Exploration Lunar Architecture

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Architecture Driven By A Strategy

Global Exploration Strategy Development → **Themes & Objectives**

National Priorities Defined ↕

Architecture Assessment → **Reference Architecture & Design Reference Mission**

Detailed Requirements Defined ↕

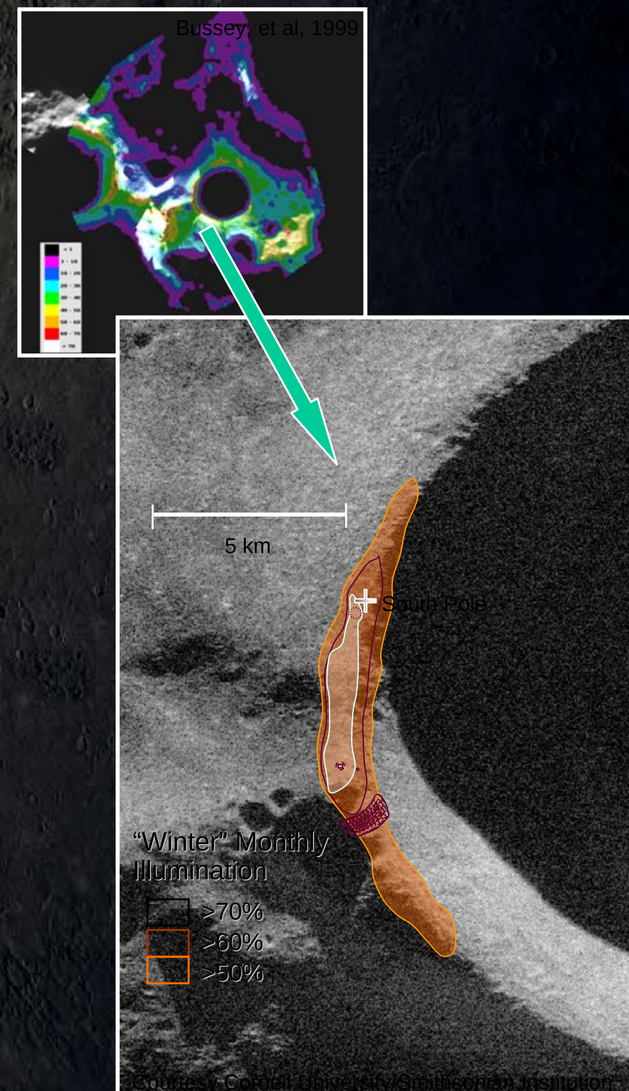
Detailed Design → **Operations Concept, Technology Needs, Element Requirements**

What are the Big Lunar Architecture Questions?

- **What are the US priorities and phasing for what we will achieve at the moon?**
- **How do priorities drive important decisions?**
  - Outpost vs. Sorties
  - Landing site(s)
  - Architecture flexibility to address lower US priorities or far-term interests
- **What infrastructure is required to support priorities? Considerations:**
  - Schedule/ flight rate
  - Cost/ available budget
- **What will we plan on developing ourselves?**
  - Critical path hardware to achieve primary objectives
  - Allowing for parallel developments from commercial and/or international communities
- **What level of limiting resources will allow for optimum realizable capability?**
  - Enabled by basic NASA transportation architecture
  - Down-mass and up-mass at the Moon
  - Power

Key Decisions: Sortie vs. Outpost

- **Three Top Themes Drive to an Outpost:**
  - “Exploration Preparation”
  - “Human Civilization”
  - “Economic Expansion”
- **Better enables “Global Partnerships”**
- **Allows development and maturation of ISRU**
- **Results in quickest path toward other destinations**
- **Many science objectives can be satisfied at an outpost as well**

