Lunar Surface Innovation
CONSORTIUM

LSIC E&C/CC Focus Group Monthly

http://lsic.jhuapl.edu/
http://lsic-wiki.jhuapl.edu/ (Confluence sign-up required)

May 29, 2024

E&C: Jibu Abraham, Sarah Hasnain, Athonu Chatterjee, Raymond Lu, Claudia Knez
CC: Lindsey Tolis, Danielle Mortensen, Angela Stickle, Milena Graziano, Mario Lento, and team!

Facilitator_ExcavationConstruction@jhuapl.edu
Facilitator_Crosscutting@jhuapl.edu

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Overview

- General updates and house-keeping – 10 minutes
  - Logistical Information
  - Upcoming Meetings
  - Funding Opportunities
- Overview of Master Planning – 10 minutes
- Panel Discussion – 20 minutes
- Speaker/Panel Q&A – 20 minutes
- Breakout Sessions! – 30 minutes

Logistical Information

CC Website

E&C Website

CC Confluence

E&C Confluence

How to Contact us!

Facilitator_ExcavationConstruction@jhuapl.edu

Facilitator_Crosscutting@jhuapl.edu

Need Confluence Access?

lsic-wiki-admins@listserv.jhuapl.edu

Upcoming Meetings

- **Space Resources Roundtable (June 4-7)**
  - https://learn.mines.edu/srr/
  - Registration is open!
- **International Conference on Environmental Systems (ICES) (July 21-25)**
  - https://www.ices.space/call-for-paper-2024/
  - Sessions include: “Advanced Technologies for In-Situ Resource Utilization”, “Space Architecture”, “Planetary and Spacecraft Dust Properties and Mitigation Technologies”, “Human/Robotics System Integration”
- **NASA Solar System Exploration Virtual Institute (SSERVI) (July 23-25)**
  - https://sservi.nasa.gov/nesf2024/
  - Abstract submission closed
- **ASCEND (July 30- August 1)**
  - https://www.ascend.events/
  - Registration open!

Funding & Opportunities

- **SBIRs and STTRs**
  - Open SBIRs and STTRs can be found here: https://www.sbir.gov/solicitations/open
- **Early Stage Innovation (ESI)**
  - https://nspires.nasaprs.com/external/solicitations/summary.do?solId={EA55B699-3845-233F-9CB7-5B013BAA8F2C}&path=&method=init
  - Proposals Due June 6th
  - University-led, possibly multi investigator, efforts on early-stage space technology research of high priority to NASA's Mission Directorates
  - Topic 1: Computational Materials Engineering for Lunar Metals Welding
  - Topic 2: Passive Lunar Dust Control through Advanced Materials and Surface Engineering
- **Development and Advancement of Lunar Instrumentation (DALI)**
  - https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId={C5EA26E3-2ACF-C494-B065-46C9A48F265D}&path=open
  - Step-2 Proposals due June 26th
- **Lunar Mapping Program**
  - https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId={83A89224-E78F-56D5-F16C-04775814C47A}&path=open
  - Proposals Due June 12th

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Lunar Launch and Landing Facilities Workshop

- Tuesday July 23rd, 2024
- Virtual Workshop hosted by LSIC Excavation & Construction
- Sessions Include:
  - Vision for Deploying Landing and Launch Facilities (LLFs) for a sustained presence on the Moon
  - Top Level Design Expectations for LLF
  - LLF Trade Space Considerations
  - State of the Art Landing Pad Analyses - Plume Surface Interaction Analyses and Failure Modes
  - Construction Options and Supporting Infrastructure
  - Networking

  - Registration is free and required – Closes July 11th

NASA CENTENNIAL CHALLENGES

NASA's BREAK THE ICE LUNAR CHALLENGE

FINAL COMPETITION & WINNER EVENT

JUNE 11TH, 8AM-4PM CT & JUNE 12TH, 8AM-6PM CT

YOU'RE INVITED:

This event is free and open to the public, government, NASA, industry, academia, and stakeholders

WITNESS GREATNESS:

After two days of live competitions, up to two finalists will receive a share of the $1.5 million grand prize!

HOSTED BY:

NASA's Centennial Challenges

Representing
NASA's Space Technology Mission Directorate's
Prizes, Challenges & Crowdsourcing

LOCATION:

