Lunar Innovation Park – Initial Surface Infrastructure to Kickstart a Space Resource Based Economy

Mark Hilburger - STMD PT for Materials, Structures, & Planetary Construction, NASA, Langley Research Center

Nathan Gelino - Sr. Principal Investigator and Capability Deputy – NASA, Kennedy Space Center, Swamp Works

Robert P. Mueller - Sr. Principal Investigator - NASA, Kennedy Space Center, Swamp Works

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Outline

- Motivation
- NASA’s Moon to Mars Vision
- Lunar Innovation Park Overview
- Lunar Innovation Park Mission Sequence
- Key Park Benefits
- Acknowledgements

Executive Order 14369 “Ensuring American Space Superiority”

18 December 2025

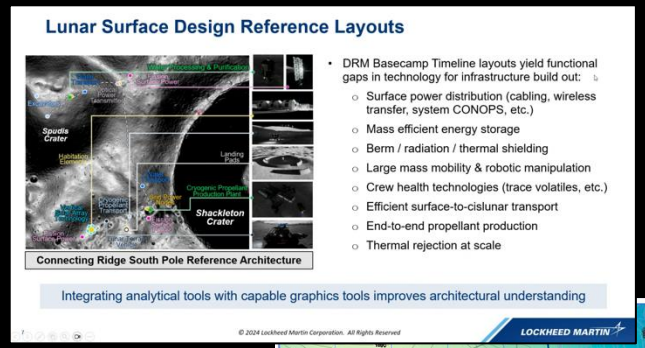
“pursue a space policy that will extend the reach of human discovery, secure the Nation’s vital economic and security interests, unleash commercial development, and lay the foundation for a new space age”.

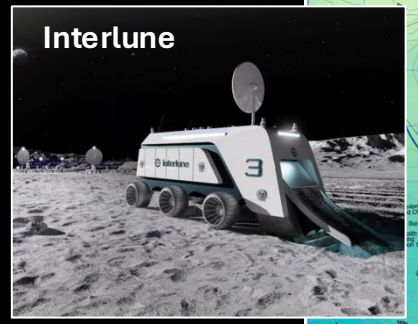
- **Reemphasizing goals from previous US policy and strategy**
  - Establishing a sustainable/enduring presence in space
  - Lunar surface utilization and development
  - Establishing a commercial space economy
  - Industry and international partner collaboration

- **Outlines a series of specific goals and timeline**
  - Returning humans to the moon by 2028
  - Laying the foundations for lunar economic development
  - Fostering economic growth by attracting at least $50 billion of additional investments in American space markets by 2028
  - Establishing initial elements of a permanent lunar outpost by 2030 (Moon Base)

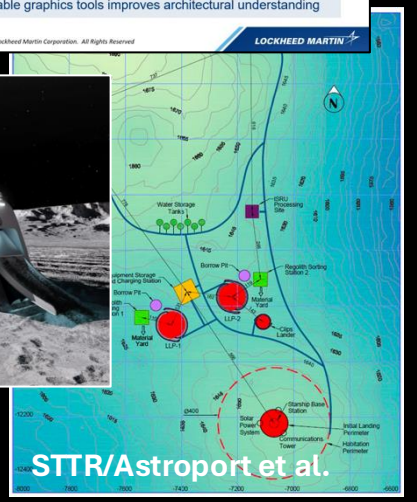
Lunar Innovation Park – Motivation

- **US Policy & Strategy**
  - A large number of NASA and US policy, and strategy documents have been released stressing the importance of space exploration and commercial activities beyond Earth's orbit with emphasis on the use of space resources.
  - **Common themes**: Sustainable/enduring presence, Lunar surface utilization/development, commercial space economy, industry collaboration
- **Strong US industry interest signal**
  - US space industry and venture capitalists investing significant time/resources to develop technologies, systems, and define architectures towards the creation of a space resource-based economy
    - produce and sell lunar ISRU-based commodities such as cryogenic propellant, water, oxygen, Helium-3, and construction and manufacturing feedstocks.
    - provide services in support of a cislunar space ecosystem including power, communications, PNT, and mobility and logistics.
  - Many potential investors remain on the sidelines waiting for NASA to initiate a formal and lasting effort to capitalize on space resources
- **Accelerate technology development and demonstration to enable infusion into Artemis missions**





GRU Space



China's Ambitions in Space

- China has defined the timeline and scope of the new space race for sustainability and prosperity
- China intends to be the foremost space power by 2045:
  - Eclipsing the U.S. in its economic activities and services ($10T annual benefit via Earth-moon economic zone)
  - Eclipsing the U.S. in its foreign partner relations and shaping of the space governance system
  - Eclipsing the U.S. in feats that inspire the world
  - Eclipsing the U.S. in military power
- China's Lunar Goals
  - 2026: Mission to lunar south pole to find water
  - 2028: Build a prototype of an International Lunar Research Station
  - Before 2032: Land Taikonauts on the Moon
  - Before 2035: Build an International Lunar Research Station (ILRS)

