Update on Lunar Architecture

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NASA Exploration Systems Mission Directorate

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The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

Global Exploration Strategy Themes

- Human Civilization
- Scientific Knowledge
- Exploration Preparation
- Public Engagement
- Global Partnerships
- Economic Expansion
In addition to supporting the basic goals and objectives of the US Space Policy, the Architecture must have the following:

- **Programmatic Flexibility** – Adaptable to changes in national priorities and budgets over several election cycles

- **Participant Flexibility** – Adaptable to changes in external participation and their priorities (Commercial or International Partners)

- **Exploration Flexibility** – Adaptable to changes in exploration priorities and methods
Summary of December 06 AIAA Briefing

Lunar Architecture Team Summary

- Human lunar missions will be used to build an outpost initially at a polar site
- Preserve the option for an outpost at other lunar locations
- Preserve the ability to fly human sorties and cargo missions with the human lander
- Initial power architecture will be solar with the potential for augmentation with nuclear power later
- The US will build the transportation infrastructure, initial communication & navigation infrastructure, and initial surface EVA capability
- Open Architecture: NASA will welcome parallel development and development of lunar surface infrastructure by international and commercial interests
Open Architecture: Infrastructure
Open for Potential External Cooperation

- 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
Open Architecture
The Pieces of a Greater Mission

Human Missions to the Moon

US/NASA Developed initial capabilities
- Launch Vehicle Architecture
- Lunar Lander: ascent vehicle, descent vehicle, basic habitation
- Initial EVA system for CEV and an Initial Surface Suit
- Basic Navigation and Communication

Open for Cooperation

Systems and Capabilities Envisioned for an Outpost including Outpost enabled sorties
- Long duration surface suit
- Advanced, long-duration Habitation
- Basic and Augmented Power Systems
- Basic, unpressurized rover
- Pressurized rover
- Logistics rover
- Augmented, high bandwidth satellite communication/navigation
- Logistics Resupply
- ISRU Production

Time

Participant Flexibility Strategy
- Welcome parallel capabilities while seeking “open architecture” contributions
- Continue success of the Global Exploration Strategy through multilateral engagement in International Space Exploration Coordination Group (ISECG)
- Continue success of US Chamber of Commerce engagement
- Build on long-standing bilateral relationships while seeking new relationships when opportunities and conditions permit
Architecture Driven By A Strategy
Where We Have Been and Next Steps

Global Exploration Strategy Development
– Themes and Objectives

Architecture Assessment (LAT1) Dec 06 – Outpost first at one of the Poles, elements critical to US

Detailed Design Concepts (LAT2) Aug 07 – Operations concepts, technology needs, element requirements

Surface system concepts but no final designs

Lunar Capabilities Concept Review June 08 – Refinement of concepts in support of the transportation system

Lunar surface concept additional analysis cycles

Lunar Transportation system SRR

Lunar surface systems SRR

Element SRRs

Time
Strategy for Second Phase of Architecture Studies

- Build on LAT 1 decisions, assessing a range of options
- Combine best features into a hybrid approach

Attributes:
- Enable lunar sustained presence early
- Develop infrastructure while actively engaged in science and exploration
- Ensure architecture supports broader range of Objectives
- Support the establishment of Mars analog
- Allow the earliest partnership opportunities for commerce and International Partners
- Continuous and focused public engagement
Hybrid Approach to Options

Surface Architecture-

- Worked as a system with the transportation architecture (Ares I&V, Orion, and Lander)
- Ares V shroud expanded to 10M dia. for lander packaging
- Cargo lander utilized to transport major components to the surface
- Outpost built up from only 2 or 3 modular habitat elements; each pre-integrated with power, life support, communications, etc.
- Mobility capability that utilizes the ‘Leg-Wheel’ concept for unloading, transportation and emplacement of elements
- Early delivery of small, agile pressurized rover
Extended Surface Exploration

- Wheel-on-leg surface carrier provides capability in addition to offloading and positioning surface elements:
  - Provides capability for mobile habitat
  - Mobile habitat drives robotically to new interim Outpost
  - Crew drives separately in pressurized rover to extended sortie site.
  - Habitat can be sent to sites for a visit from another crew and lander in super-sortie mode.
Architectural Options Evaluated

Option 1: All elements delivered with crewed flights (LAT 1)

Option 2: Derivative of LAT 1 except uncrewed lander can deliver hardware to surface provided all elements must be sized to fit on a crewed lander.