Alabama A&M University's Agribition Center

4925 Moores Mill Rd
Huntsville, Alabama

MORE INFO: NASA.GOV/WINIT • @NASAPRIZE

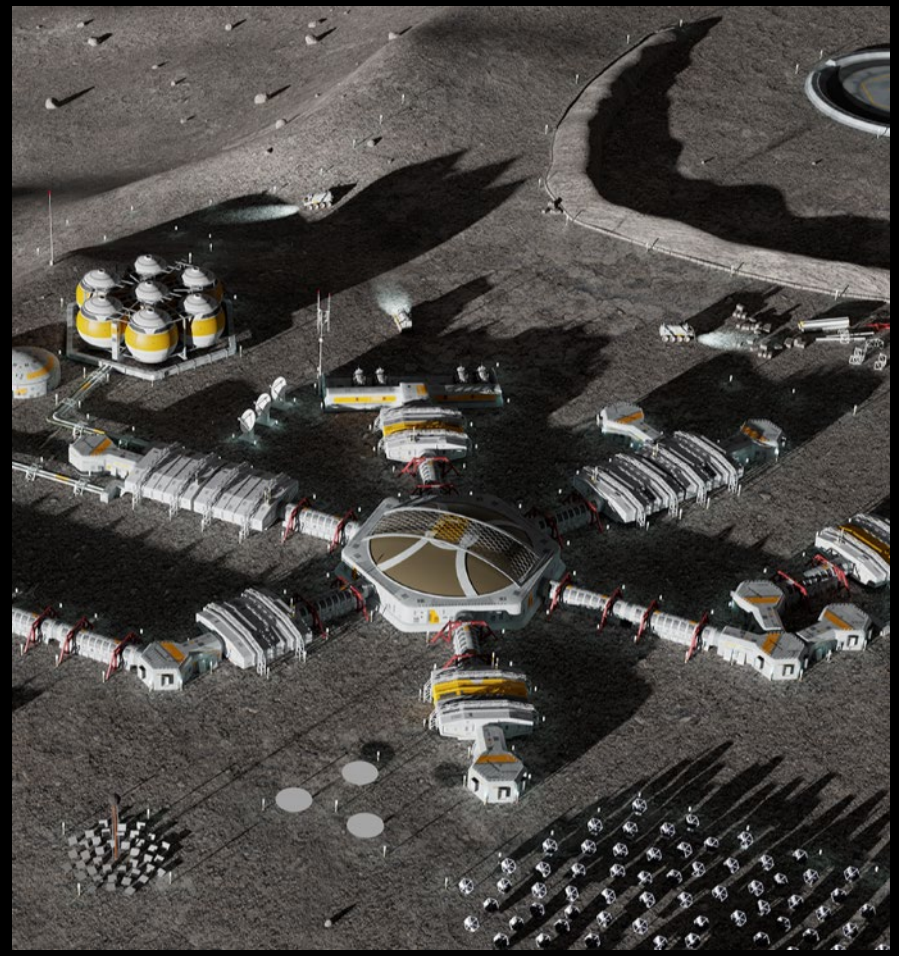
Motivation & Objectives

Successful missions are and will be the culmination of years of dedicated and consistent effort by NASA, the industrial base, and international partner space agencies – a direct result of teamwork and consistent support of external stakeholders. – NASA M2M Objectives Document

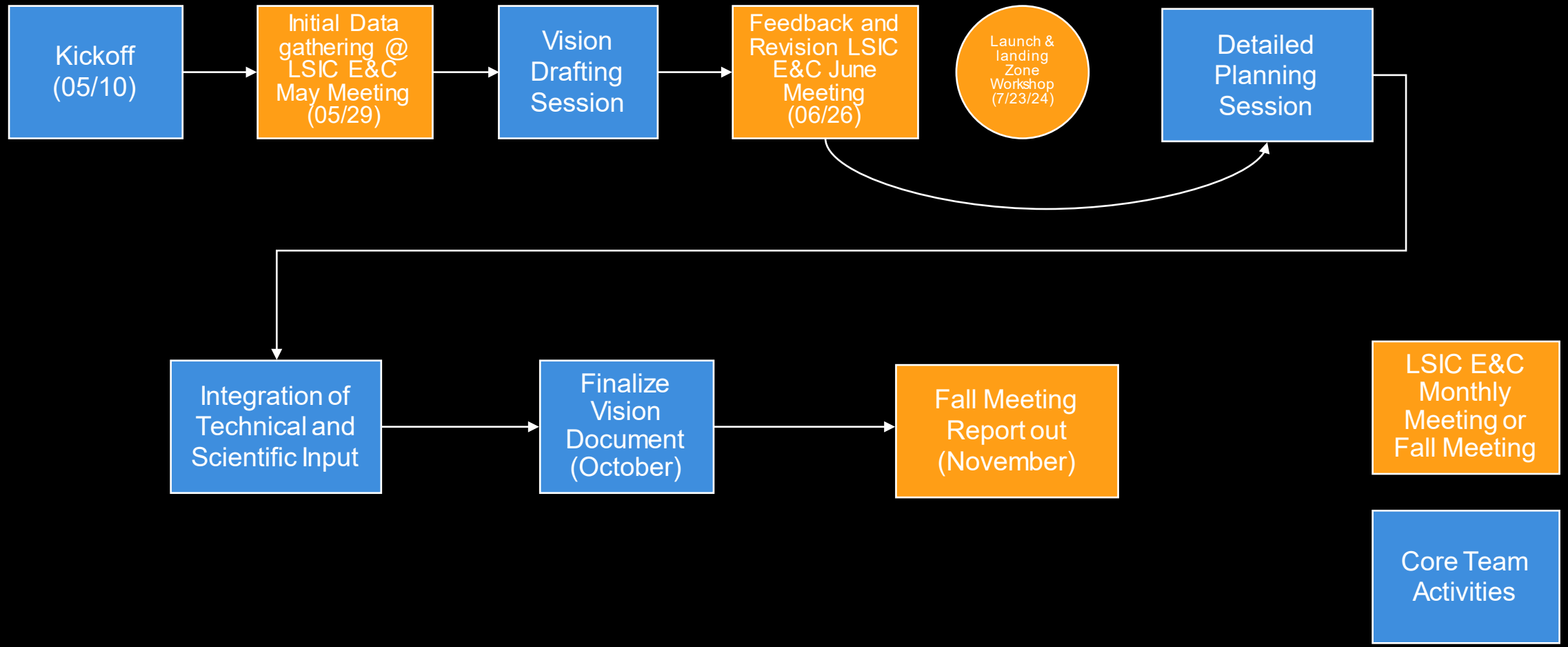
As the nation returns to the Moon there is a need to develop a shared vision for a Lunar base infrastructure. One that can support NASA led missions and complement industry needs.

Objective: Develop a community driven notional lunar infrastructure master plan recommendation. The plan will include:

1) Near Term Goals – Capture Lunar Infrastructure Vision
2) Long term goals -
    1) Identification of the functional needs
    2) Identification of key trades
    3) Identification of technology gaps
    4) Aggregate SOTA for horizontal and vertical construction elements and processes
    5) Develop Vignettes for surface activities
    6) A notional site plan



Overall Process



Technical Agenda

- Overview of Master Planning – 10 minutes
  - Ann Esbeck (Chief Innovation Officer - Bechtel Corporation)
  - Komal Dewan (Senior Vice President - AECOM)
- Panel Discussion – 20 minutes
  - David Zuniga (Senior Director - Axiom Space): Tourism / Commercial Space
  - Dave Blewett (Principal Staff - JHU Applied Physics Lab): Science
  - Stephen Indyk (Director Space Systems - Honeybee Robotics): Utilities
  - Laeeque K Daneshmend (Chair in Mine-Mechanical Engineering Queens University): Mining
- Speaker/Panel Q&A – 20 minutes
- Breakout Sessions! – 30 minutes

Overview of Master Planning

Ann Esbeck
Bechtel

Roberto deMoreas
AECOM

Panel Discussion

Dave Blewett

JHU Applied Physics Lab

Science

Laeeque Daneshmend

Queens University

Mining

Stephen Indyk

Honeybee Robotics

Utilities

David Zuniga

Axiom Space

Commercial Space / Tourism

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Breakout Sessions!

We will now move into a 20-minute breakout session! You will be randomly sorted into a breakout room (all identical) with an APL facilitator to work through the Miro activity. Have fun!