STATE OF THE SPACE INDUSTRIAL BASE 2022

Winning the New Space Race for Sustainability, Prosperity and the Planet

Summary Report by:

J. OLSON,[1] S. BUTOW,[2] E. FELT,[3] & T. COOLEY[4]

[1]United States Space Force, [2]Defense Innovation Unit, [3]Department of the Air Force and [4]Air Force Research Laboratory

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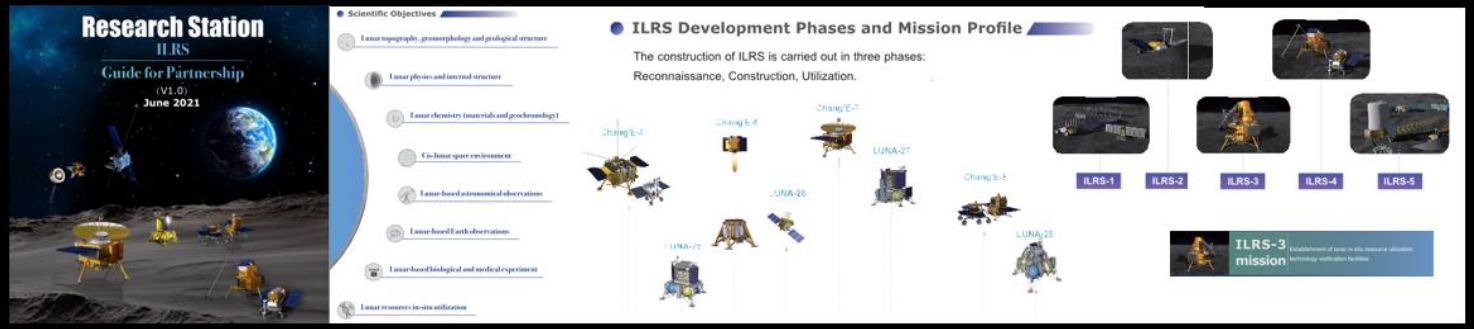
China mulls $10 trillion Earth-moon economic zone

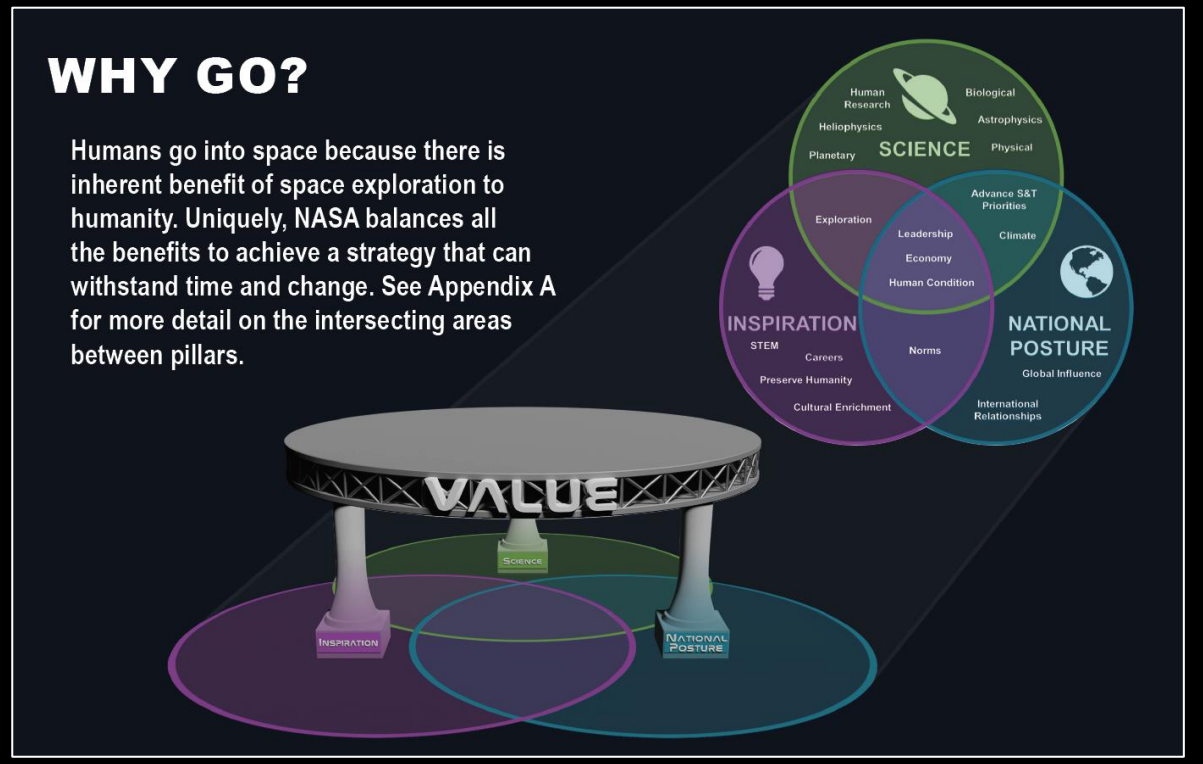


China to produce a lunar regolith brick in 2028 using concentrated sunlight to melt regolith

