LEAG LROC Special Action Team

Final Report

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Paul Lucey
lucey@higp.hawaii.edu
LEAG LROC SAT TEAM

- Chair, Paul G. Lucey, U. Hawaii
- Science Subgroup
  - Jeffrey Gillis-Davis, U. Hawaii
  - B. Ray Hawke, U. Hawaii
- ISRU subgroup
  - Larry Taylor, U. Tenn, Knoxville
  - Mike Duke, At-large lunar scientist
- Operations subgroup
  - Tye Brady, Draper Lab
  - Todd Mosher, Sierra Nevada Corporation
- Observers
  - Mike Wargo, NASA
  - Steve Mackwell, LPI
  - Clive Neal, LEAG
LEAG LROC SAT Tasking

From LEAG LROC Charter:

- Reprioritization between Tiers 1 and 2, if deemed appropriate
- Additional suggested targets and regions of interest that could replace those identified by CxPO
- Adjustment of the target coordinates if deemed appropriate
- Suggested additional regions of interest for a lower priority ranking (i.e., “Tier 3”)
LEAG LROC SAT Report Summary

- CxPO sites individually evaluated using a uniform system of metrics covering science, ISRU and operations characteristics, and compared
- Distribution of sites with respect to geographic and geochemical distribution inspected
- Results
  - SAT concurs that the CxPO sites as a whole provide a qualitatively good sample with respect to science, ISRU and operations
  - Performance metric comparison among sites suggests reordering of Tiers 1 and 2
  - Three specific site locations were moved to improve science merit
  - One site was added in South Pole-Aitken Basin to improve science balance
  - One site was added (Peary crater) that offers “drive-in” access to permanent shadow and is representative of other large flat-floored craters with this characteristic
  - Two sites with low metric scores were deleted to maintain 50 total sites
Task 1: Reprioritization between Tiers 1 and 2, if deemed appropriate

Background:

- CxPO targets have significant community heritage
  - Exploration Systems Architecture Study (ESAS), 2005.

- Lunar science, ISRU and operational constraints have evolved since these documents were produced

Proposed methodology to determine if reprioritization is appropriate:

- Quantitatively evaluate in terms of science, ISRU and operations against metrics
- Rank and compare Tier 1 and Tier 2 performance against quantitative metrics

Results

- As a group Tier 1 does not significantly outperform Tier 2
- Substantial overlap in performance suggests reassignment
Task 2: Additional suggested targets and regions of interest that could replace those identified by CxPO

Quantitative comparisons reveal gaps in Cx-provided list

- Paucity of mid-latitude, polar sites
- Distribution of targets in geochemical terranes heavily weighted toward region sampled by Apollo

**Recommendation**

- **Add SPA and Polar sites**
  - Peary Crater
    - Straightforward “drive-in” access to permanent shadow
  - SPA Aitken Rim
    - Mid-latitude SPA site
    - Samples rim of transient cavity
    - Th anomaly
Task 3: Adjustment of the target coordinates if deemed appropriate

Detailed analysis of each site revealed modifications in targeting that improve scientific value of some sites

- Aristarchus region is complex and features best exposure of pure pyroclastics
  - Two CxPO sites at Aristarchus do not occur in purest pyroclastic region. This material may have unique topography that could affect operations. Recommend adjusting “Aristarchus 2” site to better sample pyroclastic deposit

- CxPO sites undersample light plains deposits
  - Mare Frigoris is unusual low iron maria with nearby very young light plains
  - Recommend moving this site to sample light plains deposit

- South-Pole Aitken center CxPO site contaminated by cryptomare
  - Recommend move to purest SPA mafic anomaly and least young basin contamination (Petro and Pieters, 2004)
Task 4: Suggested additional regions of interest for a lower priority ranking (i.e., “Tier 3”)

- CxPO targets have significant community heritage
- LEAG recommendations replace only two sites
- Recommend no addition of “Tier 3”
Detailed Results
Comparison Methodology Overview

How to go from a list to a list with value

- Simple mechanical method to derive relative value via combination of low level, multiple, distinct, fundamental expert-assessed characteristics associated with each 50 sites
- Weighted, nested, spreadsheet approach uniformly compares sites to each other (each site has same weightings applied)
  - Derived composite score is a user configurable weighted function of:
    - Science Score
    - ISRU Score
    - Operations Score
  - Appropriate weighting has been derived by the team, but can be manipulated by stakeholder based on their values
  - Any outliers noted, inspected, and talked about
  - New sites are introduced into the system via the same metrics to see their relative score and compare their relative value
- Science, ISRU, and Ops are further broken down into individual weighted lists based on fundamental characteristics of the scored sites
  - Science: geological characteristics
  - ISRU: potential resources available
  - OPS: evaluation of site as if landing site
- Value is added by having each site characterized by experts at lowest level, with expert-defined weighting yielding a uniform high level product

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slide 10
Comparison Methodology Overview (Illustrated)

Illustrated graphically (right to left is the process)

Expert Assessment

- Apply Category Weightings
- Apply Feature Weightings

Category Ranking
- Science Ranking
- ISRU Ranking
- OPS Ranking
- Overall Ranking