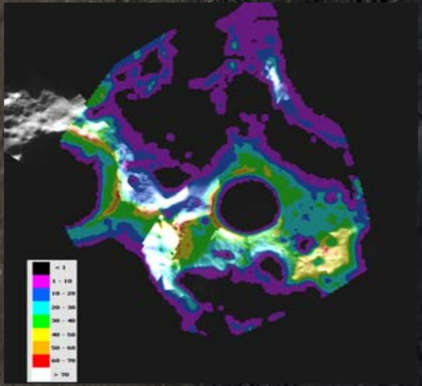


Outpost Site Location

Outpost Site: Polar

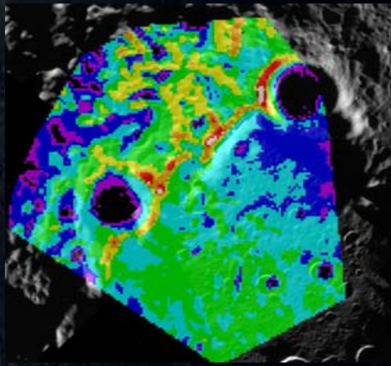
- **Safe**
  - Provides good opportunities to return
  - Opportunity to abort to surface
- **Cost Effective**
  - High percentage of sunlight
  - Allows use of solar power
  - Relatively low energy return to Earth
- **Resources**
  - Oxygen
  - Enhanced hydrogen (possibly water)
  - Potentially other volatiles
- **Flexibility**
  - Allows incremental buildup using solar power
  - Enhanced surface daylight ops
  - One communication asset (with backup)
  - More opportunities to launch
- **Exciting**
  - Not as well known as other areas
  - Offer unique, cold, dark craters

South Pole



Data obtained during southern winter (maximum darkness)

North Pole



Data obtained during northern summer (maximum sunlight)

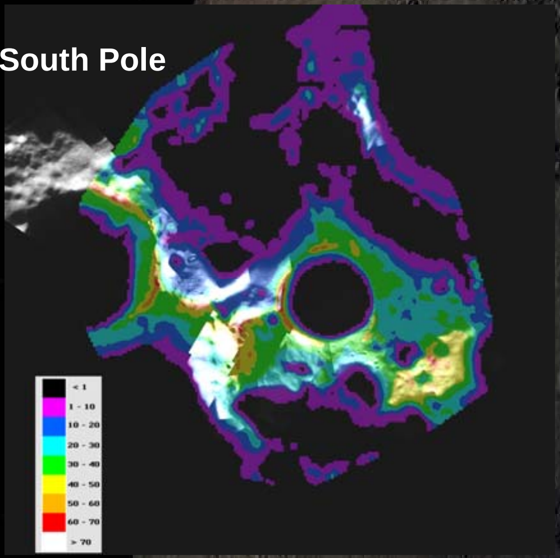
Permanent Sunlight?

South Pole:

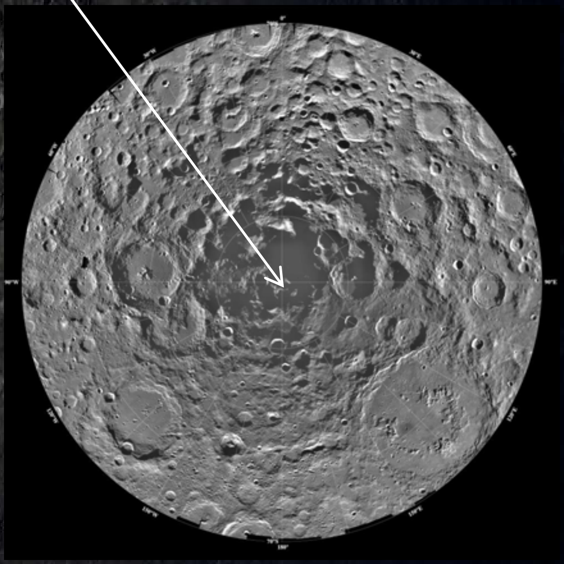
- Three areas identified with sunlight for more than 50% of lunar day
- One zone receives 70% illumination during dead of southern winter
- Lit areas in close proximity to permanent darkness (rim of Shackleton)

North Pole:

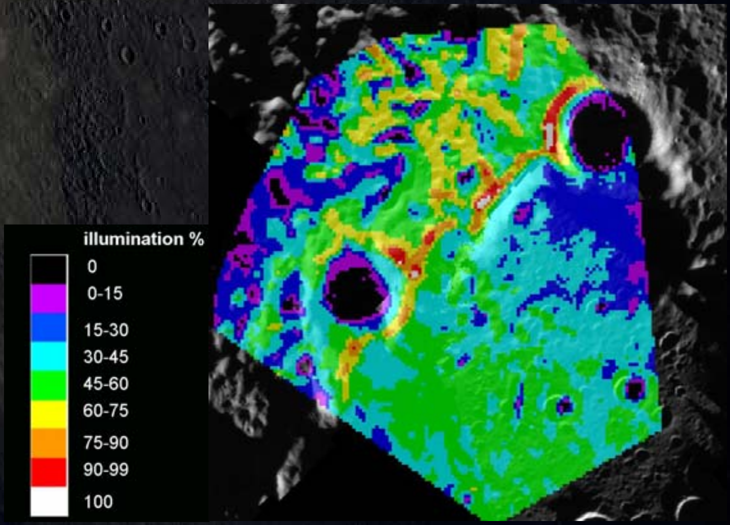
- Three areas identified with 100% sunlight
- Two zones are proximate to craters in permanent shadow
- Data taken during northern summer (maximum sunlight)