NASA's Vision for Sustained Human Presence & Exploration of Space

- NASA's Moon to Mars (M2M) Value Proposition – *Science*, *Inspiration*, *National Posture*
- National Posture
  - Global Influence
  - International Relationships
  - Advance S&T Priorities
  - Climate
  - Norms
  - Leadership
  - **Economy**
  - Human Condition

  } Intersection between pillars



From *NASA's Moon to Mars Objectives and Strategy Development* document

Thoughts and Observations:

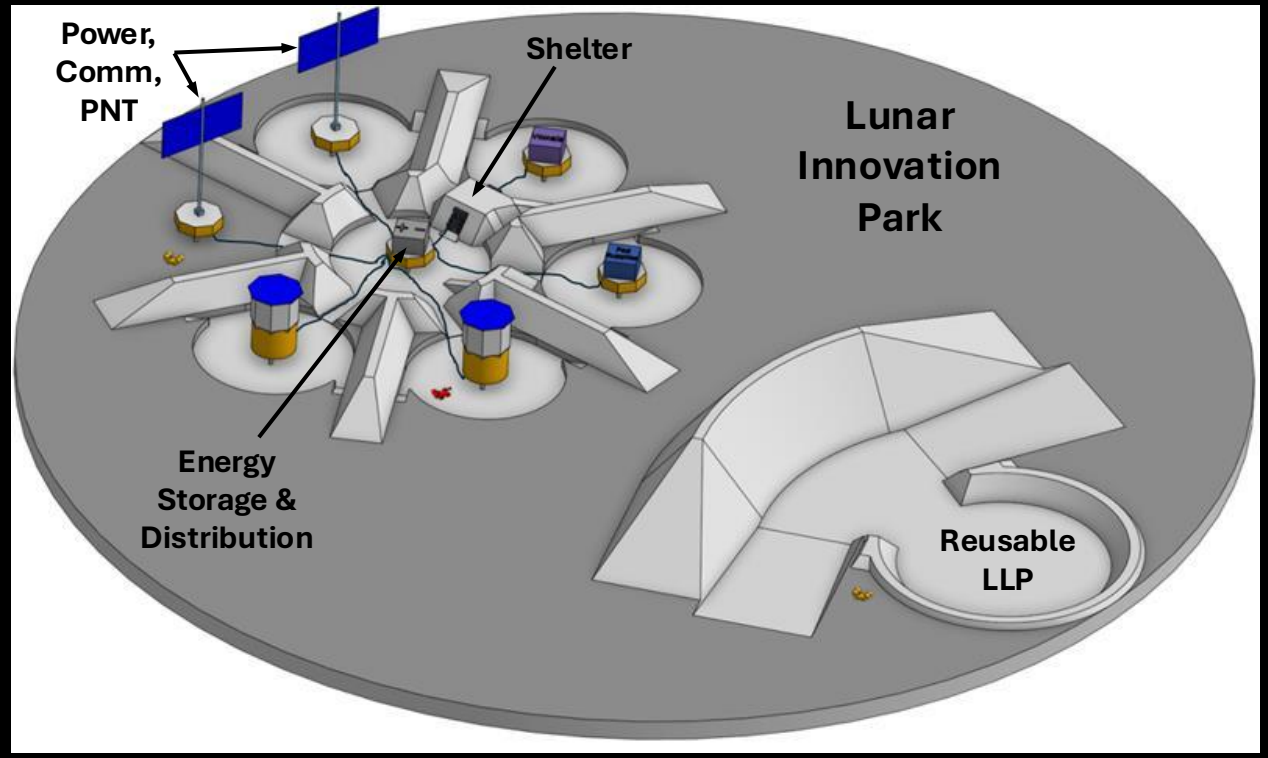
- There is a heavy emphasis on science and human exploration in NASA's execution of the M2M vision (Science and Inspiration pillars)
- Economy is identified as a central part of the M2M Value Proposition, **however**, the scope of the economic benefit of space and space resources is underappreciated and underemphasized in NASA's recent plans

➢ **A Lunar Innovation Park would help kickstart a space resource based economy and help meet NASA and US Exploration & Economic goals**

What is a Lunar Innovation Park?

