Briefing Topic:

Shackleton and Malapert Traverse Science Objectives

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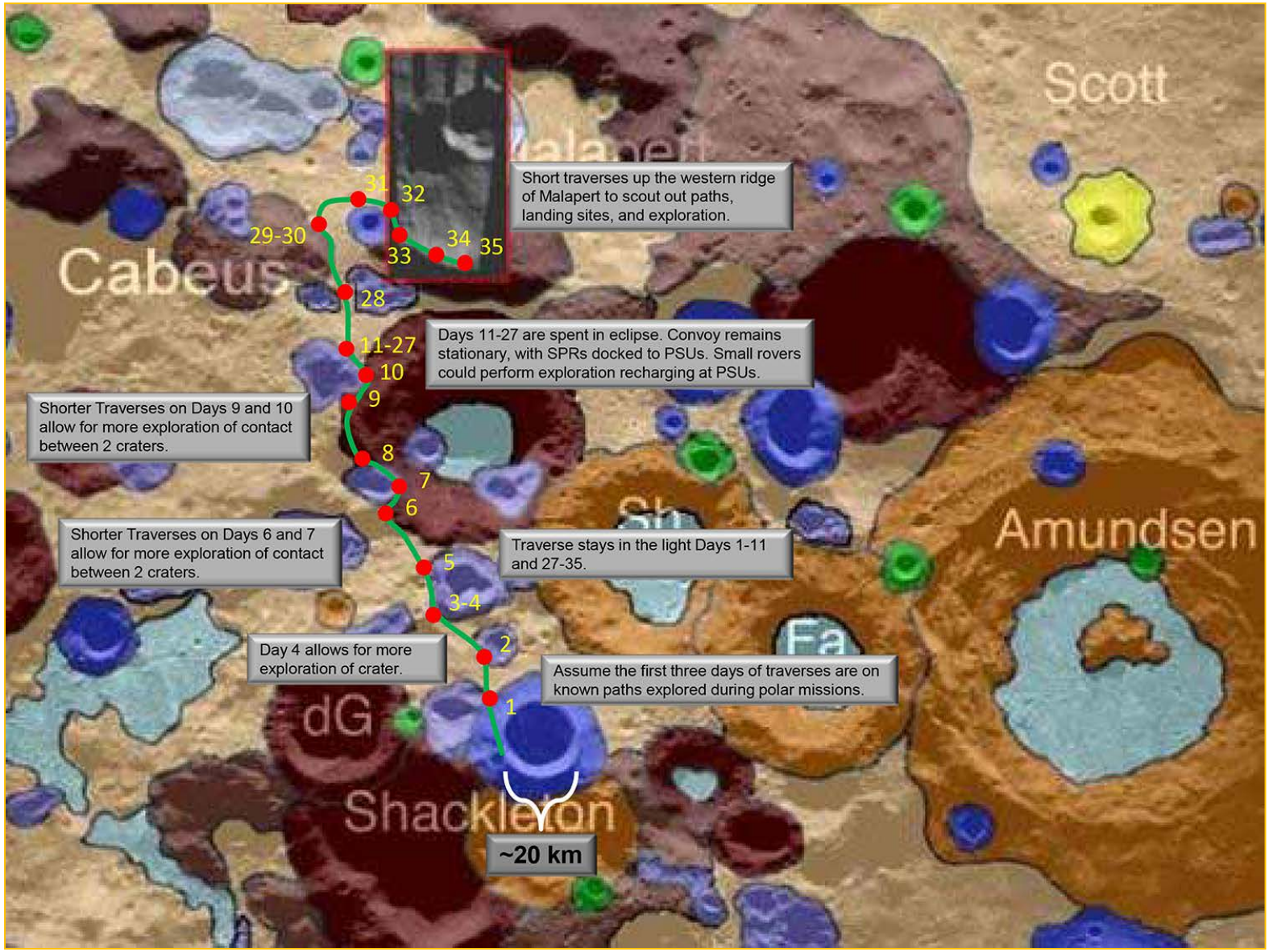
Introduction

As part of a Lunar Surface Systems study for the Constellation Program, it is assumed the first landing of crew will occur near the South Pole on the rim of Shackleton Crater. After a base is established, robotic assets are tele-robotically driven to the Malapert massif where crew will land to utilize those assets.

These assets include small pressurized rovers (SPRs) and a cargo-carrying vehicle called ATHLETE.

A notional traverse from Shackleton to Malapert was devised by David Kring, Fred Hörz, Gary Lofgren, Dean Eppler, and John Gruener.