Option 3: A single large, fully outfitted and pre-integrated Habitation launched and landed on a single uncrewed mission

Option 4: The lander has integrated surface mobility (mobile lander)

Option 5: Long range, pressurized rover delivered as early in the sequence as possible (Captured in each)

Option 6: Nuclear power used for the surface power in lieu of solar
Option 1 – Mini-habitat elements with Crew Lander (LAT-1)

Option 2 – Mini-habitat elements with Crew/Cargo Lander

Friendly to Commercial, IP roles
Flexible to redirection
Tolerant to loss of element

Assembly and maintenance intensive
Extensive unloading, transportation, emplacement and integration
Option 3 – Single Delivery, Monolithic Habitat

Hab can be integrated, checked out pre-launch
Supports Mars concepts

Less flexible to redirection and Exploration inflexible
Less tolerant to loss of element
Less adaptable to reduced transportation capability
Option 4 – Mobile Lander Habitat System

Friendly to Commercial, IP roles
Flexible to redirection
Very Exploration flexible
Tolerant to loss of element
Resolves much of the unloading and transportation issue
Smaller bone yard

Not adaptable to reduced transportation capability
High level of complex integration
Option 5
Key Decision – Surface Mobility

- Science in vicinity of Outpost can be quickly exhausted
- Extended range surface mobility is essential
- Unpressurized rovers limited because of crew suit time
- Drives need for long-distance pressurized rover capability
Why is a Pressurized Rover Necessary?
Kaguya Satellite - Lunar South Pole Image

Requires Pressurized rover to explore beyond 10 km from the outpost

Shackleton
19 km diameter

This crater is about as big as Meteor Crater in Arizona
1.2 km diameter
The New Lunar Architecture Drives Out The Need For A New Class Of EVA Surface Support Vehicles
Apollo LRV vs. Small Pressurized Rover

Dimensions

- 310cm (122”)
- 259cm (102”)
- 183cm (72”)
- 203cm (80”)
- Z = 100.0 (BOTTOM OF CHASSIS)
- 44.8” MAX
Suitports: allows suit donning and vehicle egress in < 10min with minimal gas loss

Two Pressurized Rovers: low mass, low volume design enables two pressurized vehicles, greatly extending contingency return (and thus exploration) range

Suit PLSS-based ECLSS: reduces mass, cost, volume and complexity of Pressurized Rovers ECLSS

Ice-shielded Lock / Fusible Heat Sink: lock surrounded by 2.5cm frozen water provides SPE protection. Same ice is used as a fusible heat sink, rejected heat energy by melting ice vs. evaporating water to vacuum.

Work Package Interface: allows attachment of modular work packages e.g. winch, cable reel, backhoe,

Chariot-Style Aft Driving Station: enables crew to drive rover while EVA, also part of suitport alignment
Small Pressurized Rover Design Features
(Slide 2 of 2)

Modular Design: pressurized module is transported using Mobility Chassis. Pressurized module and chassis may be delivered on separate landers or pre-integrated on same lander.