Data obtained during southern winter (maximum darkness)



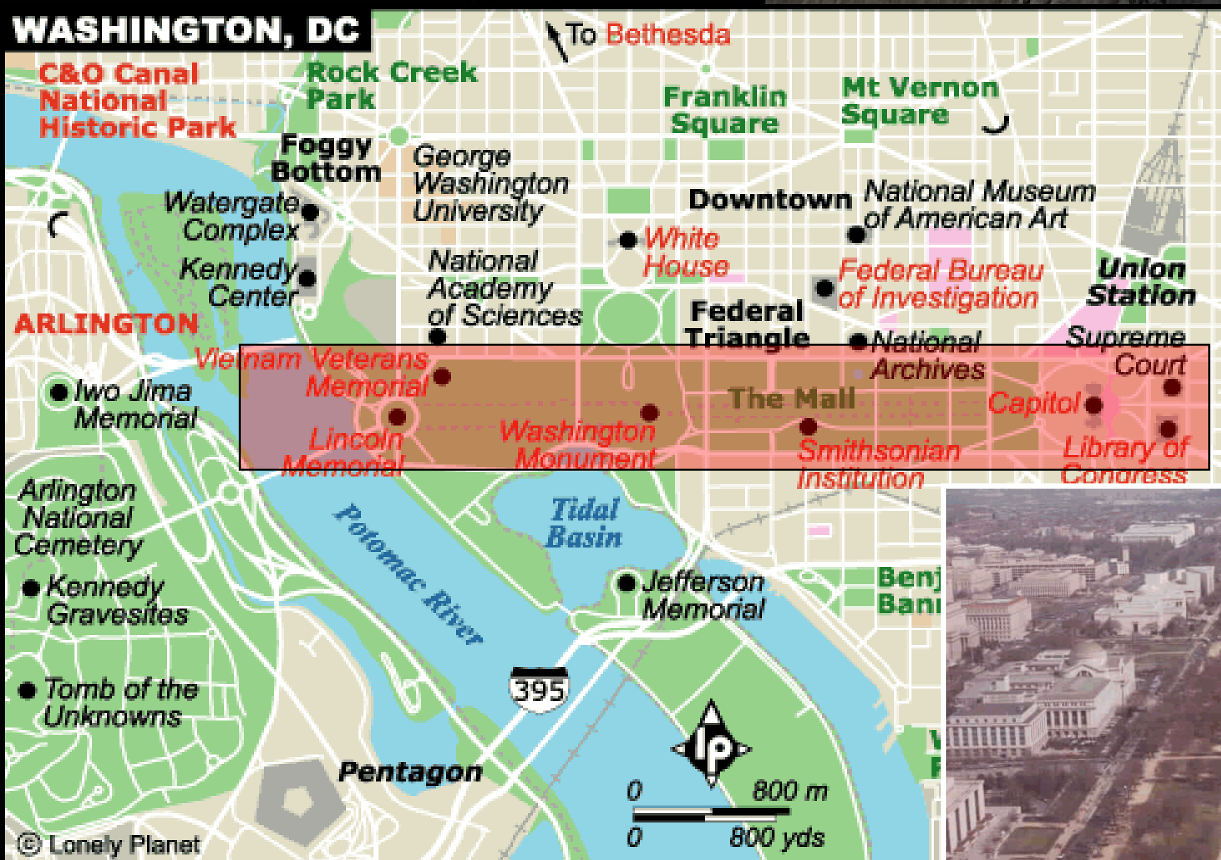
North Pole



Data obtained during northern summer (maximum sunlight)