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Engineering / Architectural Rationale

Malapert Massif was chosen as the first relocation destination due to its relative proximity to Shackleton and the chosen South Pole landing site. This is an area of scientific interest that is which will be a provide a first test of the robotic caravan driving and exploring capability which will be used extensively through the architecture. Other considerations such as light and communications availability also make the Malapert region a favorable first relocation site.

Science Rationale

The engineering/architectural rationale can be accommodated by a reasonable set of science objectives. The Malapert Massif and nearby areas provide an opportunity to (i) study cross-sections of the lunar crust that are exposed in the massifs, (ii) potentially expanding the diversity of crustal lithologies in our collections, while (iii) simultaneously allowing us to test models of massif formation. These massifs are affiliated with the South Pole-Aitken Basin, which is the largest and oldest impact basin on the Moon. Impact melt generated by that impact may be available in the region, which would allow us to (iv) anchor the age of the basin-forming epoch on the Moon. Nearby impact craters (v) excavated and exposed additional components of the lunar crust for sampling. Impact melts and breccias associated with those craters can also be used to (vi) better calibrate the impact flux to the Moon after the formation of the South Pole-Aitken Basin.

Science Rationale (continued)

An ambitious traverse was defined in January 2010 that thoroughly explored two massifs (Malapert and Leibnitz Beta) and a set of craters that excavated material from different depths and had a diverse range of ages. An evaluation of mission resources, however, required a revision of that traverse.

The modified traverse (presented here) requires the following science trades:

- Exploration of a pre-Nectarian crater that excavated material from Leibnitz Beta (a massif) is replaced by exploration of a pre-Nectarian crater that excavates material south of Malapert Massif.
- Material associated with a Eratosthenian crater is deleted from the traverse

The modified traverse maintains the following science capabilities:

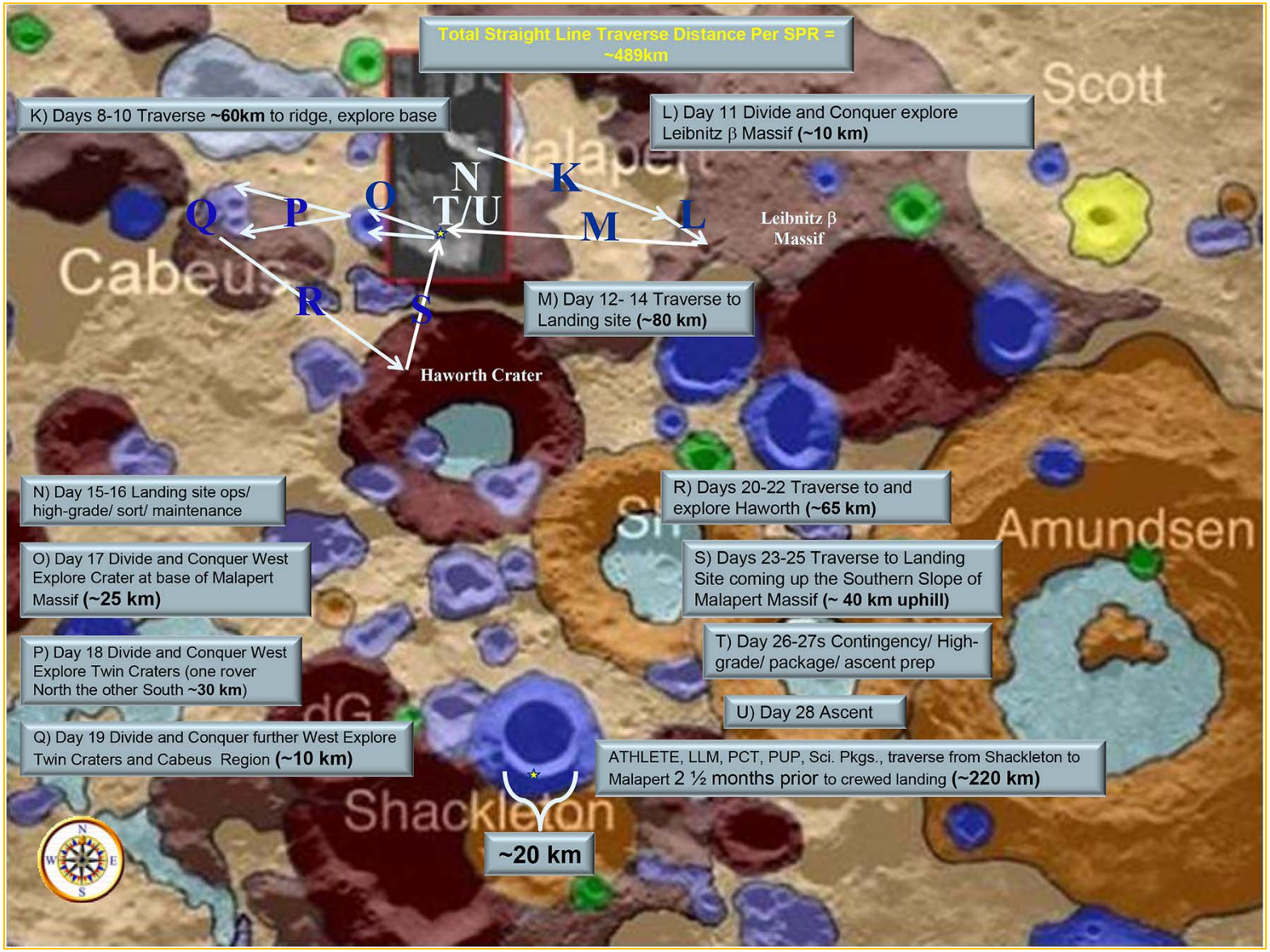
- Provides access to three massifs in the region.
- Provides access to impact melt produced by a pre-Nectarian crater, several Imbrian craters, and several small Copernican craters.