Pivoting Wheels: enables crab-style driving for docking

Docking Hatch: allows pressurized crew transfer from Rover-to-Habitat, Rover-to-Ascent Module and/or Rover-to-Rover

Radiator on Roof: allows refreezing of fusible heat sink water on extended sorties

Work Package Interface: allows attachment of modular work packages e.g. winch, cable reel, backhoe, crane

Cantilevered cockpit: Mobility Chassis does not obstruct visibility

Exercise ergometer (inside): allows crew to exercise during translations

Dome windows: provide visibility as good, or better than, EVA suit visibility
Suit Alignment Guides and Suitport Ingress/Egress

Ring being swiveled up
Stem rotated 90° so ring faces suit

Suit Alignment Guides

Suitport Ingress / Egress

Long guide cone
Guide pin

Turret at 85°
Option 6 – Nuclear Surface Fission Power

Helps non-polar Outpost sites
Good for ISRU
Supports Mars

Not flexible, reactor anchors exploration site
Not failure tolerant, still need some solar initially
Emplacement is challenging
Carries political sensitivities
Option Discriminators

- Comprehensive set of Figures of Merit developed to cover key areas
  - Affordability
  - Benefit
  - Safety & Mission Assurance
  - Programmatic Risk
  - Sustainability
- Crew Surface Time
- Relative Costs
- Assembly, Maintenance and Exploration Time
- Unloading, transportation of large elements and enhanced exploration
- Capability for Sorties
- Lander Packaging and Ares V Shroud Size
- Technology Push
- Science Objectives
- Risks
- Exploration Benefits
- Public Interest
Cumulative Surface Stay Days (Planned)

**6t Lander**
- Option 1 – Mini-Hab
- Option 2 – Mini-Hab/Cargo
- Option 3 – Monolithic
- Option 4 – Mobile
- Option 6-2 – Nuclear Mini-Hab
- Option 6-3 – Nuclear Monolithic

**2t Lander**
- Option 1 – Mini-Hab
- Option 2 – Mini-Hab/Cargo
- Option 3 – Monolithic
- Option 4 – Mobile
- Option 6-2 – Nuclear Mini-Hab
- Option 6-3 – Nuclear Monolithic

Reduced delivery lander sacrifices crew surface time

Crew surface time does not favor any one option over another
Crew Time Utilization, Mini-Hab vs. Monolithic vs. Mobile

**Option 2 – Mini-Hab**

- Science/Exploration
- Assembly
- Maintenance

**Option 3 – Monolithic**

- Science/Exploration
- Assembly
- Maintenance

**Option 4 – Mobile Lander**

- Science/Exploration
- Assembly
- Maintenance

Mission #:
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

% of EVA Hours

- Asked by NASA SMD to provide guidance on the scientific challenges and opportunities enabled by a sustained program of robotic and human exploration of the Moon during the period 2008-2023 and beyond

Key Science Findings:
- **Enabling activities** are critical in the near term
- Strong ties with **international programs** are essential
- Exploration of the **South Pole-Aitken Basin** remains a priority
- **Diversity of lunar samples** is required for major advances
- The Moon may provide a **unique location for observation and study of Earth, near-Earth space, and the universe**
181 Objectives from Global Strategy Team

ALL Science Objectives (45 “SMD” Science objectives + some others...)

Each Objective Deconstructed to Define Needed Capabilities and Mapped to Architecture

PRIORITIES from Tempe Workshop

Grouped into key reference payloads

Mapped to Architecture options

Top Objectives
Top Objectives Examples:  
Planetary Science Subcommittee Findings

- **INTERNAL STRUCTURE and DYNAMICS** - Geophysical/heat flow network - requires multiple sites, widely spaced ("global access")

- **COMPOSITION/EVOLUTION of LUNAR CRUST** - requires extensive sampling at both local and diverse sites

- **IMPACT FLUX** - requires access to impact basins and sample return for age dating

- **SOLAR EMISSIONS/GCR/ INTERSTELLAR** - requires drilling, regolith and core sample integrity, careful documentation

- **SAMPLE ANALYSIS INSTRUMENTS AND PROTOCOLS** - infrastructure for pristine sample collection, storage, documentation, and transport needed

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### Table of Objective Assessments and Rankings

