Lunar Exploration Roadmap
Theme 3: Sustainability

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Sustainability Premises

• Lunar activity should involve sustainable Science, Exploration, Commerce and Security

• Sustainability: real or anticipated return of value to stakeholders, public and private
  – scientific discovery
  – technology developments with terrestrial application
  – expected time to self-sustaining commercial activity
  – opportunity costs of lunar exploration
Roadmap: Sustainability of Lunar Exploration

- Goal A: Maximize Commercial Activity
- Goal B: Enable and Support the Collaborative Expansion of Science and Exploration
- Goal C: Enhance the Security, Peace and Safety of People on Earth
Goal A: Maximize Commercial Activity

• Summary: Actions necessary to ensure that economically self-sustaining commercial endeavor is employed except where inherently-governmental activity is necessary.

• A Key Enabler: Market Demand
  – Integrating & aggregating needs: exploration, science, international, commercial
  – Encouraging efficient delivery, sustainable market size, early start
  – Defining essential requirements within “missions”
  – Limiting autonomy to maximize opportunity
  – Combining resources to obtain capability
Maximize Commercial Activity: Objectives

- Sust-A-1 (High, Early): Policies and implementation of comprehensive, coordinated governmental and intergovernmental action
- Sust-A-2 (High, Early): Preparation-I: comprehensive resource and market assessment of potential commercial lunar support services
- Sust-A-3 (High, Early): Preparation-II: small-scale demonstrations of potentially commercial lunar support services
Maximize Commercial Activity: Objectives

- Sust-A-4 (High, Middle): Transition-I: pilot-plant scale demonstrations of potentially commercial lunar support services
- Sust-A-5 (High, Late): Transition-II: fully operational delivery of commercial lunar support services
Goal B: Enable and Support the Collaborative Expansion of Science and Exploration

- Summary: Direct, conduct and support a variety of scientific investigations in complement to exploration activities involving discovering and exploiting resources and otherwise learning to live away from the Earth.
Collaborative Expansion of Science and Exploration: Objectives

• Sust-B-1 (High, Early): Implementation of comprehensive, coordinated integration of diverse scientific and exploration activities to maximize complementary operations and minimize operational and environmental conflicts
• Sust-B-2 (High, Early): Establishment and implementation of comprehensive site-selection criteria and processes
• Sust-B-3 (High, Early): Development of surface power and energy storage systems
Collaborative Expansion of Science and Exploration: Objectives

- Sust-B-4 (High, Early): Establishment of sustainable *transportation between Earth and the lunar surface*
- Sust-B-5 (High, Early): Deployment of *robotic facilities for science and exploration operations*
- Sust-B-6 (High, Early): Establishment of *global communications and navigation capability*
Collaborative Expansion of Science and Exploration: Objectives

- Sust-B-7 (High, Late): Establishment of sustainable human transportation between lunar sites
- Sust-B-8 (High, Early): Deployment of habitat and laboratory facilities for human science and exploration operations
- Sust-B-9 (High, Early): Establishment of in-situ production of life-support, power system reagents, propellants and related resources
Collaborative Expansion of Science and Exploration: Objectives

• Sust-B-10 (High, Middle): Establishment of *in-situ food production* capability
• Sust-B-11 (Middle, Late): Establishment of *in-situ repair, fabrication, manufacturing and assembly* capability
• Sust-B-12 (High, Early): Establishment of *integrated design, development and testing* capability
Goal C: Enhance the Security, Peace and Safety of People on Earth

• Summary: Return value to Earth from missions other than scientific and exploration that cannot be accomplished in other ways
Security, Peace and Safety of People on Earth: Objectives

- Sust-C-1 (High, Late): Detection and mitigation of threats from Near-Earth objects
- Sust-C-2 (High, Late): Beamed power and other lunar-based energy sources for terrestrial consumption
- Sust-C-3 (Medium, Late): Remote and Hazardous Research and Testing
- Sust-C-4 (Medium, Early): Applied Earth observations
- Sust-C-5: Archiving of Critical Human Records and Biological Samples
Theme-Goal-Objective-Initiatives

• 3: Sustainability > B: Science/Exploration
  – 6: Robotic Facilities for Science and Exploration
    • Initiative A: Develop *standardized robotic platforms* for lunar operations that reduce the unit cost of such platforms through amortization of development costs and economies of scale in manufacturing and delivery.
    • Initiative B: Utilize *robotic precursor missions* to conduct selected *lunar science investigations* that focus on characterizing the pristine lunar environment and contribute to identifying lunar resource concentrations.
    • Initiative C: Utilize *robotic precursors* to evaluate and obtain critical *fundamental, applied, design, and engineering data for lunar infrastructure* (ex. life support, power, ISRU, communications, etc.).
  • … through “L”
Sustainability of Lunar Exploration: Summary

• Sustainability depends on efficiencies in planning and execution:

• Sustainability depends on adopting it’s principles early
  – Removal of Barriers to Commerce
  – Robotic Missions for Science, Resource Prospecting, and Technology Risk Reduction
  – Infrastructure development

Sustainability: Return of Value to Stakeholders