Lunar Innovation Park is a location on the Moon where NASA and industry technologies, systems, and capabilities can evolve and grow to eliminate risk, increase investment in lunar commercial operations, and enable the start of a Cislunar space ecosystem

- Innovation Park infrastructure:
  - Power generation, storage, distribution
  - Comm & Nav.
  - Protective shelters with utilities
  - Landing pads & roads/paths
- Support and encourage technology development and validation by:
  - Establishing infrastructure so each mission builds off the last; No need to refly power, communication, navigation for each mission.
  - Location for demonstrating sustained surface operations and performance
- Provide ecosystem for collaboration and investment.
  - NASA facilitates the establishment of early Innovation Park capabilities and services
  - Companies can take over and expand initial infrastructure capabilities provided by NASA
  - Enable/promote new collaborations between companies and utilize previously deployed/demonstrated hardware



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.

Lunar Innovation Park – Design Objectives

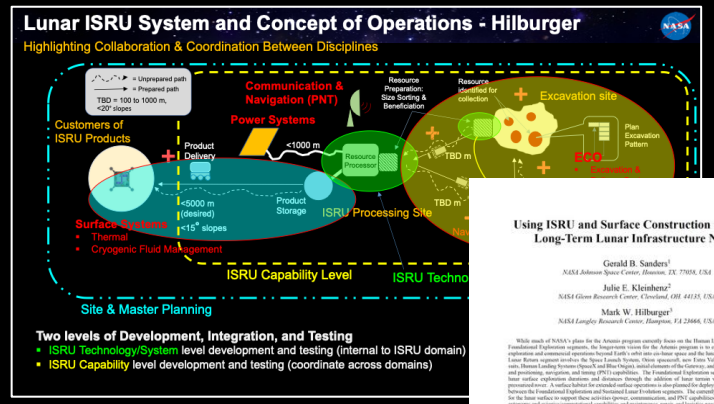
- **Provide scalable power, communications and navigation aids** - to support the construction and operation of the LIP and to support a limited number of science missions and or commercial users
- **Enable lunar night survival** - Provide power for lunar night survival for all landed assets and users
- **Enable close-proximity precision landing (~20m)** – landing near established LIP surface assets to reduce complexity of LIP construction, minimize footprint, and simplify logistics and access
- **Provide logistics services** - to deliver and manipulate small payloads, and support infrastructure assembly and outfitting
- **Construct an unpressurized shelter** - to provide radiation, thermal, meteorite protection to surface assets (e.g., rovers, computers, sensitive payloads)
- **Enable routine and repeated access to the LIP** – provide a reusable landing facility and landing aids
- **Use existing and near-term technologies** to create LIP now (TRL4-TRL9)
- **Use the LIP construction and operations to demonstrate and mature foundational technologies needed for commercial-scale operations and future Artemis exploration and science missions**

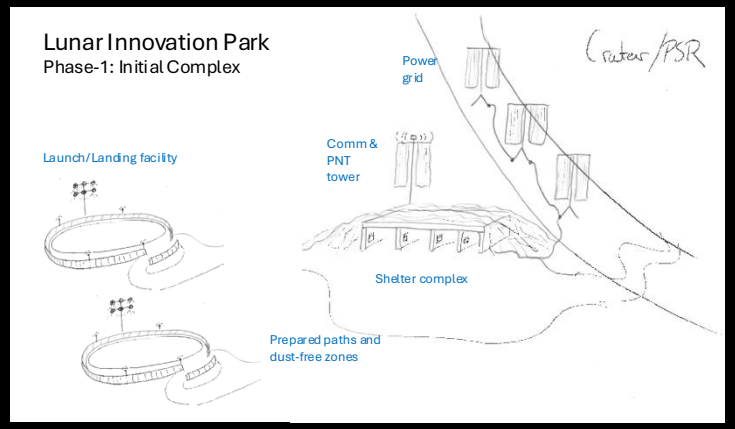
Lunar Innovation Park – Prior STMD Work

- **NASA Envisioned Future Priorities (EFPs)**
  - ISRU & Excavation, Construction, and Outfitting (ECO)
  - Led to initial **concepts** for lunar infrastructure construction and ISRU operations, **Roadmaps**, **Technology Development Plans**
- **Collaborative work between ISRU and ECO teams**
  - Recognized that "ISRU operates as part of a larger architecture" - Sanders
  - Goal: to develop a coordinated vision to enable NASA and commercial lunar surface ISRU operations and kickstart cislunar space ecosystem
    - Various concepts developed and presented since 2023 to establish infrastructure to support ISRU commodity production and distribution
    - Established an understanding of basic infrastructure needs such as: Power, Comm, Nav, Roads and Landing Pads, Shelters, Logistics, etc.
- **Led to the development of the Lunar Innovation Park concept - Feb. 2025**

ECO EFP

ISRU EFP





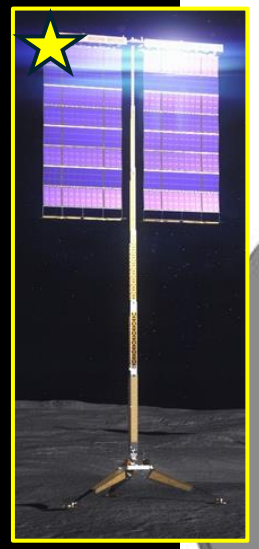

Using ISRU and Surface Construction to Define Long-Term Lunar Infrastructure Needs