<table>
<thead>
<tr>
<th>Objective</th>
<th>73A Objective summary</th>
<th>Limiting Factors</th>
<th>Method of Data Collection</th>
<th>Implementation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characterize the surface and subsurface of the Moon for its potential value as an operational or strategic asset.</td>
<td>High priority</td>
<td>Low rank</td>
<td>High rank</td>
<td>Medium rank</td>
</tr>
<tr>
<td>Characterize the surface and subsurface of the Moon for its potential value as a place of scientific importance.</td>
<td>High priority</td>
<td>Low rank</td>
<td>High rank</td>
<td>Medium rank</td>
</tr>
<tr>
<td>Characterize the surface and subsurface of the Moon for its potential value as a place of historical or cultural importance.</td>
<td>High priority</td>
<td>Low rank</td>
<td>High rank</td>
<td>Medium rank</td>
</tr>
<tr>
<td>Characterize the surface and subsurface of the Moon for its potential value as a place of environmental importance.</td>
<td>High priority</td>
<td>Low rank</td>
<td>High rank</td>
<td>Medium rank</td>
</tr>
</tbody>
</table>

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Appendix 5-12
## Representative Science Payload Elements

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Environmental Monitoring Station (LEMS)</td>
<td>Volatiles, plasma field, radiation monitoring, dust – should be deployed early to monitor site evolution</td>
</tr>
<tr>
<td>Traverse and Sampling Package (TSP)</td>
<td>Diverse kit including sampling tools and containers, rover-carried sample selection instruments, and traverse geophysics instruments</td>
</tr>
<tr>
<td>Sampling Resupply Kit (SRK)</td>
<td>Sample containers and tools to replace consumables in TSP</td>
</tr>
<tr>
<td>Lunar Interior Monitoring Station (LIMS)</td>
<td>Geophysics station – seismology, heat flow, etc.</td>
</tr>
<tr>
<td>Lab in Hab (LAB)</td>
<td>Instruments inside “lab” at outpost for sample screening</td>
</tr>
<tr>
<td>Automated Sample Handling System (SHED)</td>
<td>Automated sample handling equipment outside the hab-lab for handling samples in the “rock garden”</td>
</tr>
<tr>
<td>Telescope (OBS)</td>
<td>Small observatory for earth observation or astrophysics applications</td>
</tr>
<tr>
<td>Orbiter Packages (ORB)</td>
<td>Orbital science to be carried either in “SIM bay” or to be kicked out into lunar orbit – mostly heliophysics science</td>
</tr>
</tbody>
</table>
Lunar Telescope
Science Goals and Study Objectives

• **Science Goals and Measurements**
  – A simple and autonomous Earth-observing system
  – A study of the light and chemical signatures of Earth can provide information on the planet’s habitability and biology
  – The signature of the direct and spectroscopic light-curves of the Earth will be used to understand current and future observations of Earth-like exoplanets
  – Will measure variations in photometric, spectral, and polarization signatures over visible and near-infrared wavelengths
  – Provides near-simultaneous imaging, polarimetry, and spectral data of the full Earth disk

• **Study Objectives**
  – Based on ALIVE Lunar Telescope proposal, develop a Lunar Telescope support system to be installed on the Lunar surface
Lunar Environmental Monitoring Station Science Goals and System Components

• **Science Goals and Measurements**
  – Comprehensively characterize the Lunar environment
  – Measure coordinated multitude of lunar environmental parameters: high energy particles, imaging, solar flares, cosmic rays, plasma waves, magnetic fields, solar wind, volatiles, dust, etc.

• **System Components**
  – Multiple instruments
    • XRS X-ray Spectrometer (Solar Flares)
    • GRNP High Energy Protons and Neutrons, Gamma-rays
    • MS Mass Spectrometer
    • EF DC Electric Field/AC Electric Field (Plasma Waves)
    • MAG DC Magnetic Field
    • SC (Search Coil) AC Magnetic Field (Radio Waves)
    • LEP, MEP, HEP Energetic Particle Analyzers
    • DUST 3D Dust Detection
    • Camera Illumination, dust obscuration
## Science Manifesting Guidelines