Miro Activity here! →

Miro board link:
https://miro.com/app/board/uXjVKMxGy1Y=/

Password:
LSICECCC

Lunar Surface Innovation
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Ideas on Science Infrastructure at a Lunar Base

David T. Blewett
Moon and Rocky Planets Group
JHU Applied Physics Lab

Joint meeting of the LSIC Excavation & Construction and Cross-Cutting Focus Groups
2024 May 29

APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

- Top Level Lunar Vision Statement
  - How would you fill in this Vision Statement?
    - By 2054 we will have power, crew quarters, support staff, and lab space to support 20 scientists in order to enable a full portfolio of scientific research in multiple disciplines.

- Stakeholder Vision
  - Look to 2054 - What surface activities do you hope to facilitate?
    - Lunar/Planetary Geoscience
    - Lunar Environment
    - Heliophysics/Space Physics
    - Astronomy/Astrophysics
    - Biological / Materials Sciences

- Interactions
  - What components of the lunar infrastructure are required to support the stakeholder?
    - Power, living and work space for human staff (safe from radiation and micrometeoroids), reliable supply of consumables needed for the human staff, transportation to and from field sites.

- Challenges and Solutions
  - Identify major challenges your community anticipates in the development and sustainability of the lunar base.
    - Funding, changing priorities.
  - Propose potential solutions or approaches to overcome these challenges.
    - Public-private partnerships, e.g. CLPS; Contribution of international partners.

- Collaboration Opportunities
  - What is the role of governmental stakeholders in enabling collaboration? When is this direction necessary?
    - Model of the U.S. Antarctic Program – U.S. leadership in science.
  - Suggest how collaborations with other stakeholders could enhance the effectiveness and sustainability of the lunar base.
    - Cooperation with tourism or mining could help to sustain the science operations.

Science at a Lunar Base

- Lunar & Planetary Geoscience
  - "Wet" lab for analysis of rocks and soils: sieving, sawing for preparation of thin sections, binocular microscopes, petrographic microscopes, small scanning electron microscope, field/lab spectrometer (UV-vis-NIR, mid-IR).
  - Core cold-storage facility – Keep drill cores (ice, or ice/volatile-bearing regolith) frozen, with area for preparation of samples. Need to be able to transport the cores from the drill site to the storage facility and maintain low temperatures.
  - Lab for analysis of volatiles – Mass spectrometer, etc. for research similar to that done by the teams that studied the *Apollo 17* pristine samples (ANGSA).
  - Rock magnetism lab – possibly separated from other infrastructure.
  - Seismometers, heat-flow packages deployed at the base and at remote locations.

Science at a Lunar Base

- Lunar Environment
  - Micrometeoroid impact detector (high speed) – near the main base to assess impacts from lander arrivals/departures; others at shielded locations to measure natural hypervelocity impacts.
  - Detector for levitated surface dust (low speed) – near the main base to assess dust stirred by lander arrivals/departures and human/rover activities; others at locations to measure natural electrostatic dust motions.
  - Lunar atmosphere/exosphere – neutral mass spectrometer, ultraviolet-visible spectrometer.

Science at a Lunar Base

- Heliophysics/Space Physics
  - Ion/electron spectrometers – plasma studies
  - Magnetometers

Science at a Lunar Base

- Astronomy/Astrophysics*
  - UV-Vis-IR telescopes – away from dust, vibration disturbance at the human base. Needs site prep/foundation. Distributed systems to get wide field of view or for interferometry.
  - Energetic particle detectors.
  - Low-frequency radio telescope - can be a thin sheet deployed over the ground covering a large area.
  - High-frequency radio telescope – likely needs site prep and a foundation like an optical telescope.