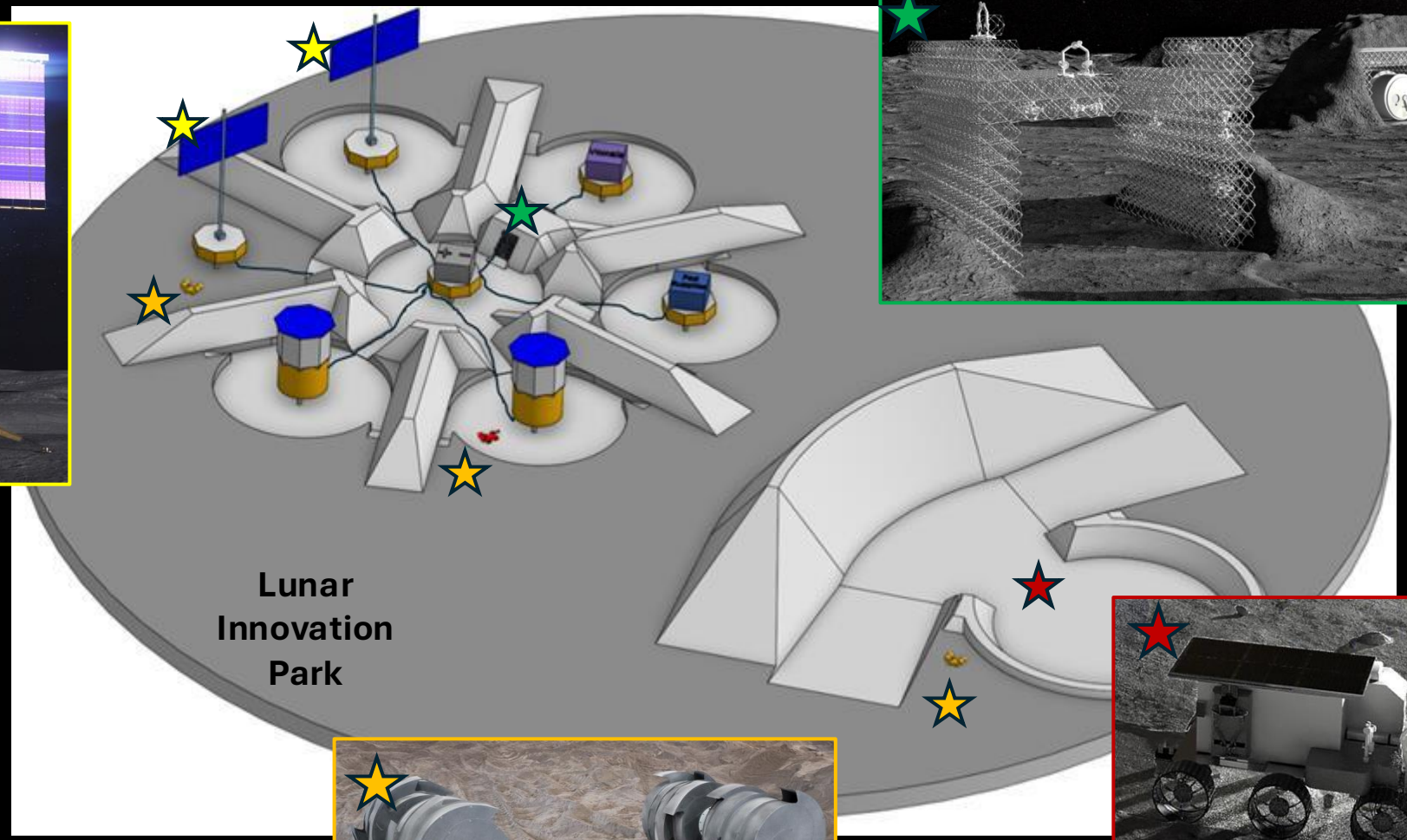
AIAA 2024-4840, ASCEND July 2024

Lunar Innovation Park – How we could get it done

Many of the basic technologies are close in hand with funding from NASA but not fully mature

VSAT /Comms /Nav.