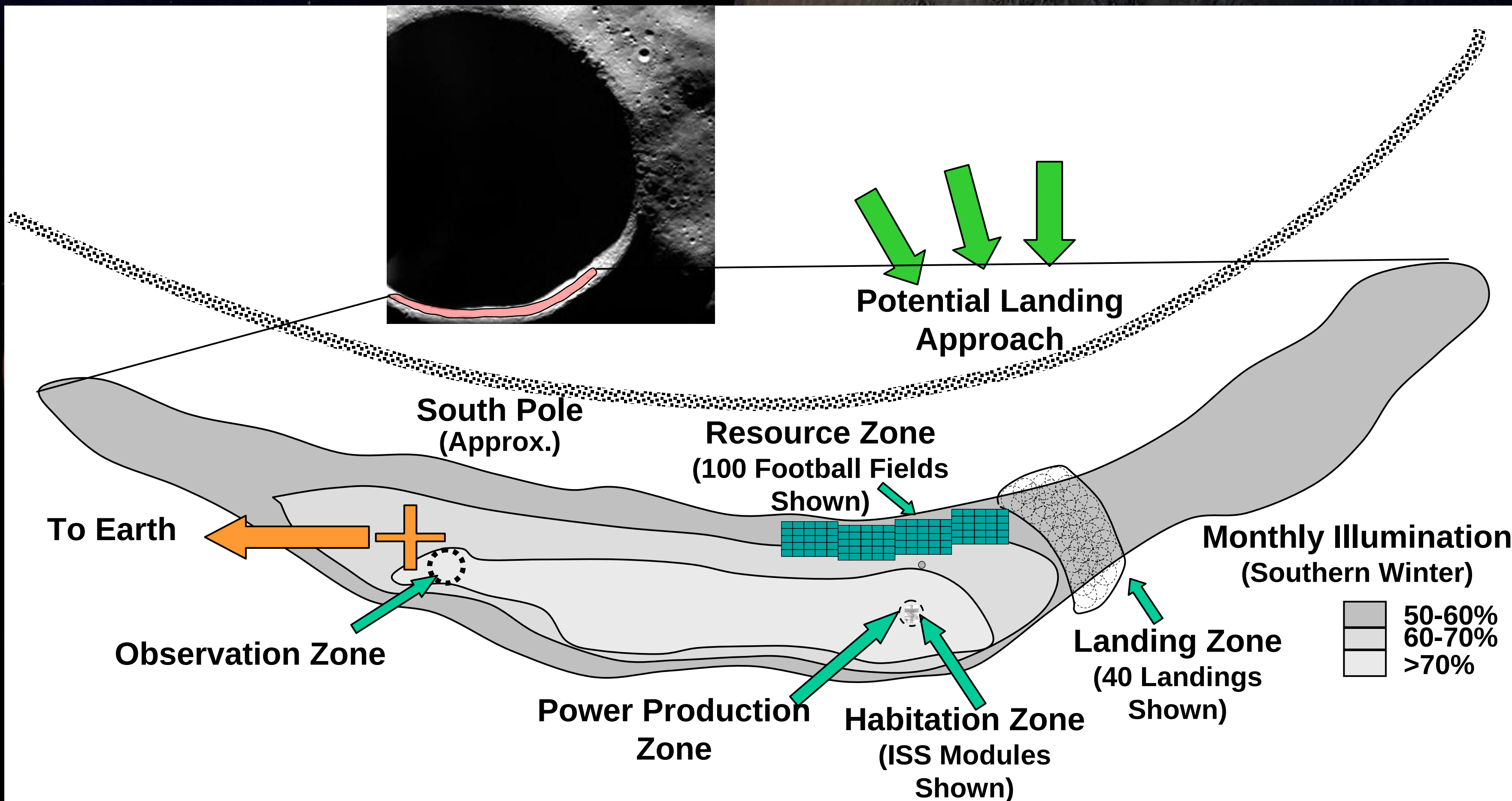
Shackleton Crater Rim Size Comparison Example-Possible Landing Site

The area of Shackleton Crater rim illuminated approximately 80% of the lunar day in southern winter, with even better illumination in southern summer (Bussey et al., 1999)