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Manifesting Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Environmental Monitoring Station (LEMS)</td>
<td>HIGH PRIORITY -- Important to get this down as early as possible to monitor site evolution as humans come. 5 year life – replace after 5 yrs</td>
</tr>
<tr>
<td>Traverse and Sampling Package (TSP)</td>
<td>HIGH PRIORITY -- Need one of these for each rover. In absence of rover, at least need sample supplies up to available mass.</td>
</tr>
<tr>
<td>Sampling Resupply Kit (SRK)</td>
<td>HIGH PRIORITY -- Need one of these for each crewed mission – can stockpile ahead of time</td>
</tr>
<tr>
<td>Lunar Interior Monitoring Station (LIMS)</td>
<td>MEDIUM PRIORITY 1 – Bring 1 LIMS ASAP after LEMS and adequate sampling supplies. If mobility of ~500 km is possible, bring 2 more LIMS ASAP. 5 year life – replace after 5 yrs</td>
</tr>
<tr>
<td>Lab in Hab (LAB)</td>
<td>This is most critical after stays get long (≥~a month), and assuming there is room to set it up in the hab</td>
</tr>
<tr>
<td>Automated Sample Handling System (SHED)</td>
<td>This is needed once the lab is functioning.</td>
</tr>
<tr>
<td>Telescope (OBS)</td>
<td>MEDIUM PRIORITY 2 – bring as soon as can be accommodated but after LIMS. Can bring more then 1 as this is a “generic” telescope</td>
</tr>
<tr>
<td>Orbiter Packages (ORB)</td>
<td>MEDIUM PRIORITY 3 – bring as soon as can be accommodated but after LIMS and OBS. Can bring more then 1 as this is a “generic” orbiter</td>
</tr>
</tbody>
</table>
The Architecture Maintains Sortie Capability: Possible Sortie Locations to Optimize for Geophysics

<table>
<thead>
<tr>
<th>Site</th>
<th>Lat.</th>
<th>Long.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A South Pole</td>
<td>89.9° S</td>
<td>180° W</td>
</tr>
<tr>
<td>B Aitken Basin</td>
<td>54° S</td>
<td>162° W</td>
</tr>
<tr>
<td>C Orientale Basin</td>
<td>19 S</td>
<td>88° W</td>
</tr>
<tr>
<td>D Oceanus Procellarum</td>
<td>3° S</td>
<td>43° W</td>
</tr>
<tr>
<td>E Mare Smythii</td>
<td>2.5° N</td>
<td>86.5° E</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Lat.</th>
<th>Long.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F Mare Tranquillitatis</td>
<td>8° N</td>
<td>21° E</td>
</tr>
<tr>
<td>G Rima Bode</td>
<td>13° N</td>
<td>3.9° W</td>
</tr>
<tr>
<td>H Aristarchus Plateau</td>
<td>26° N</td>
<td>49° W</td>
</tr>
<tr>
<td>I Central Far Side Highlands</td>
<td>26° N</td>
<td>178° E</td>
</tr>
<tr>
<td>J North Pole</td>
<td>89.5° N</td>
<td>91° E</td>
</tr>
</tbody>
</table>
Scientific Context for Exploration of the Moon: Highest Priority Science Objectives

- Test the cataclysm hypothesis by determining the **spacing in time of the creation of the lunar basins**.
- Anchor the early Earth-Moon impact flux curve by determining the **age of the oldest lunar basin** (South Pole-Aitken Basin).
- Establish a **precise absolute chronology**.
- Determine the compositional state (elemental, isotopic, mineralogic) and compositional distribution (lateral and depth) of the **volatile component in lunar polar regions**.
- Determine the extent and composition of the ... feldspathic crust, KREEP layer and other **products of planetary differentiation**.
- Determine the **thickness of the lunar crust** (upper and lower) and characterize its lateral variability on regional and global scales.
- Characterize the **chemical/physical stratification in the mantle**, particularly the nature of the putative 500-km discontinuity and the composition of the lower mantle.
- Determine the global density, composition, and time variability of the fragile **lunar atmosphere** before it is perturbed by ... human activity.
- Determine the size, composition, and state (solid/liquid) of the **core of the Moon**.
- Inventory the variety, age, distribution, and origin of **lunar rock types**.
- Determine the size, charge, and spatial distribution of **electrostatically transported dust grains** and assess their likely effects on lunar exploration and lunar-based astronomy.
Summary