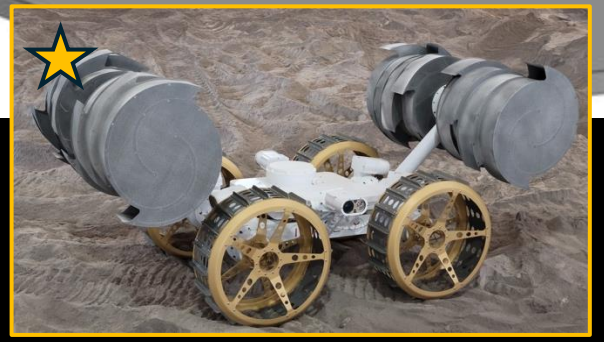


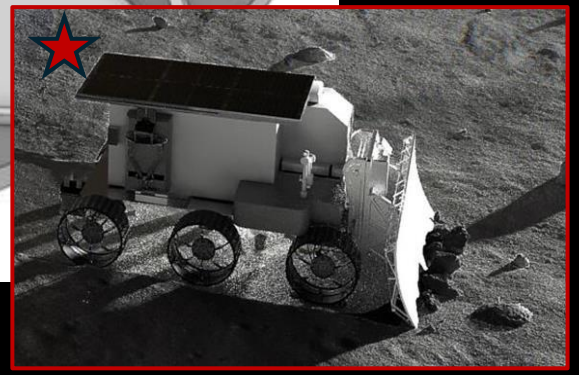


ARMADAS/TLT

- International Space Agencies and US Industry investments
  - Construction - AI SpaceFactory, Astroport, Astrobotic, Cislune, Ethos Space, GITAI, HEBI Robotics, Icon, Lockheed Martin, Motiv, PSI, Redwire
  - Water Mining - Argo Space, Orbit Fab, Starpath, JAXA
  - Oxygen Extraction - ASI, Blue Origin, Lunar Resources, CSA, DLR, ESA, Israel

IPEx





LLP Construction: RW-Mason, ICON-VMX

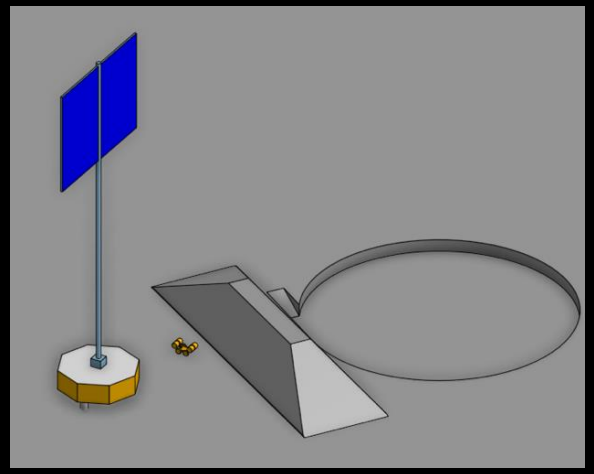
Lunar Innovation Park – Concept Details

- **Two 5 kWe deployable and retractable VSAT**
- **Seven 125W inductive chargers**
- **41 kWhr batteries** – provide lunar night keep-alive power to all LIP assets and LIP customers
- **3GPP 5G communications, WiFi6 and dual band DTE**
- **Two prepared single-use customer landing sites** – sites for medium-scale commercial and/or science landers (in addition to the sites prepared for LIP construction landers)
- **One reusable LLP** - land and launch medium to large scale landers
- **One unpressurized protective shelter** – protection for surface assets (9 m^3 internal volume). Includes power and communications.
- **Two Infrastructure Pilot Excavator (IPEx) systems** - site survey, site preparation and regolith manipulation, surface system inspections via on-board cameras and sensors
- **One multi-purpose Construction and Logistics Pilot Robot (CPEx) system** - advanced site prep, construction and logistics support, surface system inspections

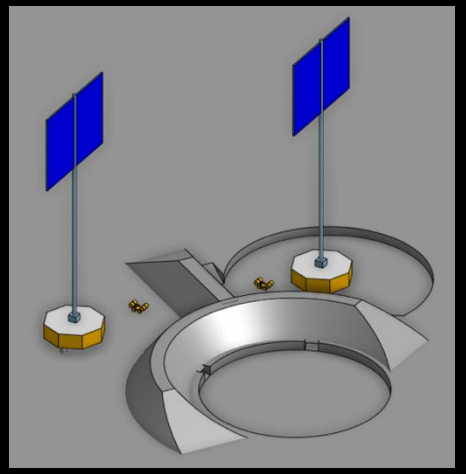
Lunar Innovation Park Mission Sequence*

- **Mission 1**- Establish a foothold with 5kWe power, communications, and nav., prepare landing site for Mission 2
- **Mission 2**- Provide system redundancy and 5kWe power augmentation, prepare landing site for Mission 3
- **Mission 3** – 21kWhr power storage and commission the first lunar power grid, add a customer landing site
- **Mission 4** – Unpressurized shelter construction and landing areas for Mission 5 and a second customer lander