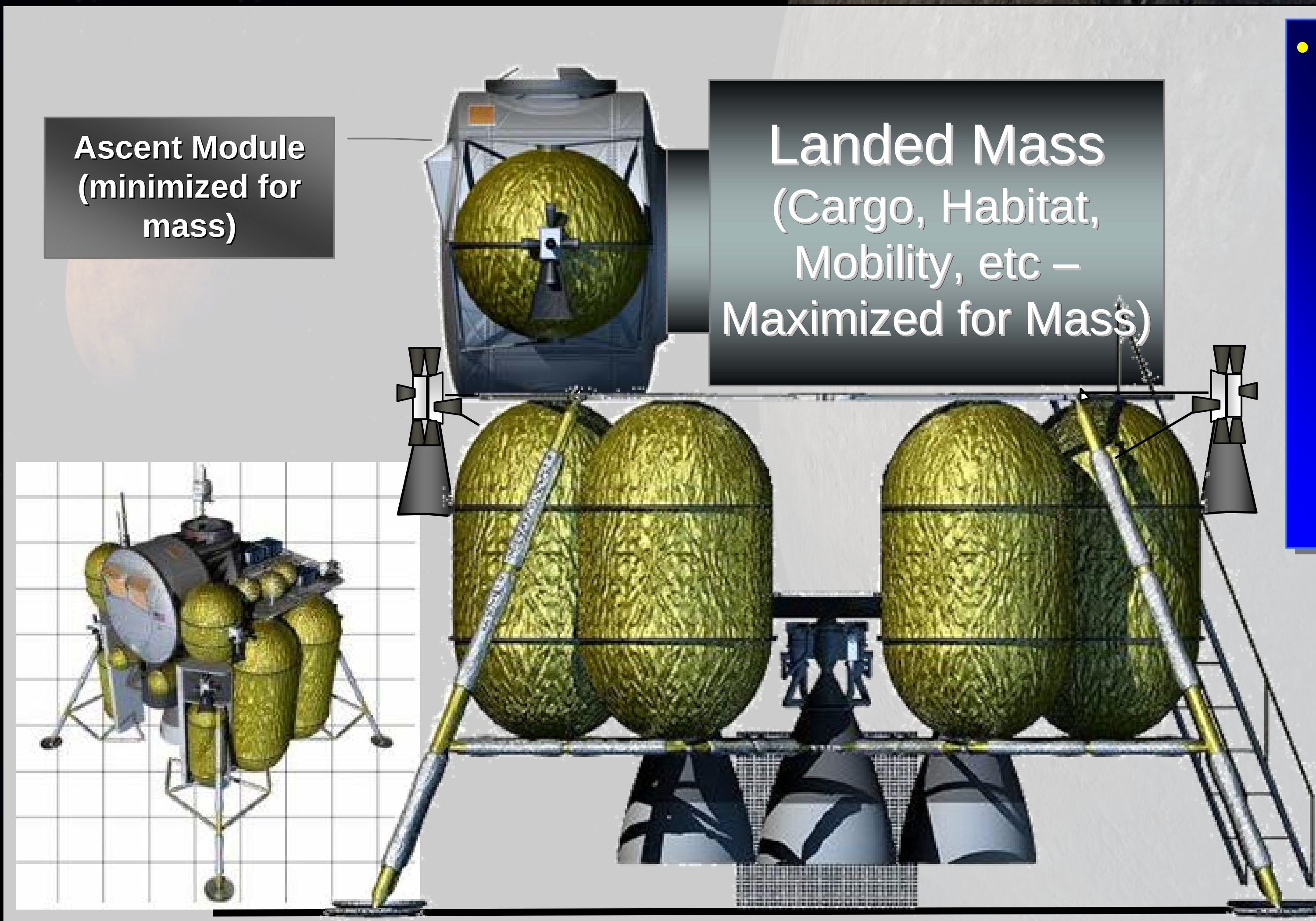


Note: 'Red Zone' = 750 m x 5 km (personal communication with Paul Spudis)

Shackleton Crater Rim with Notional Activity Zones



Lander Basic Architecture

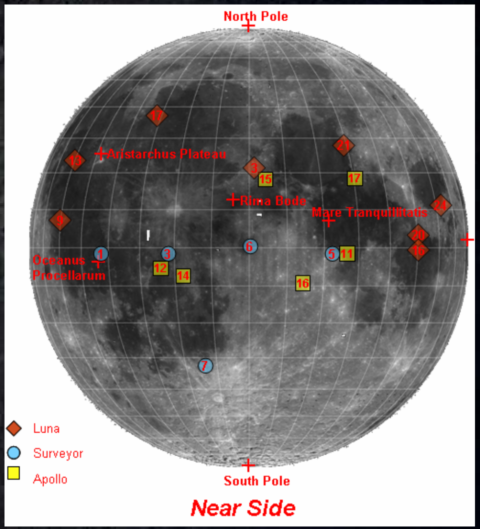


- Design Goals
  - Minimize Ascent Module mass
  - Minimize Descent Module mass
  - Maximize landed “payload” mass
  - Simplify interfaces
  - Move functions across interfaces when it makes sense