• Builds on architecture decisions presented at December 2006 Exploration Conference

• Utilizes the robust transportation system provided by Ares 1 and Ares 5

• Open architecture facilitates different modular functions and operations

• Early exploration
  – Reduced assembly through pre-integrated habitats

• Modular mobile habitation
  – Facilitates “super sortie” mobility for 100’s km distances from the outpost
  – Facilitates greater lunar access to capture exploration and science objectives beyond LAT1 results

• Early small pressurized rover
  – Augments EVA operations by allowing astronauts to explore in shirt sleeve environment using EVA judiciously
The Goldstone Solar System Radar (GSSR)

- A unique NASA facility for high-resolution ranging and imaging of planetary and small-body targets
  - One transmitting, multiple receiving antennas for interferometry
  - 500 kW X-band transmitter
  - Very sensitive maser receiver
- Provides a wide variety of information
  - Simultaneous, co-registered radar image and topography - even in Lunar unlit areas
  - Surface characteristics, structure and composition
  - Orbits, rotations, spin axis
- Leverages DSN assets for radar Mission support and radar science
  - Deep Space Network (DSN) primary function is communication and nav for space missions beyond low Earth orbit
Incidence angle, $\iota$, to the south polar region of the moon is at near grazing incidence angles of $80^\circ$-$90^\circ$. Thus the ground projected range resolution is nearly equal to the range resolution of 18 m.
## Previous Lunar Polar Measurements

<table>
<thead>
<tr>
<th>Measurement Source</th>
<th>Date</th>
<th>Polar Coverage</th>
<th>Topography</th>
<th>Spatial Resolution</th>
<th>Height Resolution</th>
<th>Polar Topography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Orbiter 4</td>
<td>1967</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td>No topography</td>
</tr>
<tr>
<td>Apollo 15-17 Lidar &amp; Radar</td>
<td>1971-1972</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
<td>No polar data</td>
</tr>
<tr>
<td>Clementine / Lidar</td>
<td>1994</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
<td>No polar data</td>
</tr>
<tr>
<td>Clementine / Stereo Imager</td>
<td>1994</td>
<td>Yes</td>
<td>Yes</td>
<td>1 km</td>
<td>1 km</td>
<td></td>
</tr>
<tr>
<td>Lunar Prospector</td>
<td>1998</td>
<td>No imaging</td>
<td>No</td>
<td></td>
<td></td>
<td>No topography</td>
</tr>
<tr>
<td>GSSR</td>
<td>1997</td>
<td>Yes</td>
<td>Yes</td>
<td>150 m</td>
<td>50 m</td>
<td></td>
</tr>
<tr>
<td>Arecibo</td>
<td>2006</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td>No topography</td>
</tr>
</tbody>
</table>

Only Clementine & GSSR measured polar topography
• Three ~90 min. acquisitions of Lunar South Pole data at optimum librations
• DEM processing to 40-m pixels, 5-m height accuracy complete
• Image processing to 20-m pixels nearly complete
• Being tested for planimetric, topographic accuracy against Unified Lunar Control Net, orbital photography
Fills in Gaps in Solar Illumination Imagery

Clementine stereo topography

GSSR data overlay
GSSR Image of South Pole Region
Enlargement of Shackleton Rim Area
Digital Elevation Map of Lunar South Pole Region

Elevation (m)

Kilometers
Contour Map

Contour lines: Each color cycle represents 2 km in elevation change.
Slope Map

Slope Magnitude (deg)

Kilometers
Shackleton Rim Area Detail

Elevation Contours

Slopes

Elevation Change (km)

Slope Magnitude (deg)
Backup
Lunar Capabilities Concept Review  
(Transporation System)

• The LCCR is the CxP’s equivalent of the NPR 7123.1A Mission Content Review (MCR) – Scheduled for June 2008
  • The LCCR will evaluate the feasibility and merit of the proposed Lunar Architecture concept for mutually compatible:
    – Technical performance
    – Cost
    – Schedule that can accomplish mission objectives within an acceptable level of risk.
  • The LCCR will examine the maturity of the architecture concepts and planning for adequacy to proceed to System Requirements Review (technical, cost, schedule and risk baseline).