*These ideas contributed by APL's Rick Miller

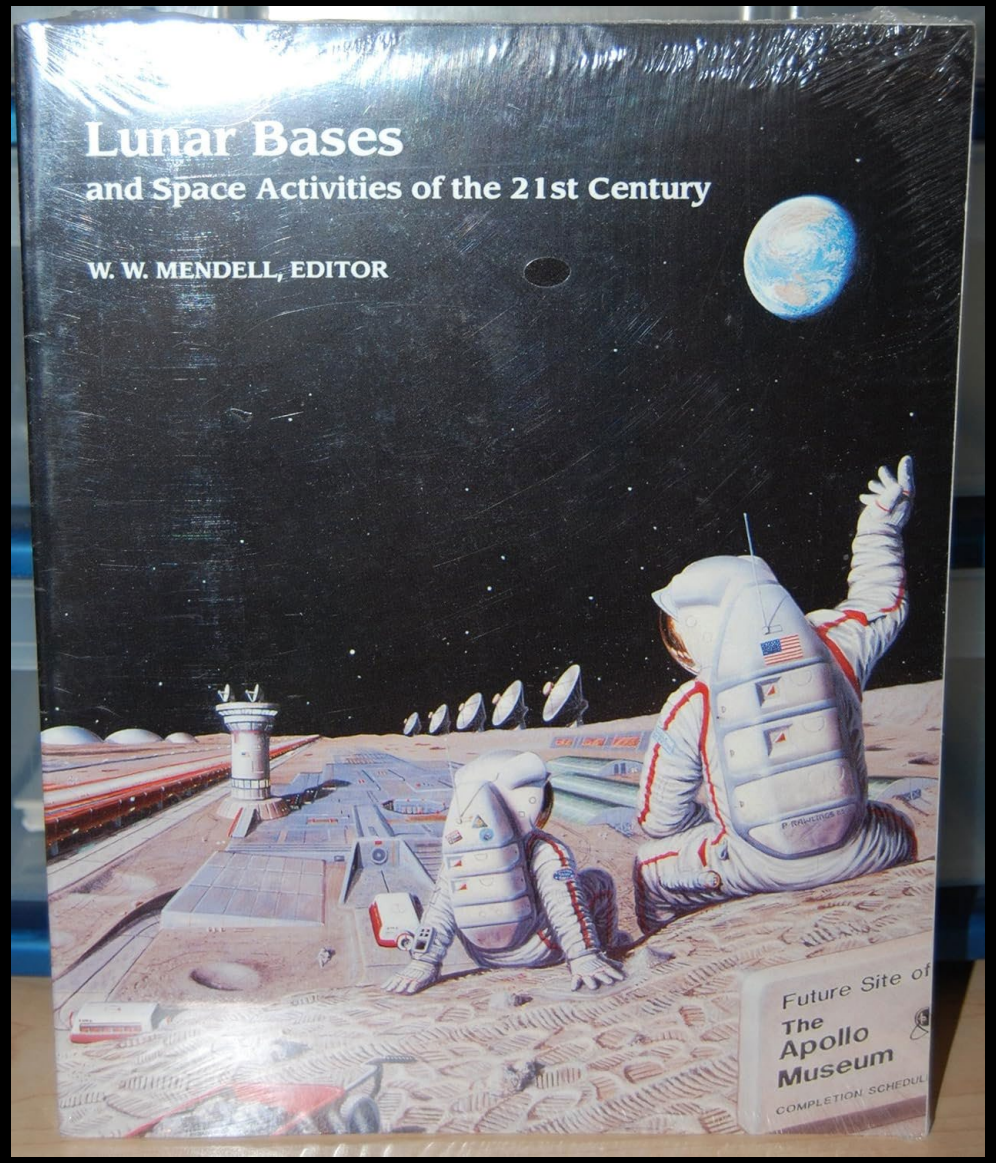
Science at a Lunar Base

- Biological / Materials Sciences
  - 1/6 G is useful for some research. Wet-chemistry lab.

Science at a Lunar Base

- Considerations for all
  - Power
  - Communications
  - Need for site preparation (leveling, foundation)?

Science at a Lunar Base



THE ROBERT M. BUCHAN DEPARTMENT OF MINING

Joint LSIC Communities Meeting
Excavation & Construction / Cross-Cutting
On-Line – May 29, 2024

125 YEARS QUEEN'S MINING

Long-Term Vision for Sustained Lunar Presence: 2054

A **Mining** Stakeholder Perspective

Laeeque Daneshmend
Noranda-Falconbridge Chair in Mine-Mechanical Engineering
The Robert M. Buchan Department of Mining
Queen's University, Kingston, Ontario, CANADA

Top Level Lunar Vision Statement - Mining

By 2054 we will be able to undertake
large-scale mineral prospecting,
targeted mineral exploration
leading to economic ore body discovery
and **selective** in-situ resource extraction
to support dozens of diverse users on the lunar surface,

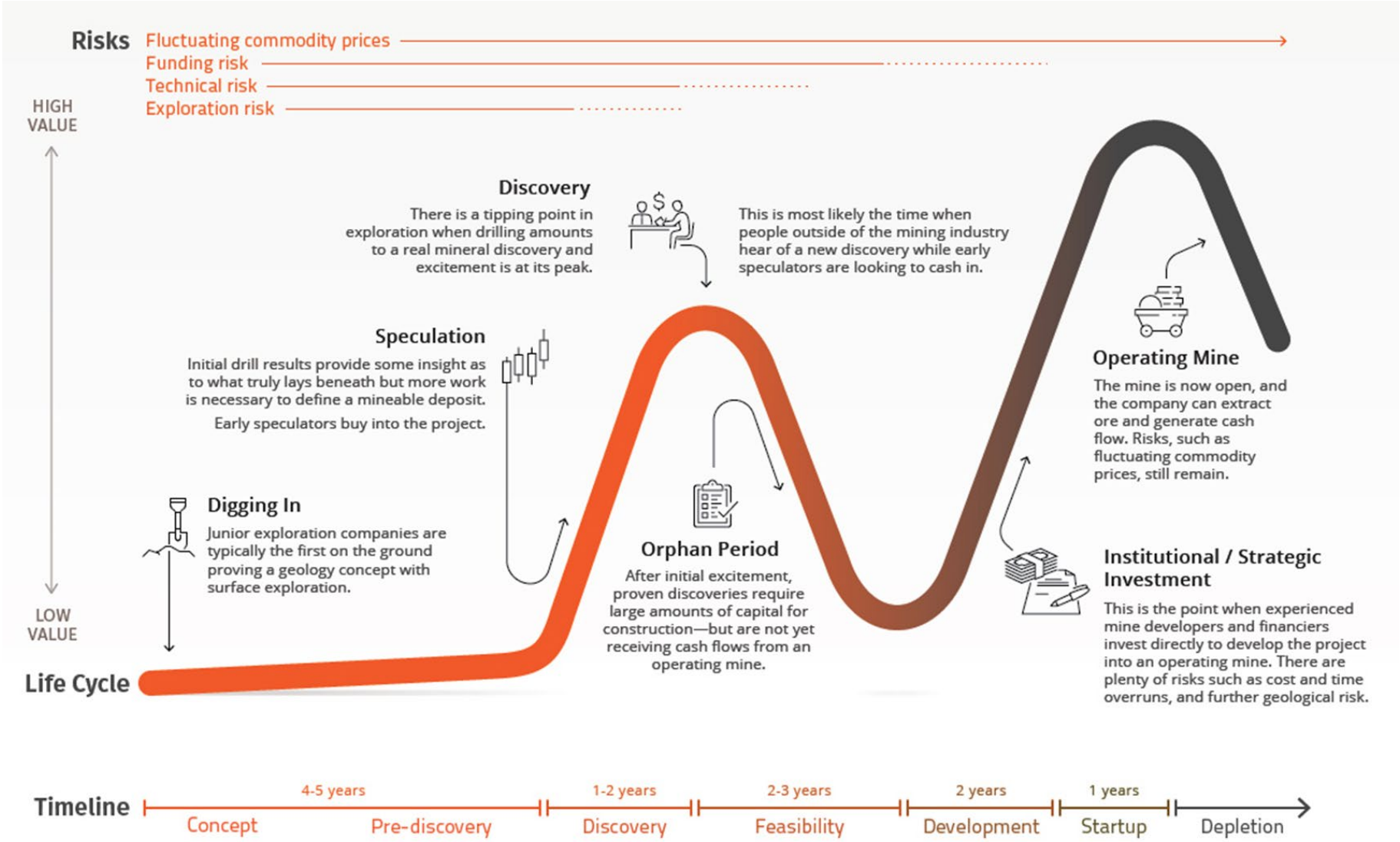
in order to enable growth
& sustainment of a viable lunar economy.

Top Level Lunar Vision Statement – Mining - **DERISKING**

c.f. Terrestrial Mining Projects – Uncertainty vs Risks vs **Value**

[LePan, N., Visualizing the Life Cycle of a Mineral Discovery, Visual Capitalist, September 12, 2019 https://www.visualcapitalist.com/visualizing-the-life-cycle-of-a-mineral-discovery/]

By 2054 we will be able to undertake large-scale mineral prospecting, targeted mineral exploration leading to economic ore body discovery and selective in-situ resource extraction to support dozens of diverse users on the lunar surface, in order to enable growth & sustainment of a viable lunar economy.



