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LSIC Dust Mitigation

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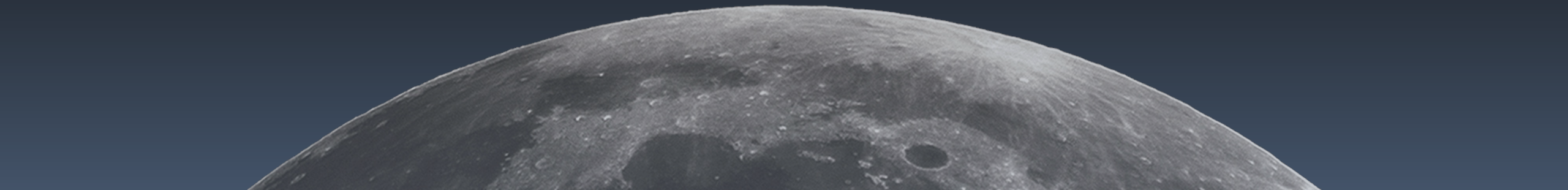
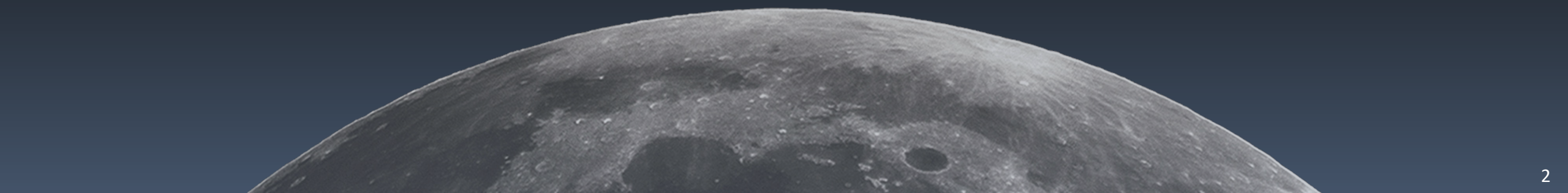


LSIC | White Paper: The Path to an Enduring Lunar Presence

Goals for today's LSIC Dust Mitigation Focus Group Meeting:

- Provide the LSIC Dust Mitigation FG an introduction the ongoing LSIC Paper effort
- Highlight near-term opportunities to provide feedback on the WIP paper
  - FG Meetings
  - Spring Meeting
- Engage in community discussion to provide inputs to the Dust Mitigation section of the paper
  - "Raise Hand" in Zoom or share in chat during discussion portion



LSIC | White Paper: The Path to an Enduring Lunar Presence

- **Decisions we make now are critically important to achieve the 10+ year goals of the Nation on the Moon and beyond**

- APL with LSIC is developing a community-derived white paper on the path from early NASA missions to an Enduring Lunar Presence with a robust lunar ecosystem
  - "In satisfying NASA's baseline objectives, how do we ensure robust participation from industry that also enables a transition away from NASA as a sole customer?"

- Stakeholder alignment – NASA will not achieve goals alone
- Phased development and key early investments/decisions
- Opportunities for "systems of systems" tech demos – terrestrial or lunar

LSIC | White Paper: The Path to an Enduring Lunar Presence

- Structure of the paper:
  - Estimated 10 pages – high level, in family with M2M Objectives and OSTP Cislunar document
  - Identify key infrastructure from industry's perspective
    - What enables the evolution of the Moon into an exploration proving grounds?
    - What are the technologies that have shared applicability across all stakeholders and how do we best motivate their development?
    - The 6 LSII focus areas are integrated in the process – not independent efforts
  - What combined tech demos could retire key questions?

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Early insights from prior engagements/breakouts:

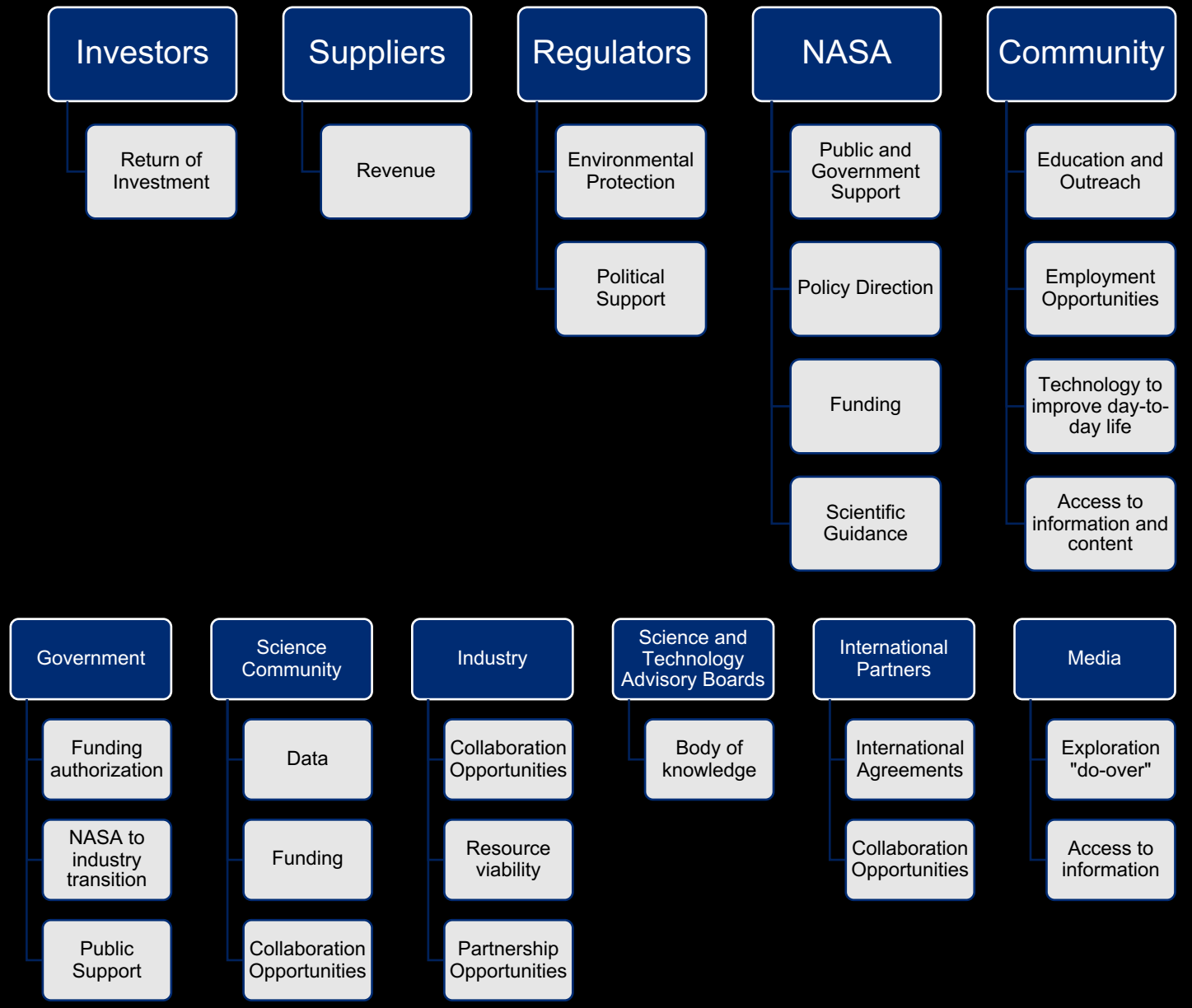
- "The Moon as a proving ground" means many things
  - For proving out **science and exploration technologies**
  - Demonstrates **unity of purpose** and commitment to achieving long-term goals
  - To **test and mature acquisition strategies** that can amplify NASA's investments and show that we can work in a "whole-of-nation" fashion

- Preliminary take-aways from breakouts:
  - Translational technologies abound and offer multiplier on NASA's investments
  - Multi-stakeholder involvement provides a key signal of stability for industry
  - If NASA cannot succeed on the Moon, there is little confidence in the community for taking humans to Mars
    - **How do we know when we're ready to move on to Mars?**

Overview / Introduction

Stakeholder Needs

- Understanding what upstream influences exist, and how they can be managed, will be critical for reducing ambiguity in the Lunar architecture. Some common upstream influences include:
  - Regulations (applicability), technology (infusion), competitive environment, strategy (amount of risk willing to take)
- Architectures often fail due to upstream influences and stem from how engagement with the stakeholders is carried out. Common failures include:
  - Failure to understand stakeholders needs; failure to consider the cost of regulation compliance; failure to consider technology maturation timelines; technology infusion; failure to estimate demand; knowledge of failures products and systems must endure and still operate