• Success Criteria
  – Architecture trades are clearly communicated and presented, along with a comparison of results
  – Key Drivers for the architecture are clearly shown
  – An Operational Concept is presented that clearly articulates the reference transportation architecture and surface mission sets
  – Alternate mission options are presented
  – Preliminary risk assessment and mitigation strategy are clear and shown to be factored into the program life cycle cost
  – Cost projections demonstrate the ability to meet the Agency budget allocation
Altair Products Delivered to CxAT Lunar Team

Products Delivered to the CxAT_Lunar and Mass Team over the past months include:

✓ **p0710-A concept**
  - Based on LDAC-1 Concept – mid-bay cargo concept with separate ascent and habitat modules
  - “Basis Mission: Crew optimized Outpost Sortie Mission: 4 crew, 7 days, 500 kg down, 100 kg up, polar mission, CEV = 20.2 t
  - Corresponding cargo capability.

✓ **p0710-B concept**
  - Variant of the p0710-A concept removing the Lunar Orbit Insertion (LOI) requirement.

✓ **p0711-B**
  - Lander update based on LDAC-1-Delta Concept – flat-top Descent Module concept with integrated ascent and habitat module, with separate airlock
  - Corresponding cargo capability.

✓ **Sensitivity Study Based on p0711-B**
  - Case 3a: Sensitivity to LOI delta-V
  - Case 3b: Sensitivity to Active Vehicle Days
  - Case 3c: Sensitivity of Payload Down
  - Case 3d: Sensitivity to Payload Up
  - Case 3e: Sensitivity to CEV mass
  - Case 3f: Sensitivity to number of crew
Initial Structures Concepts

**Side/Vertical/Mid Loading**
Vertical Storage good for large cargo or habitats. Less convenient for other cargo. Tall with high CG. May not provide space for AM engine. Poor packaging efficiency. Difficult to accommodate integrated AM/HM.

**Bottom Loading**
Good for large cargo with easy offloading (maybe). Less convenient for other cargo. High CG at launch. Difficult to accommodate integrated AM/HM/Airlock.

**Top Loading**
Efficient packaging. Modular system accommodates wide variety of cargo shapes/sizes including integrated AM/HM as a special "cargo package". High CG at landing. Cargo must be lowered to surface.

Selected by Altair/Surface System TIM for 1st round CxAT_Lunar
Surface Systems Trade Space 1 Overview

- Develop a fully functional outpost capability as early as possible based on the recommendations from LAT-2
  - Series of cargo landers mixed with human missions
- Ability to pause outpost buildup to accommodate sortie missions to other locations
- Outpost buildup can recover rapidly from loss of elements (modular and reconfigurable)
- Ability to adapt outpost elements to any location on the lunar surface
- Ability for partners to contribute elements and systems beyond basic sortie capability
- Outpost configuration and capabilities (layout, mission duration, power) can be implemented to emulate and evaluate Mars surface scenarios
- Pervasive mobility for mission flexibility
  - All architecture elements have the capability to be relocated
  - Mobility capabilities can be tailored to *Science objectives* as needed
Also considering inflatable structures, but outpost functionality remains unchanged.
Ares V / Altair / Hab Integration

Hard Shell

Launch Vehicle

Inflatable

Lander

Surface

Dimensions

8.17 m (int)

9.8 m (int)

3.5 m (int)

3.9 m

3.6 m ht.

9.8 m (int)