Science Rationale (continued)

Even though some science objectives are lost, the science trades are reasonable because

- The massifs are important structural elements of the South Pole-Aitken Basin, are interesting features that uniquely characterize the region, and may provide unique exposures of the lunar crust.
- Eratosthenian craters occur near Shackleton Crater and will likely be sampled during earlier stages of the exploration program.

Furthermore, the highest science priorities for lunar exploration (to test the lunar cataclysm, determine the age of the South Pole-Aitken Basin, and determine the impact flux to the Moon) are ideally addressed in the Schrödinger Basin, which is the exploration objective in the next element of the planning process. Thus, in a multi-mission exploration program that includes the Schrödinger Basin, the diverse science priorities can be accommodated by different missions at different sites.



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The traverse and individual stations address several objectives defined by the NRC (2007) report *The Scientific Context for Exploration of the Moon*. That report identified eight concepts and thirty-five objectives within those concepts.

Links with the traverse are:

Day 1 – Landing at Malapert Massif

Day 2 – Explore fresh crater (# km diameter) near landing site

- Sample collection of impact-melts from the crater address Objectives 1c and 1d
- Observations and potential sampling of lithologies in the crater walls and crater rim address Objective 6c; if that is combined with sampling of the crater ejecta blanket, it also addresses Objective 6d.
- Sample collection of massif material (excavated by the crater or in regolith breccias around the crater) address Objective 3b. Because the massif is also part of an impact basin, this site provides an initial assessment of Objective 6b.

Day 3 – Malapert Massif ridge

- Sample collection of massif material and observations of structure within the massif along the traverse path address Objectives 3b and 6b.
- Because this site is used to deploy a science package and may be a site for additional infrastructure in the future, it addresses Objective 7b.

Day 3 – Malapert Massif ridge (continued)

- That science package may also contain a seismometer, in which case it will provide data that addresses Objective 2a and 2c. If that package contains a heat probe, it will also address Objective 2d.

Day 4 – Explore small crater (# km diameter) near summit of Malapert Massif and drive towards crater chains on flank of massif

- Sample collection of impact-melts (or ejected blocks suitable for cosmogenic nuclide studies) from the crater address Objectives 1c and 1d.
- Observations and potential sampling of lithologies in the crater walls and crater rim address Objective 6c; if that is combined with sampling of the crater ejecta blanket, it also addresses Objective 6d.

Day 5 – Explore crater chains that may contain blocks excavated from basins elsewhere on the Moon and that may provide an indirect age for those basin-forming impacts

- Sample collection of any fragments from the blocks that produced the crater chains addresses Objectives 3b, 3d, and 6d.
- Sample collection of material that may provide an age for those crater chains addresses Objectives 1a.
- Sample collection of massif material and observations of structure within the massif along the traverse path address Objectives 3b and 6b.

Day 6 – Traverse to, and exploration of, southern rim of fresh impact crater (# km diameter) north of Malapert Massif

- Sample collection of impact melts from the crater address Objectives 1c and 1d.
- Because these samples will likely be different than those from the Malapert Massif, they will provide a broader assessment of the diversity of crustal lithologies, particularly as they are related to Objective 3d.
- Observations and potential sampling of lithologies in the crater walls and crater rim address Objective 6c; if that is combined with sampling of the crater ejecta blanket, it also addresses Objective 6d.
- Sample collection of the regolith, when compared to similar samples at the Day 3-5 sites, addresses Objective 7b and potentially 7a.