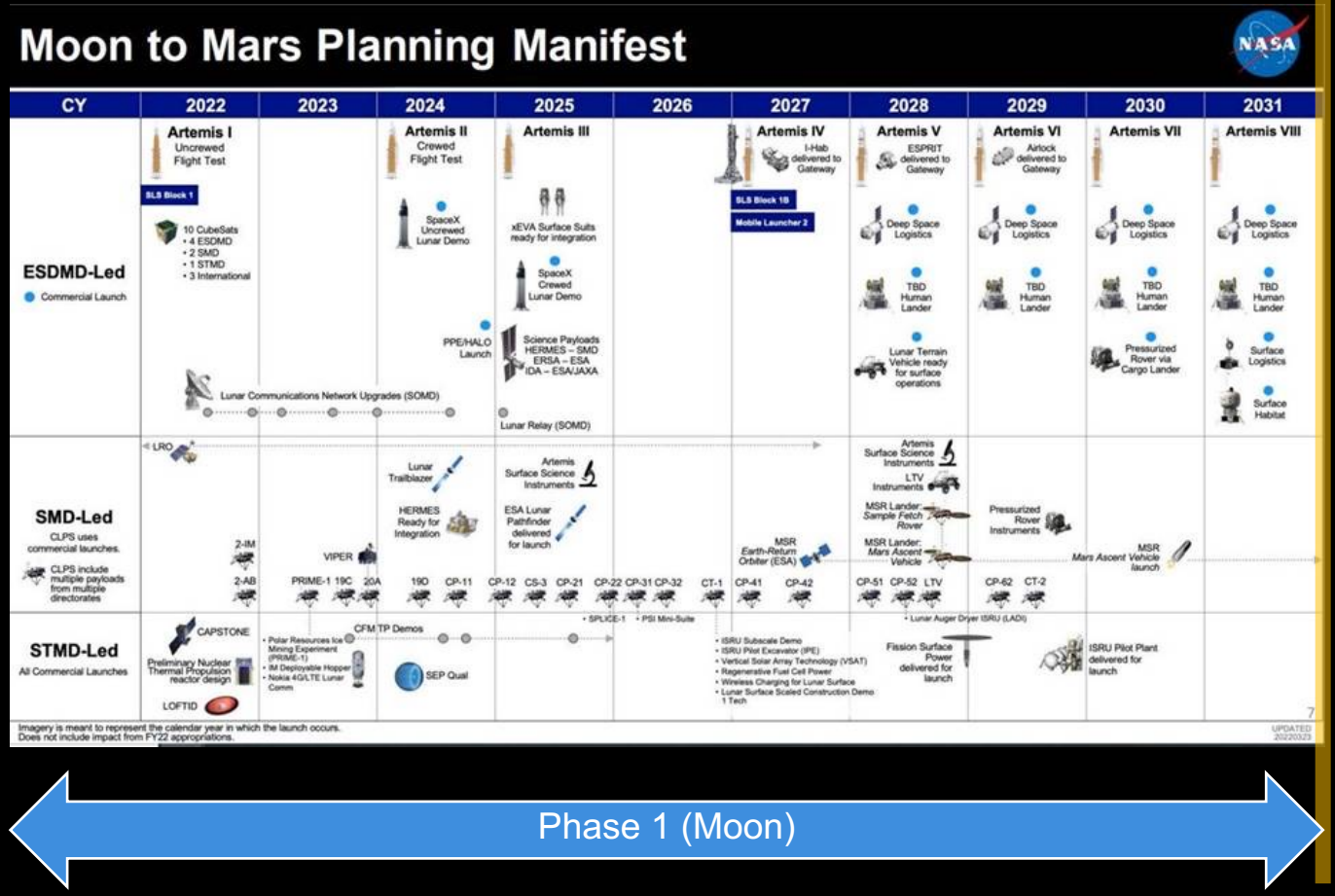


Transition to Industry

- Transition to industry is likely to accelerate after the ARTEMIS campaign
- NASA shifts focus to Mars missions (Moon to Mars)
- Breaks into natural Lunar development phases
  - (Moon)Phase 1 – Artemis I-VIII **(to 2031)**
  - **(To) Phase 2 – Artemis IX – Mars Development (2030s)**
  - (Mars) Phase 3 – Mars Development and Lunar Operations as a service **(2040s)**

- **Highlight industry priorities throughout this process – What is important to you that needs to happen now?**
  - Identify key gaps where NASA/OGAs need to lead
  - Areas for collaboration between NASA/OGA/Academia

Reference: https://www.nasa.gov/sites/default/files/atoms/files/fy23_nasa_budget_request_summary.pdf



Lunar Goals

Moon to Mars Threshold Objectives

- Support Moon to Mars
  - The Moon is a proving ground for Mars across all domains
    - Technology
    - Policy
    - Systems Engineering
  - Baselined on good faith interpretations of NASA's current plans

"Desirement"

- There will be a long term sustainable presence on the Moon with substantial commercial involvement – "Commercial Ecosystem"
  - Commercial sale of propellant
  - Lunar Tourism
  - Life off of Earth
  - Extended Science Operations
  - Off-planet field testing
  - Lunar Manufacturing
  - Mission pulls are broad here

Reference: https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf

Lunar Infrastructure (LI) Goal: Create an interoperable global lunar utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing science objectives and testing for Mars.