Point of Departure Only

Human Sortie Missions: Lander Capability

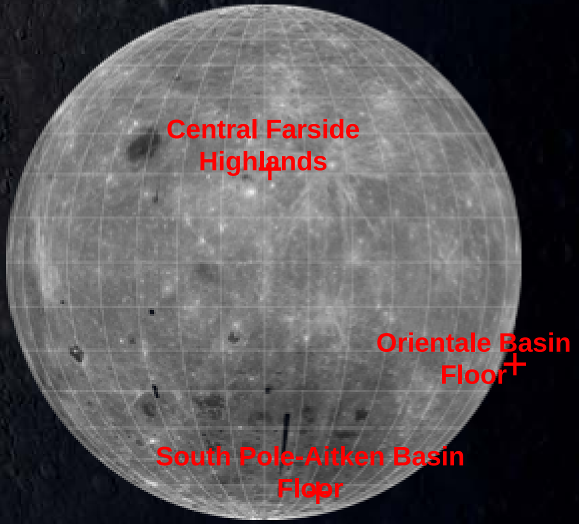
- **The LAT lander (augmented with extra fuel cells) is capable of reaching all of the top ten ESAS sites with a crew of two for 7 days with substantial science cargo**
- **The LAT lander is also capable of reaching all but three of the ESAS top ten sites with a crew of 4 assuming a 3 MT surface hab augmentation of the ascent module which reduces available science payload**



DOWNMASS (kg)

Site	Latitude	Longitude	LOI DV (m/s)	2 Crew 7 days	4 crew 3 days*
South Pole	89.9 S	180.0 W	845	4,254	853
Far Side South Pole Aitken Basin	54.0 S	162.0 W	1,060	982	-2,426
Orientale Basin Floor	19.0 N	88.0 W	873	3,799	396
Oceanus Procellarum	3.0 S	43.0 W	857	4,058	656
Mare Smythii	2.5 N	86.5 E	848	4,205	803
W/NW Mare Tranquilitatis	8.0 N	21.0 E	902	3,336	-67
Rima Bode	13.0 N	3.9 W	905	3,289	-114
Aristarchus Plateau	26.0 N	49.0 W	865	3,928	526
Central Far Side Highlands	26.0 N	178.0 E	939	2,761	-643
North Pole	89.5 S	91.0 E	845	4,254	853
Aristarchus Science Station	26.0 N	49.0 W	865	4,649	1,247

*Assumes extra habitation module to accommodate 2 extra crew @ 3 mT)

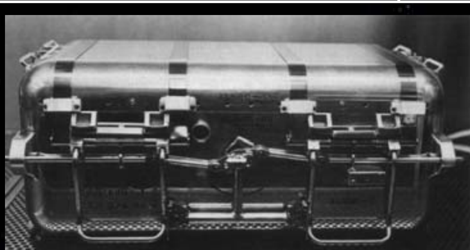


Far Side

Potential Option: Occasionally Trade additional Sample Return for a Crewmember

- **Apollo Lunar Sample Return Container filled with various uniform sized samples**
- **Void fraction = percentage of "air"**

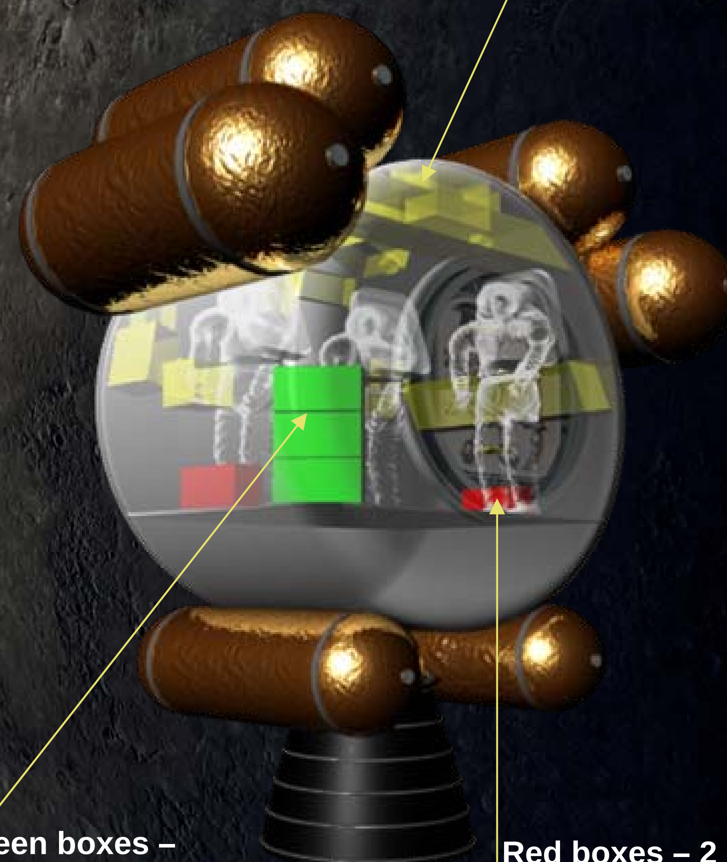
Density	Void Fraction	Resulting Mass*
Lunar Regolith (1.5-1.8 g/cm^3)	0%	24.3 kg – 29.1 kg
2-cm spherical dia Rock (3.0-4.0 g/cm^3)	26%	35.9 kg – 47.9 kg
8-cm spherical dia Rock (3.0-4.0 g/cm^3)	50%	24.3 kg – 32.4 kg
Monolithic Rock (3.0-4.0 g/cm^3)	10%	43.7 kg – 58.4 kg