Day 7 – Explore fresh crater and traverse to rim of larger crater north of Malapert Massif

- Sample collection of any impact-reset lithologies associated with the large crater can test the hypothesis that it is a secondary crater of the Imbrium basin-forming impact event, addressing Objective 1e.
- Observations and potential sampling of the walls and ejecta associated with the large crater will constrain models of secondary crater production and its affect on regolith mixing, which address Objectives 6c, and 6d.

Days 8, 9, & 10 – Traversing to base of Leibnitz Beta

- Sample collection of regolith and impact ejecta along the traverse address Objectives 3d, 6d, 7a, and 7b.

Day 11 – Explore base of Leibnitz Beta

- Sample collection of massif material and observations of structure within the massif along the traverse path address Objectives 3b and 6b.

Days 12, 13, & 14 – Traversing back to landing site

- Sample collection of regolith and impact ejecta along the traverse address Objectives 3d, 6d, 7a, and 7b

Days 15 & 16 – Landing site operations

- minimal science

Day 17 – Explore western base of Malapert Massif

- Sample collection of massif material and observations of structure within the massif along the traverse path address Objectives 3b and 6b.
- Sample collection of impact-melts from the Imbrian-age crater address Objectives 1c and 1d.

Day 18 – Traverse to “twin craters”on third massif

- Sample collection of regolith and impact ejecta along the traverse address Objectives 6d, 7a, and 7b.
- Sample collection of massif material and observations of structure within the massif along the traverse path address Objectives 3b and 6b.
- The “twin craters” are mapped as secondary craters fro Orientale. Sample collection of any impact-reset lithologies associated with those craters may provide an age for Orientale, addressing Objective 1a and 1c.
- Sample collection of surviving debris from Orientale addresses Objectives 3a and 3b.
- Observations and potential sampling of the walls and ejecta associated with the secondary craters will constrain models of secondary crater production and its affect on regolith mixing, which address Objectives 6c and 6d.

Day 19 – Continue exploration of “twin craters” and Cabeus Crater region

- The “twin craters” are mapped as secondary craters fro Orientale. Sample collection of any impact-reset lithologies associated with those craters may provide an age for Orientale, addressing Objective 1a and 1c.
- Sample collection of surviving debris from Orientale addresses Objectives 3a and 3b.
- Observations and potential sampling of the walls and ejecta associated with the secondary craters will constrain models of secondary crater production and its affect on regolith mixing, which address Objectives 6c and 6d.
- Sample collection of impact lithologies from an unnamed Imbrium-age crater adjacent to “twin craters” may address Objective 1c.

Day 19 – Continue exploration of “twin craters” and Cabeus Crater region (continued)

- Sample collection of massif material (excavated by the crater or in regolith breccias around the crater) address Objective 3b.
- Because the massif is also part of an impact basin, this site provides an initial assessment of Objective 6b.

Days 20, 21, & 22 – Traverse to and exploration of Haworth Crater

- Sample collection of impact-reset lithologies from this crater will provide one of the first ages of a pre-Nectarian impact crater, which addresses Objectives 1a and 1c.
- Sample collection of excavated components, when compared to components in the Malapert massif, will provide a measure of the lithological variation in the lunar crust, which address Objectives 3a, 3b, and 3d.
- Because of the crater’s significant excavation depth, it has the (albeit uncertain) potential of providing a glimpse of the vertical extent and structure of the megaregolith, which addresses Objective 3e.

Days 23, 24, & 25 – Traverse to landing site via southern ridge of the Malapert Massif

- Sample collection of massif material and observations of structure within the massif along the traverse path addresses Objectives 3b and 6b.

Days 26 & 27 – Landing site operations

- Minimal science

Day 28 – Return ascent

Additional components of study

The notional traverses designed here are part of a larger Lunar Surface Systems study that includes assessments of communication, illumination, slope, and power available for vehicles.

Importantly, the study also revealed two traverse mode options:

- Lead & Trail: Wherein SPRs stay within line of sight of each other, exploring the same region, with ALTHLETE following on the same path.
- Divide & Conquer: Wherein SPRs are not constrained by line of sight and are able to explore adjacent geological regions rather than the same region.

A goal is to test this and other trades in a mission simulation in an analogue terrain near Flagstaff, Arizona.