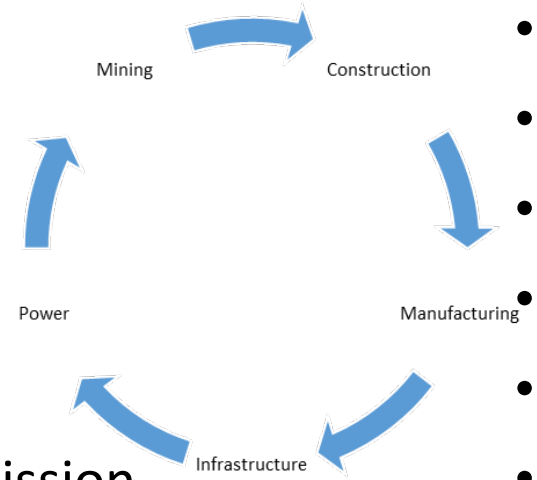
Mining Stakeholder Vision:

Accelerating Scale-Up Across the Lunar ISRU Value Chain

Surface activities – scale-up

<u>facilitated / supported / enabled by Mining</u>

- Construction
- Material Processing
- Manufacturing
- Transportation
- Communications
- Power Generation & Transmission
- Maintenance of Infrastructure & Equipment
  - including Habit Sustainment



Supports Required

reciprocal… SYNERGIES!

- Construction (*infrastructure, machines,...*)
- Materials Processing (*mineral processing*)
- Manufacturing (*machines, consumables*)
- Transportation (*infrastructure, machines,...*)
- Communications (*infrastructure*)
- Power Generation & Transmission (*infrastructure*)
- Maintenance of Infrastructure & Equipment
  - including Habit Sustainment
    (*parts and consumables*)

Lunar Mining Challenges (& Solutions?)

CHALLENGES/GAPS

Technical

- Prospecting
- Exploration
- Excavation
- Mineral Processing

Economic

- ROI – Value Proposition…
- Demand / Pull (chicken & egg!)

SOLUTIONS

Developments/Investments in

- Lunar Infrastructure for Remote Geosensing
- Lunar Geosciences & Geometallurgy
- Long-lived, modular, repairable, reconfigurable, nimble mobile machines – for a variety of tasks
  - Prospecting & Exploration
  - Construction & Mining
- Minerals Processing & Materials Processing Systems

Economic Stimulus:

- An initiative to jump-start Demand…
  - Based on holistic approach that terrestrial mining industry uses for Derisking
    - Find viable orebodies, pool appropriate technologies, optimize extraction processes, establish downstream supply chains…

Collaboration: Needs / Opportunities

- Terrestrial Mining vs Lunar ISRU
  - Potential value for both communities to learn from each other – e.g.
    - ➢ lunar ISRU could benefit from how terrestrial mining achieves long-lived systems
    - ➢ terrestrial mining could benefit from future advances in lunar machine autonomy
    - ➢ …
- Lunar Excavation & Construction vs Lunar ISRU / Mining
  - ➢ obvious synergies and overlaps – designs, components,…

- Private Sector
  - ➢ lunar ISRU could emulate Derisking business models from terrestrial mining
  - ➢ consortium approach with a commercial intent to pull technology and resources together, resulting in a venture that is similar to a mining company

(feel free to contact Salar Javid or myself regarding this)

Terra2Astra

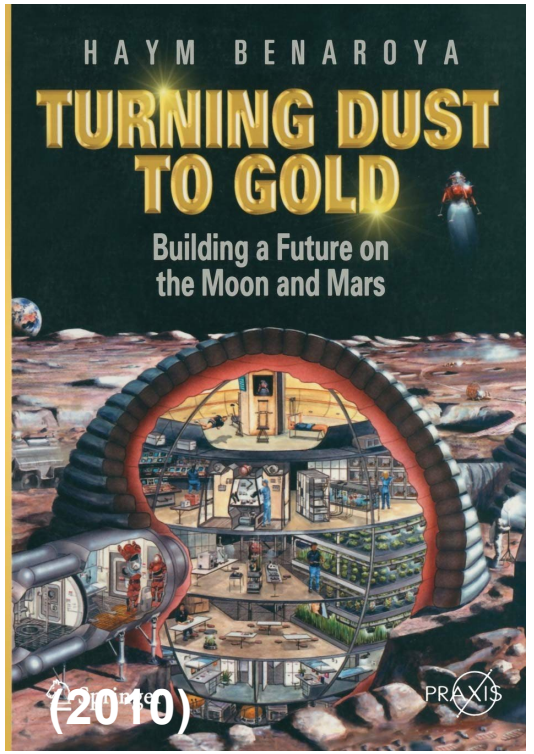
- Role of governmental stakeholders
  - ➢ Helping bridge the “cultural divide”
  - ➢ “Two solitudes” – miners versus space geeks!