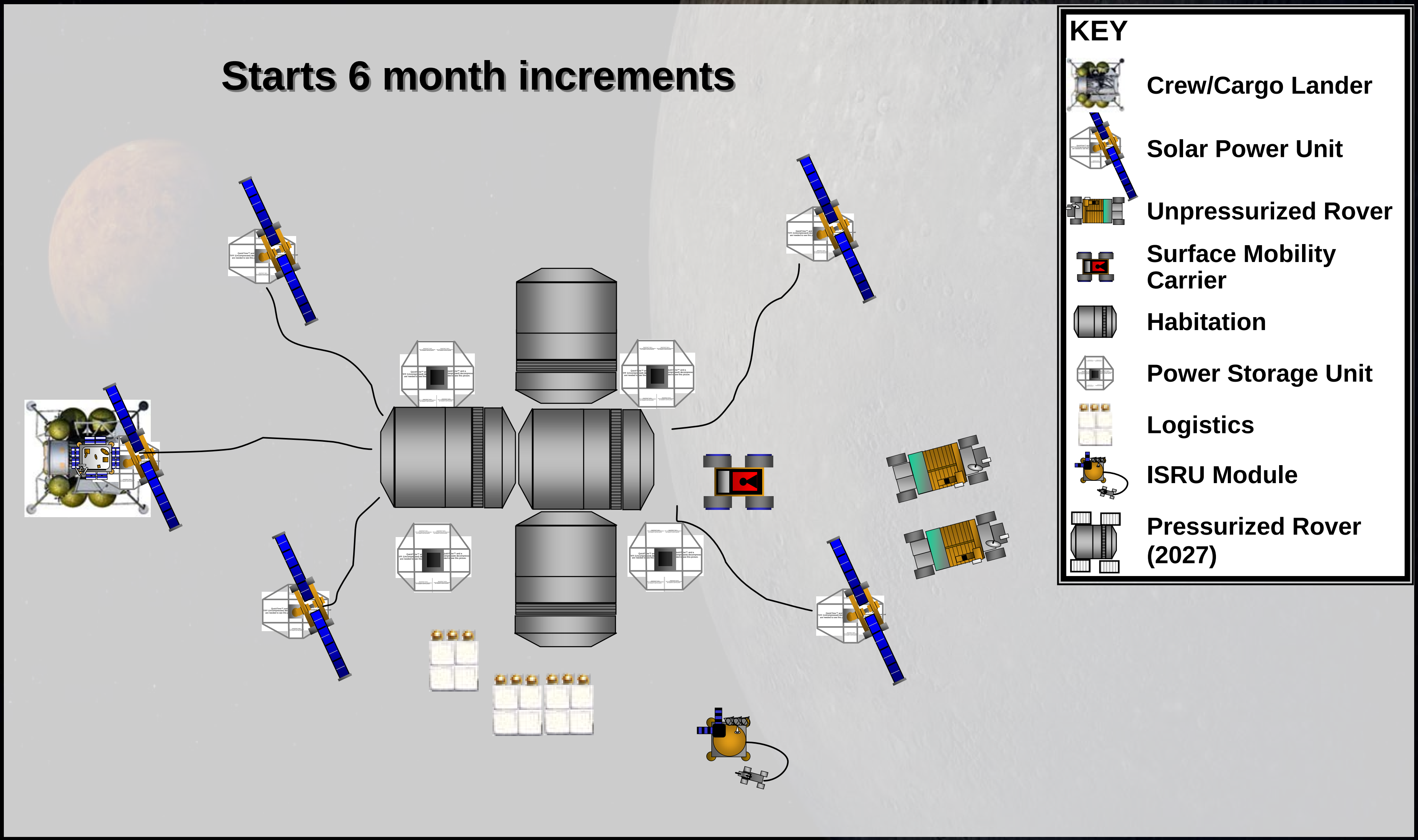
- **Mass – 6.7 kg**
- **Dimensions – 48 cm x 30 cm x 20 cm**
- **Interior volume – 16,000 cm^3**
- **Container held 30-50 kg for Apollo 15-17 missions**