Overall Ranking

Category Ranking

List of 25 Tier_1 sites and 25 Tier_2 Sites, each with specified coordinates (and list of any newly considered candidates)

Expert opinion on scientific features designated for each site

- More Volcanism
- Highland Components (Grias)
- Cratering
- Tectonics
- Other Geology
- Terrace

- Resources Available
- Terrain Usage
- Terrain at Landing
- Approach for Landing
- Lighting Conditions
- Digital Elevation Map Availability
- Infrastructure Required

Expert opinion on ISRU features designated for each site

Expert opinion on operational features designated for each site

GROUP RECOMMENDATIONS

Expert Assessment
### Preliminary Results: Ranking by Individual Scores

#### Tier 1

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#### Weighted Summary

**Tier 1** insignificantly outperforms **Tier 2**: Does not support current Tier assignments.

- **Avg Grade**: 77.7
- **Avg Grade**: 77.3

*Highlights are LEAG SAT modified sites*
Individual scoring methodology does not take diversity of sites into account. Gaps in important parameters are detected.

- Science
- ISRU
- Operational
Moon exhibits three major terranes based on geochemical characteristics:
- Procellarum KREEP Terrane (PKT)
- Feldspathic Highlands Terrane (FHT)
- South Pole-Aitken Terrane (SPA)

Each is believed to have distinct origins and histories.

Apollo, Luna
- Sampled PKT extensively
- Sampled outer FHT

Lunar meteorites
- May sample inner FHT

Tier 1, big dot; Tier 2, small dot
Geochemical Terrane

- Taken together, CxPO sites oversample PKT and outer FHT
  - These terranes extensively sampled by Apollo
  - Some of this due to majority of maria in PKT
- Unsampled SPA and inner FHT constitute only 28% (14 of 50) sites
- Partial solution offered:
  - Add polar, SPA sites

**Distribution T1 Terranes**

- PKT: 48%
- FHT (outer): 24%
- FHT (inner): 8%
- SPA: 20%

**Distribution T2 Terranes**

- PKT: 25%
- FHT (inner): 17%
- FHT (outer): 45%
- SPA: 13%
- Overall CxPO sites provide good balance
- Tier 1 somewhat undersamples cumulate minerals and pyroclastics
Operational Parameter Distribution: Mare v Highland

- Majority of sites are highland or mixed mare/highland
Operational Parameter Distribution: Nearside v Farside v Polar

- Polar sites greatly underrepresented in CxPO list
- Farside sites underrepresented
Operational Parameter Distribution: Latitude

* T1 sites are not evenly distributed
* Majority of T1 sites are equatorial
* Mid latitudes are not represented

Northern middle and high latitudes absent (88° to 37°)

72% (18/25) of the T1 sites are located around the equator between (N30° to S30°)

Southern middle and high latitudes absent (-51° to -85°)
Operational Parameter Distribution: Latitude

* T2 sites are somewhat evenly distributed in latitude
**Alternate Site List**

- **Criteria are:**
  - Farside Polar or Midlatitude location
  - SPA inner or FHT terrane
- **Mutus Crater and Schickard cryptomare are deleted based on low scores and redundancy**
  - Mutus: 75
  - Schickard: 71

- **NORTH POLE: South Floor of Peary Crater**
  - Long 30, Lat 88.5; polar farside site
  - Floor at the south rim of Peary crater is in permanent shadow with low permanent model temperatures. Rest of floor is not in permanent shadow, exhibits low relief, has good southern landing approaches and allows zero slope access to permanent shadow.
  - Within Feldspathic Highland Terrane

- **SOUTH POLE-AITKEN RIM**
  - Long 170.92, Lat -51.00; farside mid latitude site
  - SPA Terrane
  - Near the rim of the transient crater, deepest portions of the transient cavity formed by the SPA impact expected
  - Highest SPA thorium abundances. There are SPA mare basalts in the vicinity, which should be represented in the regolith.
Re-Order of Tier 1 and Tier 2

- Quantitative rankings of CxPO Tiers show no significant difference
- Both Tiers show wide distribution of weighted scores
- Recommend reassign Tiers by score
## Recommended New Tier 1 Assignments

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*Highlights are LEAG SAT modified sites*
## Recommended New Tier 2 Assignments

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<td>x</td>
<td>74 80 65</td>
<td>72.7 C</td>
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<td>Hortensius Domes</td>
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<td>6.93</td>
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<td>x</td>
<td>63 83 65</td>
<td>70.0 C</td>
</tr>
</tbody>
</table>

*Highlights are LEAG SAT modified sites*
Summary

- Uniform debiased methodologies applied to tasking
- CxPO site selection endorsed by LEAG SAT
- Detailed assignment to Tiers not supported by analysis
- Gaps in Science and Operational parameters overall
  - Unsampled geochemical terranes underrepresented
  - Polar sites underrepresented
  - Midlatitude sites underrepresented
  - Light plains underrepresented
- Two sites replaced with SPA/polar sites
- Three sites moved to improve science value