Honeybee Robotics Lunar Utilities

May 29, 2024

Stephen Indyk
Director of Space Systems
Honeybee Robotics

LinkedIn @Stephen-Indyk
sjindyk@honeybeerobotics.com



Utilities

HONEYBEE ROBOTICS
Exploration Technology

Terrestrial

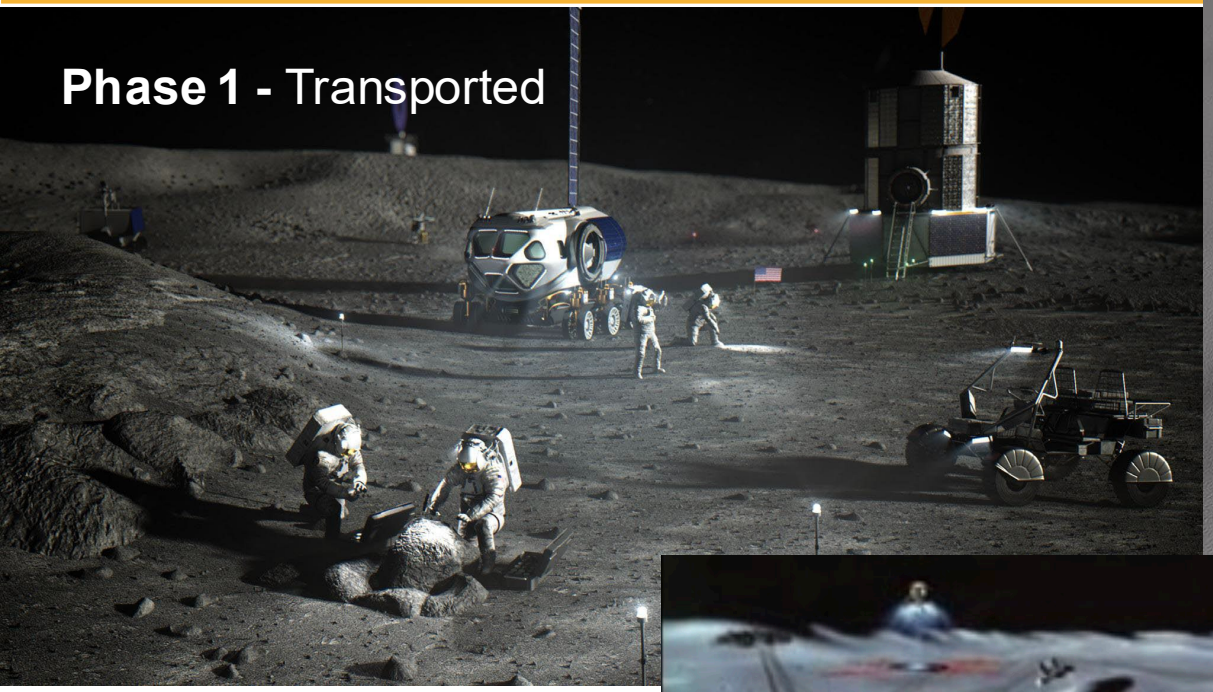
- ❑ Water
- ❑ Sewage
- ❑ Trash collection
- ❑ Recycling
- ❑ Electricity
- ❑ Communication
  - ❖ Phone
  - ❖ Internet
  - ❖ TV/Streaming
  - ❖ Postal
- ❑ Heating/Cooling