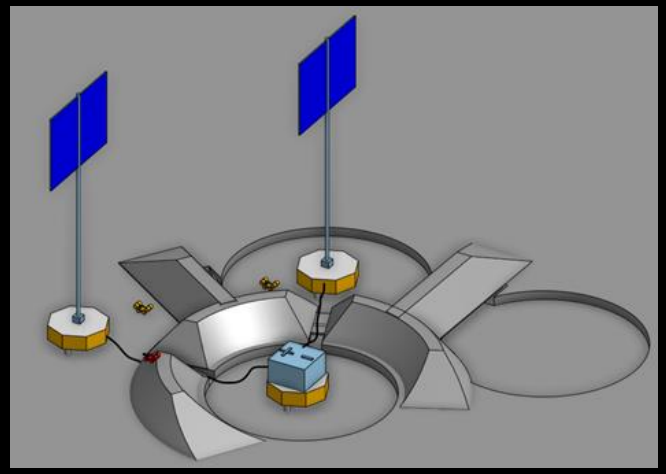
* Assume 625kg payload per Mission



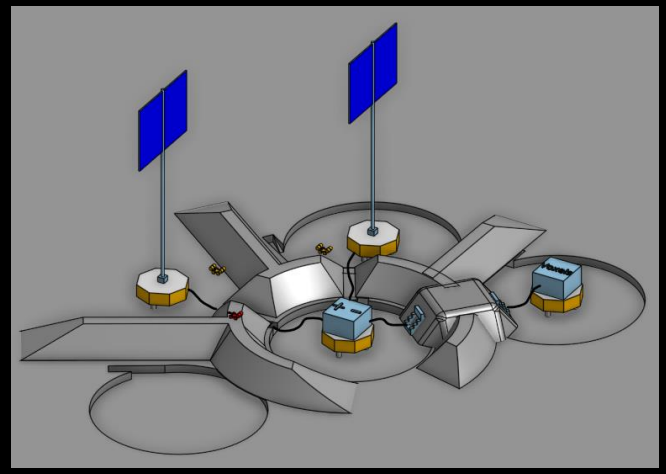
Mission 1



Mission 2



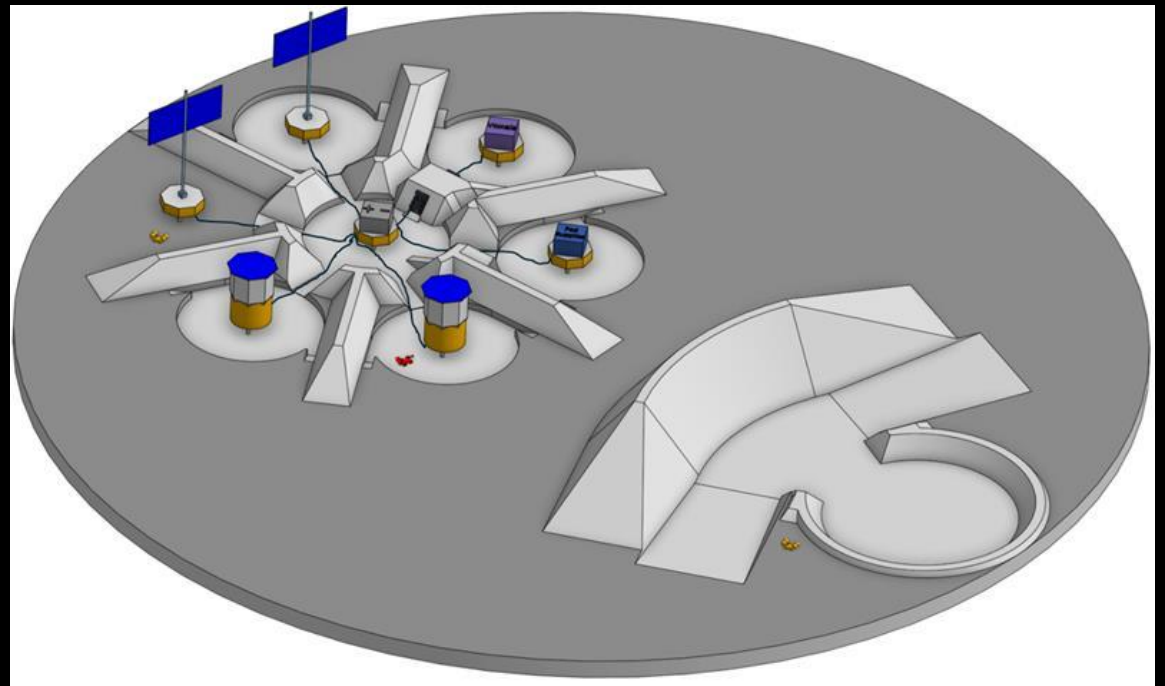
Mission 3

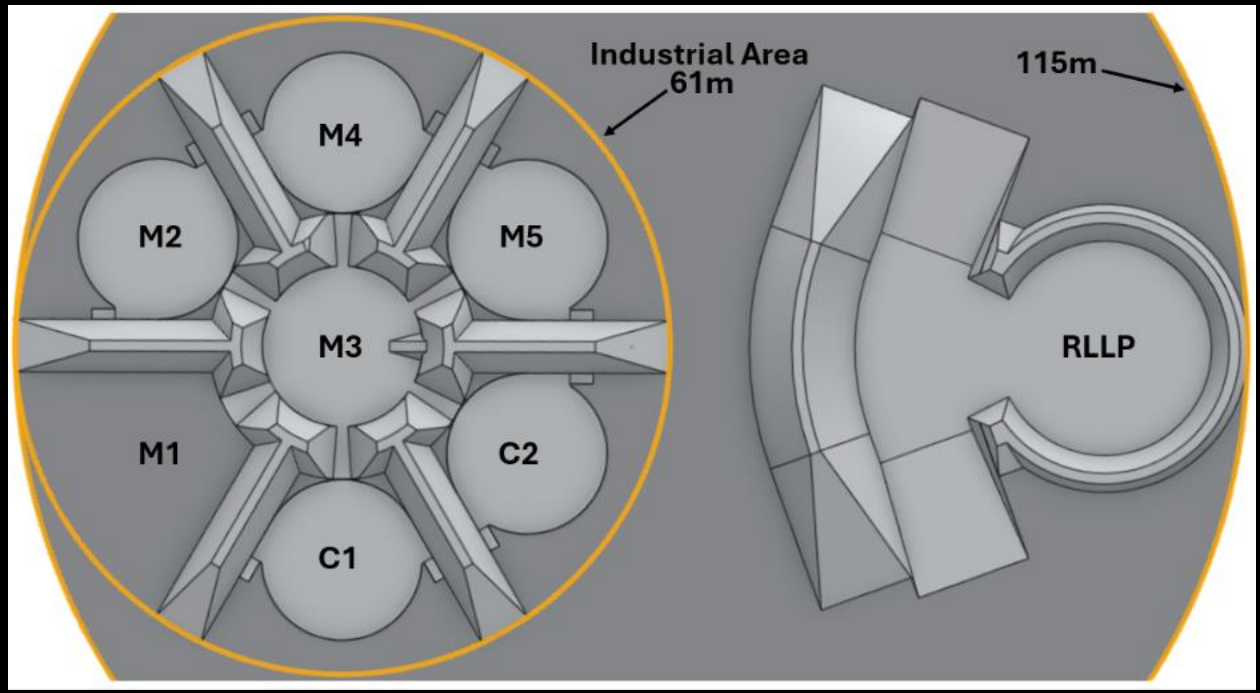


Mission 4

Lunar Innovation Park Complete

- **Mission 5-** Build a Reusable Landing & Launch Pad (RLLP)
  - RLLP can be constructed using a variety of methods including deployable/assembled high-temperature surface or emerging in-situ regolith construction methods such as microwave sintering, laser or inductive melting, or polymer/regolith extrusion
  - Park expansion and upgrades/augmentation can occur as the demand for the infrastructure increase and new services are required, e.g., FSP, ISRU systems, logistics, advanced construction demos





Key Park Benefits

Science Missions

- Enable **8-12x more science** assuming four, 3-year life rovers that utilize the Park for the same cost of six, 2-week life rovers (disposable systems that don't use the Park)
- Cost savings would significantly **accelerate scientific discovery** by offering increased mission opportunity on the lunar surface.

Artemis Risk Reduction and Moon Base Construction

- Steady incremental build up and operation of the Park provides **valuable risk reduction** demonstrations of technologies for subsequent human exploration and will enable **Moon Base construction**
- FSP site preparations, foundations and radiation protection berms

Early ISRU Demonstrations & Commodity Production