ALSRC Images: Judith Allton, "Catalog of Apollo Lunar Surface Geological Sampling Tools and Containers", March 1989

Notional Sample Return Containers in Ascent Stage



Key Points: Outpost Build up



Point of Departure Only – Not to Scale

Lunar Architecture Framework — Point of Departure

- **Human lunar missions will be used to build an outpost at a polar site**
- **The ability to fly human sorties and cargo missions with the human lander will be preserved**
- **Initial power architecture will be solar with the potential augmentation of nuclear power at a later time**

- **Robotic missions will be used to:**
  - Characterize critical environmental parameters and lunar resources
  - Test technical capabilities as needed
- **The ability to fly robotic missions from the outpost or from Earth will be a possible augmentation**

NASA Implementation Philosophy

- **The US will build the transportation infrastructure and initial communication & navigation and initial surface mobility**
- **Open Architecture: NASA will welcome external development of lunar surface infrastructure**

- **The US will perform early demonstrations to encourage subsequent development**
- **External parallel development of NASA developed capabilities will be welcomed**

Open Architecture: Infrastructure
Open for Potential External Cooperation

- **Lander and ascent vehicle**
- **EVA system**
  - CEV and Initial Surface capability
  - Long duration surface suit
- Power
  - Basic power
  - Augmented
- Habitation
- Mobility
  - Basic rover
  - Pressurized rover
  - Other; mules, regolith moving, module unloading
- Navigation and Communication
  - Basic mission support
  - Augmented
  - High bandwidth
- ISRU
  - Characterization
  - Demos
  - Production

- **Robotic Missions**
  - LRO- Remote sensing and map development
  - Basic environmental data
  - Flight system validation (Descent and landing)
  - Lander
  - Small sats
  - Rovers
  - Instrumentation
  - Materials identification and characterization for ISRU
  - ISRU demonstration
  - ISRU Production
  - Parallel missions
- Logistics Resupply
- Specific Capabilities
  - Drills, scoops, sample handling, arms
  - Logistics rover
  - Instrumentation
  - Components
  - Sample return

**** US/NASA Developed hardware**

Post-Buildup Opportunities

NASA will have developed the capabilities required to enable various future paths. Agency decision: Which future path(s) to take?

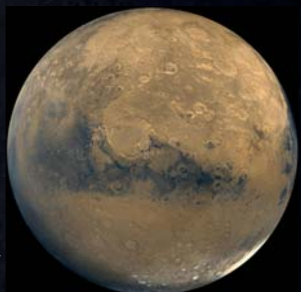
Agency Decision on Future Path(s)

Capabilities

- Mature transportation system
- Closed loop habitat
- Long duration human missions beyond LEO
- Surface EVA and mobility
- Autonomous operations
- Advanced robotic missions
- Minimize reliance on Earth via In-Situ fabrication and resource utilization
- Enhanced by Commercial and International Partners

NASA Follow-on Strategy

Humans to Mars



Mars

Expand Lunar Outpost Site Exploration

Expand Lunar Outpost via Commercial and/or International Partners

Human Exploration of Other Lunar Sites via Sorties

Forward Work (January – July 07)

Using current architecture as a point of departure

- **Update objectives that drive the architecture**
- **Coordinate lunar exploration plans with interested communities**
  - Find opportunities to collaborate
- **Refine campaign and architecture concepts**
- **Refine element hardware concepts**
- **Develop Mars Reference Mission**
- **Update and baseline ESMD Requirements**
- **Continue to engage academia, the private sector, and other stakeholders in defining a sustainable program of exploration**