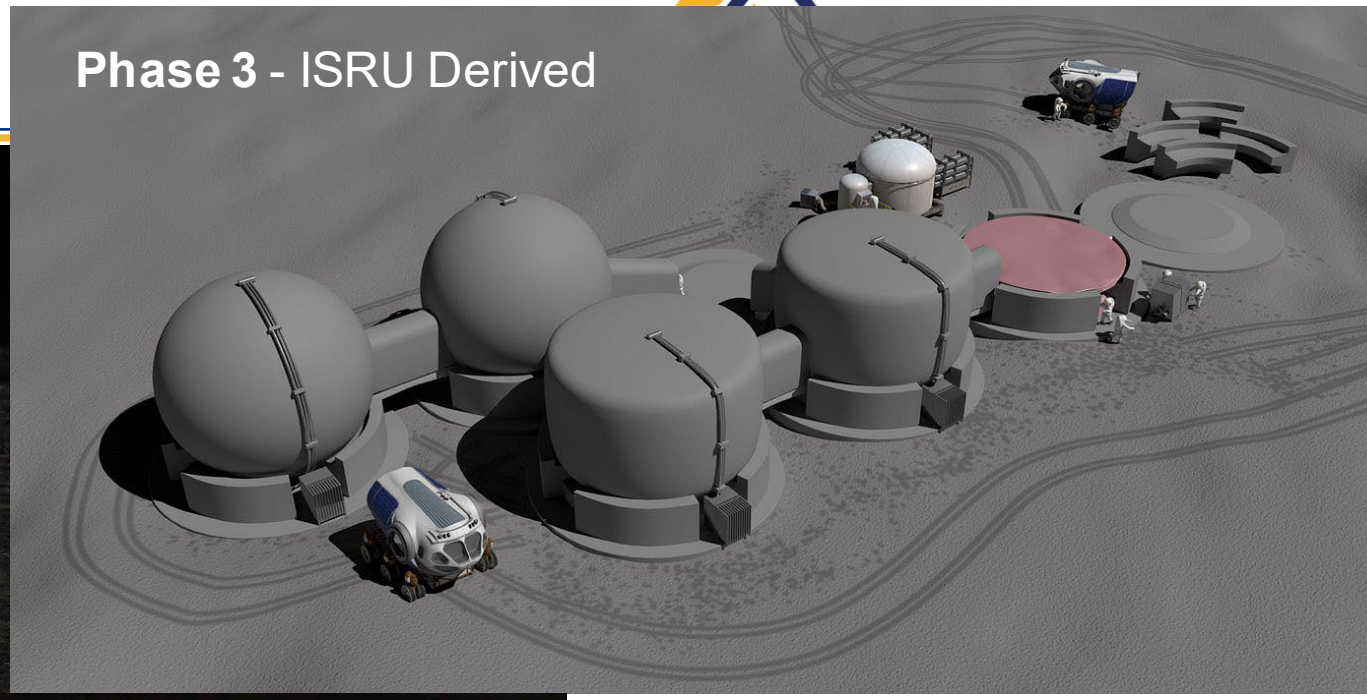
Lunar

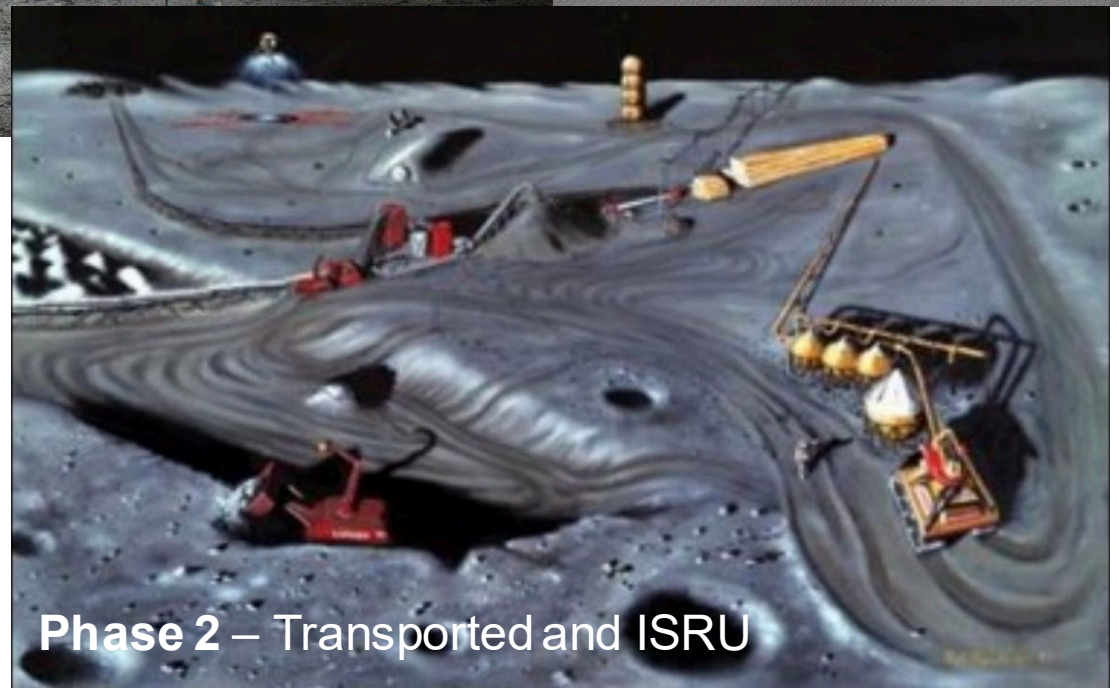
- ❑ Power
- ❑ Thermal
- ❑ Communication

- ❑ Water
- ❑ Air
- ❑ Recycling
- ❑ Waste management

Phases of Lunar Infrastructure







https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf?emrc=f43185
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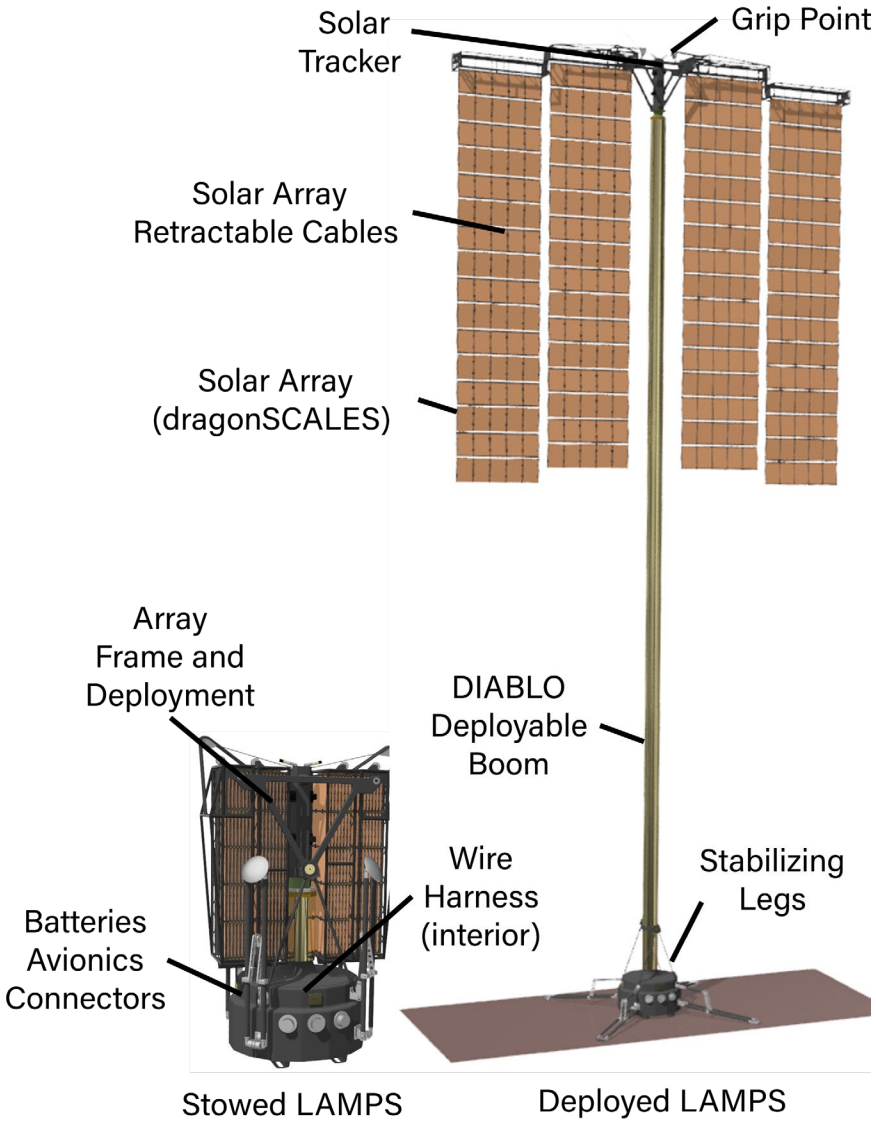
https://medium.com/the-aerospace-corporation/regishell-a10fcef300a4

LAMPS Basics



LAMPS is a 10kW mobile, deployable, Lunar vertical solar array.

