Questions

• What can we learn from robotic missions before the next human landing?
• What do we need to learn from robotic missions before lunar settlement and commercial development?
• What role could be played by small, robotic lunar missions?
• What role could state governments play in lunar exploration?
• Can the CEV SIM Bay be used for deployment of robotic exploration missions?
Important Themes

• There is a long list of measurements to make and tests to do before and after human missions
• These will enhance lunar exploration
• There are innovative ways of implementing missions that could lead to lower cost
Why do robotic precursor missions?

• **Strategic knowledge**
  – Important information on lunar environment and materials obtained before people return
  – Scientific and operational reconnaissance

• **Programmatic milestones**
  – Decade between LRO and first human landings
  – Sustain program with cadence of visible milestones

• **Emplacement of assets**
  – Pre-landed machines can prepare site, emplace equipment for later human use

• **Site Precedence**
  – Assets in orbit and landed payloads are statement of intent to use lunar resources
Why do robotic scientific missions?

- Characterize processes and environments likely to be changed as a result of human presence (e.g., lunar atmosphere)
- Obtain information on unknown or poorly understood processes and history (e.g., polar deposits)
- Reconnoiter areas and sites to make subsequent human exploration more productive
- Explore to characterize, map, learn and understand (all sites)
Important Measurements to Enhance Exploration

• Useful Lunar Information
  – Dust characterization & mitigation
  – Landing site reconnaissance
  – Lunar model validation (tie to ground truth)
  – Local radiation measurement
  – Spacecraft charging evaluation
  – Regolith handling/site preparation
  – ISRU characterization and demonstration
  – Lighting perspective (permanent low incidence at poles)
Important Measurements to Enhance Exploration

• **Useful Lunar Information: Polar Volatiles**
  • Inventory of trapped ice
  • Composition of ice
  • Variability in ice composition
  • State of volatiles (ices, amorphous compounds, separate phases, clathrates)
  • Spatial distribution of ice
  • How ice binds soil grains
  • Whether ice reacts with soil grains
  • Geotechnical properties of ice-bearing regolith in cold traps
  • Physical environment of polar regions
Technology Demonstrations

- Communications (surface mobile comm)
- Mechanisms (1/6G performance, dust impact on lifetime)
- Materials (dust compatibility)
- Thermal (surface influence, radiator dust exposure)
- Navigation and guidance (Precision Landing)
- Propulsion (system performance, plume interaction)
- Mobility (traction, dust impact)
- Power (Re-charging mobile robotic assets, fuel cell tech)
- Avionics (Open architecture, Rad hard)
- Cryo handling & storage (test demo)
- ECLSS (water loop performance in 1/6g, dust filters)
Innovative Robotic Approaches:
Multiple hard landers for polar studies

- Cover diversity of polar lighting conditions
  - Ideal dispersion is at least one in light, one in dark
- Assure sensor release (no null results due to inverted orientation)
  - Will need to clear H-bearing material on spacecraft for accurate measurement of regolith
- Mission Redundancy
  - Assure at least one probe works and gives ground truth
Innovative Robotic Approaches: Small Spacecraft

• Key Features
  – Low Mission Costs ($50-100M), Short Schedule <24Months
  – Low Mass < 300kg, Low Cost Launch Vehicles

• Benefits
  – Lower Cost Enables Increased Number Of Missions
  – Faster Learning Cycle, Leads to Lower Costs
  – Demonstrate New Technology Sooner, Lowers Cost of Large Missions
  – Lower Overall Program Risk by Providing Several Flight Opportunities
  – Smaller Teams, Fewer Interfaces, Improved Collaboration

• Drawbacks
  – Size, Mass Eliminate Some Missions for Small Spacecraft
  – Higher Individual Risk Of Missions compared with $1B Spacecraft
  – Use of “Yet To Be Proven” Launch Vehicles, or Fly as a Secondary Payload
Lunar Science Robotic Campaign

- Establish an aggressive lunar science campaign to the lunar surface
- Enabled by commercial leveraging with NASA
  – Could follow approach to develop commercial orbital transportation system (COTS)
- Could lead to a near-term technology demonstration on the surface
- Campaign (series of missions) would provide information needed for exploration and science
- LEAG through NAC could define the campaign
Role of the States

• Why should states get involved?
  – Affordability demands State participation
  – Sustainability demands State participation
  – The public benefits more when States participate.
  – Industry is critical, but it has to make money
  – The States can bring everything together

• Roles states can play
  – Education
  – Promotion (e.g., tax structures for business)
  – Recruitment and incubation of space business
  – Build infrastructure