- Park is capable of supporting **ISRU technology demonstrations** and early small-scale production of commodities such as O_2, H_2, and H_2O (Sanders et al. 2024)
- ISRU Pilot Plant demos to produce **1000 kg of O_2 and 125 kg of H_2** or the production of up to **2000 kg of O_2** per year for ascent vehicle refueling

Lunar Innovation Park – Consultants

- **Jeremiah McNatt** - NASA Principal Technologist for Advanced Power
- **Bernie Edwards** – NASA System Capability Leadership Team for Advanced Communications and Navigation
- **Michelle Munk (ret.), John Carson** – NASA System Capability Leadership Team for Entry, Decent & Landing
- **Josh Mehling** – NASA Principal Technologist for Robotics
- **Jerry Sanders** (ret.), **Julie Kleinhenz -** NASA System Capability Leadership Team for In-situ Resource Utilization
- **Jason Schuler** – PI Infrastucture Pilot Excavator Project, Granular Mechanics and Regolith Operations Lab, NASA Kennedy Space Center
- **Kenny Cheung, Greenfield Trinh** – ARMADAS Project PI/PM, Intelligent Systems Division, Ames Research Center
- **Glenn Research Center Compass Team** – Mission design and feasibility analysis
- **Various industry contacts** (e.g., technology developers, campaign architects, space policy experts)

Concluding Remarks

- **Lunar Innovation Park -** a concept for establishing the minimum viable infrastructure needed to kickstart lunar surface operations and commercial economic development
- **The Park concept is highly aligned with the Artemis Moon Base**
  - We are engaged with the Moon Base Team
  - Expect similar themes coming out of Moon Base planning
  - Respond to the Ignition RFI

Ignition RFI