- Radar EMI avoidance
- Other?

Coordination of Orbital Missions for Extended Mission Comm Relays

- Requires Relay Capability
- Requires Comm Orbit

Coordination of Spacecraft Radar Measurements

- Each spacecraft orbit is fixed in inertial space.
- Some coordinated measurements like collaboration between the two radars on LRO and Chandrayaan require a degree of co-planarity
  - decisions made before launch.
  - LRO aims for beta = 0 during lunar solstices.

Understand Mission Impacts On the Lunar Atmosphere

- Lunar atmospheric studies must be performed before heavy rocket traffic of human missions and an outpost destroy the native environment.
- Every orbiting spacecraft engine maneuver perturbs the atmosphere by injecting effluents. Study these events using Selene-PACE, LRO-LAMP, etc.
- Create a common database of expected events from each mission to facilitate studies of these perturbing events.

Coordination with LCROSS

- Offer/Coordinate with Selene's PACE ion/electron mass spectrometer to observe the LCROSS event.
  - Search for possible H_2O and other impact products
  - Track time variation from before to several days after impact.

Coordination with LCROSS

- Coordinate the entire constellation of lunar orbital assets to observe the LCROSS impact over-flight and post-impact plume as it evolves.
  - Search for possible H_2O and other impact products
  - Pay attention to the relative positioning of all spacecraft in the constellation.

End of Orbital Mission Impacts

- “All missions are doomed to impact”
  - Learn from Smart 1 and then LCROSS
  - Take advantage of all impacts to study polar deposits, impact mechanics, etc.
  - Coordinate impact observations

Understand Energetic Particle Events

- Understanding energetic particle events are important for exploration and science goals.
- Preserve SEU data, other engineering data, and keep particle monitors on during events to help design future lunar missions.
- Also aids some kinds of science observations, radiation hazard research.

Safety and Interference Coordination With Ground Assets

- RF coordination – interference from spacecraft and Arecibo active interactions may damage instruments any other active assets including lasers.
- Glint from ground lasers and laser ranging may affect imaging instruments

Prepare for Coordination for Lander Missions

- E.g., Active experiments – observe from orbit, propagation of released gasses.
- Coordinate landing site selections to maximum benefit of lunar exploration

EPO Coordination

- E.g., missions photograph one another from orbit

Coordination of Project Scientists

- For all missions
  - Set up a WG of the project scientists
  - Coordinate various issues and opportunities
  - Discuss changes in mission strategies
  - Meet regularly

Cooperative Scientific Opportunities

OBSTACLES

- Schedule – many decisions must be made early based on events such as launch dates and LCROSS impact
- Conflicting science and exploration objectives
  - E.g., it may make sense on some level to coordinate orbital planes of the spacecraft but individual spacecraft may all go for the same perceived optimal lighting conditions
- Primary mission – spacecraft generally must fulfill full mission success before taking on supplemental science objectives
- Cost – Study, implementation and analysis of cooperative measurements may require additional funding.
- Management – decisions to go forward will require buy-in at multiple levels of each agency.
- Many good ideas. Can’t do them all, need to prioritize and develop consensus
- Safety – **Must coordinate** mission or Earth observations to prevent damage to spacecraft and instruments or data corruption.

Cooperative Scientific Opportunities

OPTIONS for taking advantage of opportunities and overcoming obstacles

- E-mail communication between project scientist or representatives (email list coordination J. Keller)
  - To inform within a few days of major changes to spacecraft operations.
  - Way to communicate white papers for high level descriptions of the instrument
  - Orbital information and *rationale* and general engineering data (ephemeris etc.)
  - Coordinate session at science meetings (COSPAR AGU etc.)
  - Sub-groups (measurement types, science objectives) will develop channels of communication amongst like-minded investigators.
- Form a core working group consisting of PI’s, agency leadership, and lunar science community – white paper with specific recommendations
  - Recommend follow-on meeting devoted to this subject.
  - Solicit agencies funding to support study group
  - Effective steps can be low impact and implemented under the radar screen – **keep talking to each other!**
- Develop Event List from all relevant operations (volunteer???)
  - Earth observations e.g. radar, lasers
  - Inter-spacecraft interactions
  - Individual Instrument teams should assess risks.

Cooperative Scientific Opportunities

IDEAS FOR COMMUNICATING OUR FINDINGS

- Short note in COSPAR publication
- EOS communication describing this meeting.
- Linking web sites – each site could have a page devoted to cooperative measurements.