LI-1[L]:	Develop an incremental lunar power generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.
LI-2[L]:	Develop a lunar surface, orbital, and Moon-to-Earth communications architecture capable of scaling to support long term science, exploration, and industrial needs.
LI-3[L]:	Develop a lunar position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs.
LI-4[L]:	Demonstrate advanced manufacturing and autonomous construction capabilities in support of continuous human lunar presence and a robust lunar economy.
LI-5[L]:	Demonstrate precision landing capabilities in support of continuous human lunar presence and a robust lunar economy.
LI-6[L]:	Demonstrate local, regional, and global surface transportation and mobility capabilities in support of continuous human lunar presence and a robust lunar economy.
LI-7[L]:	Demonstrate industrial scale ISRU capabilities in support of continuous human lunar presence and a robust lunar economy.
LI-8[L]:	Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing maximizing the use of in-situ resources, and support systems needed for continuous human/robotic presence.
LI-9[L]:	Develop environmental monitoring, situational awareness, and early warning capabilities to support a resilient, continuous human/robotic lunar presence.

DEVELOP: Design, build, and deploy a system, ready to be operated by the user, to fully meet architectural objectives.

DEMONSTRATE:
Deploy an initial capability to enable system maturation and future industry growth in alignment with architecture objectives.

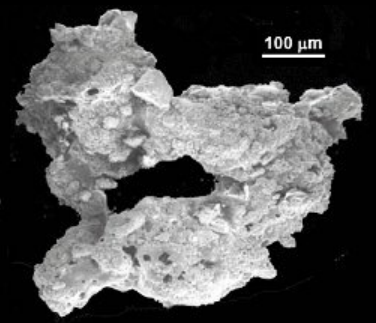
How might industry partner and accelerate the M2M process in regards to Dust Mitigation?

Dust Mitigation Section

Cross-Cutting – Dust Mitigation

- Lunar Dust Characteristics
  - Silicate/Aluminosilicate (~80%), Oxide (~20%), trace minerals & metals
  - Wide range of sizes, shapes
    - “dust” is regolith < 20 μm… or is it 100 μm? Or 1000 μm? Depends on source!
    - Measured sizes as small as 0.01 μm
    - Sharp, abrasive
    - Mix of sizes/shapes/components highly dependent on location
  - High adhesion
  - Surface electric fields – Solar Wind, GCRs, high vacuum

- What does lunar dust impact? Everything
  - Equipment maintenance/repair/replacement cycles
    - Abrasion, clogging, seal failures, EM effects
    - Higher variability in MTBF and MTBR
  - Measurement accuracy – requires highly sensitive instruments
  - Visibility
    - Human eyesight, displays, instrument readouts, science
  - Traction
  - Thermal control (insulator)
  - Human Health/ECLSS (inhalation/irritation risks)
  - Resource location
  - Transport
  - Landing
    - Distance from people, resources
    - How to minimize lofting?
  - Activity planning (scheduling, resource allocation)



Lunar dust under a microscope.
David S. McKay, NASA/JSC

LSIC Community perspectives on dust mitigation gaps and opportunities

- State-of-the-Art (SOTA) in DM for Phase 2
- Gaps
  - Technologies
  - Requirements/Guidelines
  - Stakeholder Engagement
- Opportunities: How might we bridge these gaps?

Dust Mitigation Community Discussion

- What does the State-of-the-Art (SOTA) in Dust Mitigation need to be for a sustained lunar presence when NASA pivots from Moon to Mars? (Phase 2)
- Gaps: What Dust Mitigation technology, requirements/guidelines, etc. do we need for Phase 2 that does not exist or is not planned right now?
- Opportunities: How might we bridge these gaps?
- Stakeholder Engagement: Who should be communicating, collaborating, etc. but isn't (yet!)?
- How might industry partner and accelerate the M2M process in regards to Dust Mitigation?
- **What is important to you that needs to happen now in order to ensure an Enduring Lunar Presence?**