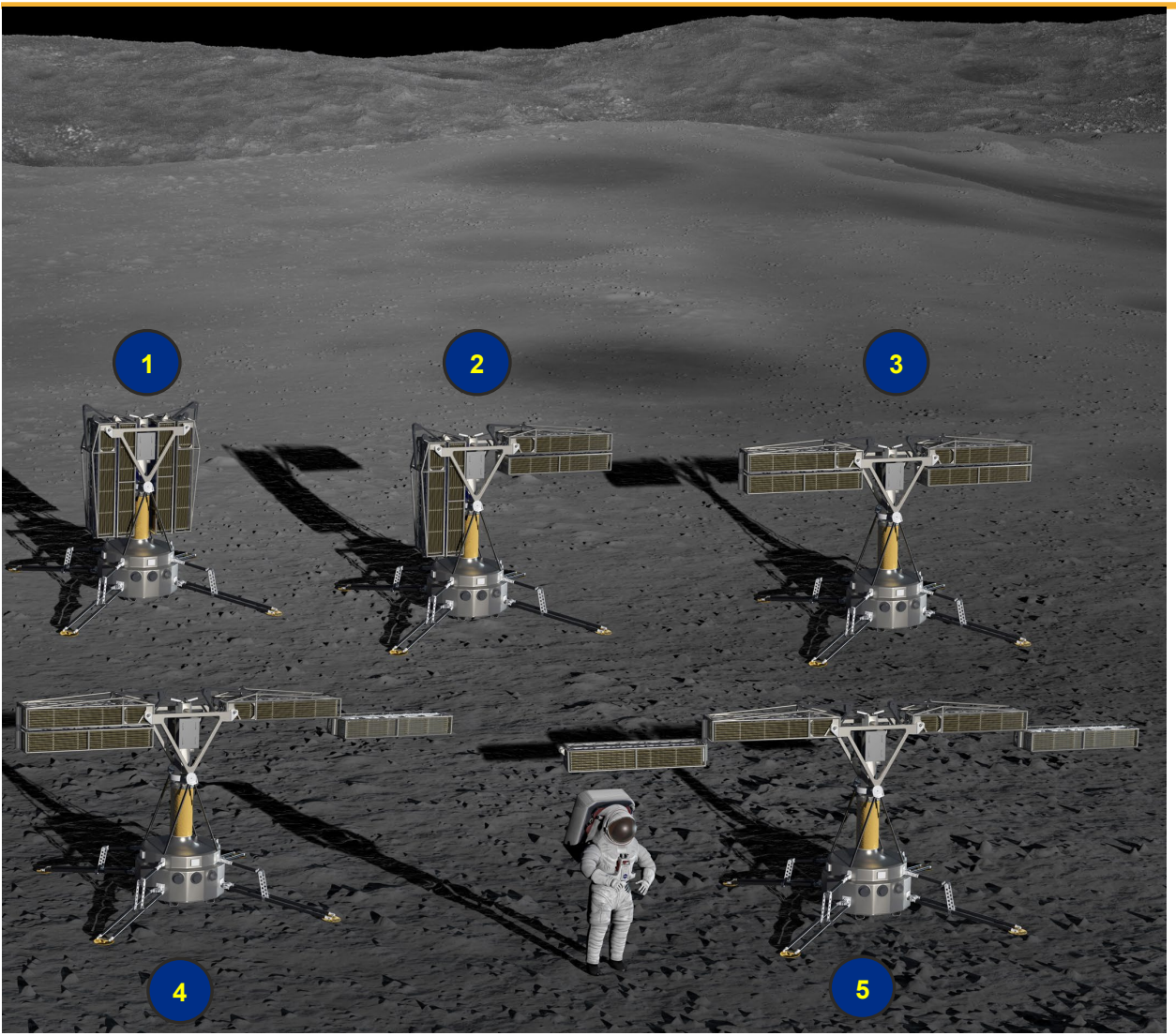
The goal of LAMPS is to jump start Lunar Permanence and provide affordable, as-needed power to a variety of end users.

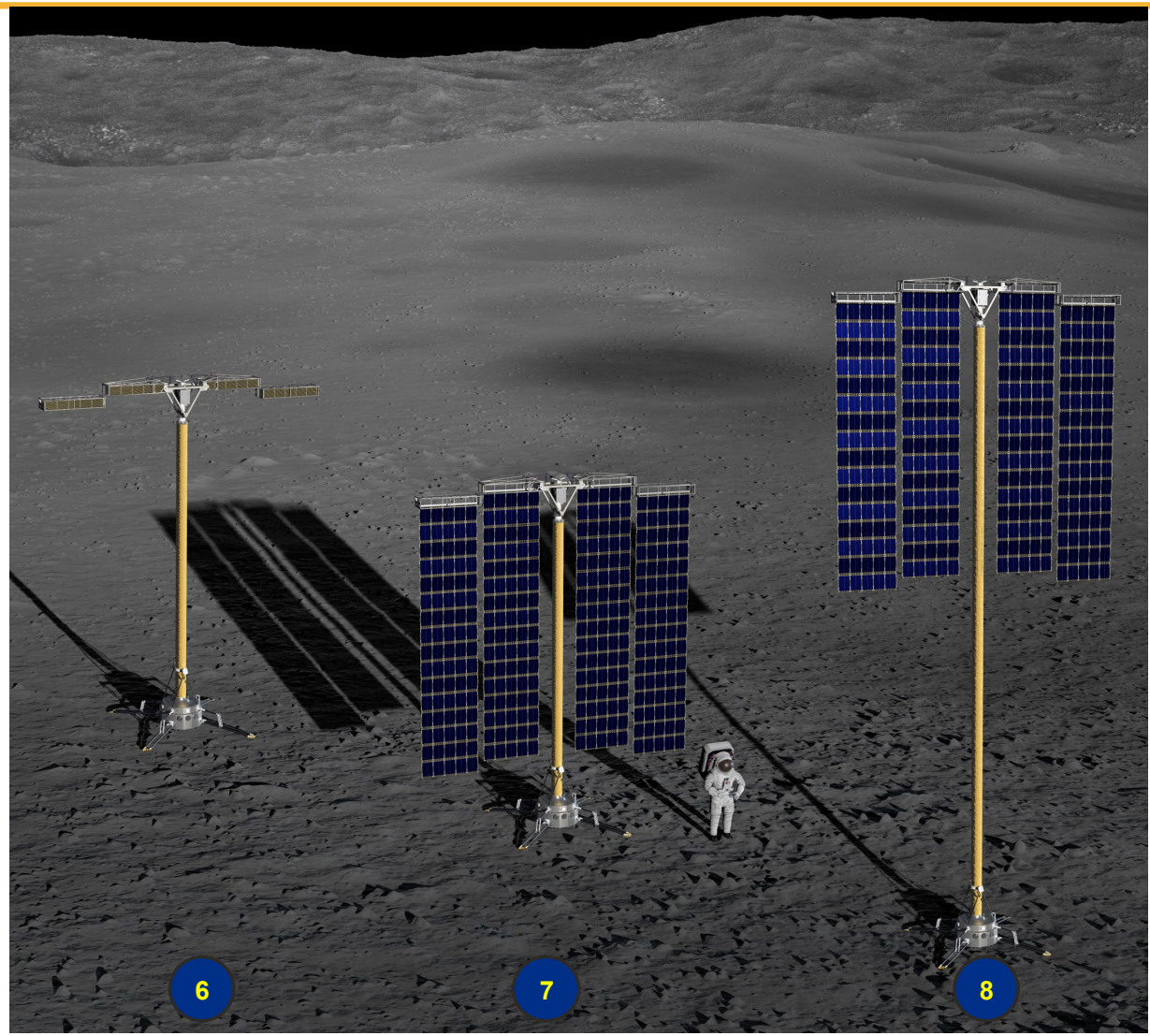
Key elements of LAMPS:

- dragonSCALES flexible solar panels
- Scalable, deployable boom
- Dust tolerant electrical connectors
- Avionics with Honeybee flight heritage
- Self leveling subsystem
- Low temperature and dust tolerant actuators

LAMPS Deployment Sequence

HONEYBEE ROBOTICS
Exploration Technology





HONEYBEE ROBOTICS
Exploration Technology

Thank you!

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