3.5 John Gruener

Mr. John Gruener is a systems engineer working in the Lunar Surface Systems Project Office, part of the Constellation Program Office. His primary responsibility is science integration in NASA's exploration mission planning and architecture development activities.

Mr. Gruener began working in the space program in May, 1986, after receiving a B.S. in aerospace engineering from the University of Texas at Austin. He first worked supporting Space Shuttle missions and the design of the ISS, but quickly moved to advanced mission planning activities for human and robotic exploration beyond low Earth orbit. Mr. Gruener participated in NASA's 90-Day Study on Human Exploration of the Moon and Mars in 1989, and the subsequent government-wide study known as the Synthesis Group on America's Space Exploration Initiative.

Mr. Gruener received an M.S. in physical science, with an emphasis in planetary geology, from the University of Houston-Clear Lake in 1994. He then began working with NASA JSC's Solar System Exploration Division on the development of prototype planetary science instruments, the development of a mineral-based substrate for nutrient delivery to plant growth systems in bio-regenerative life support systems, and in support of the Mars Exploration Rover missions in rock and mineral identification.

In 2004, Mr. Gruener again participated in a renewed effort to plan and design missions to the Moon, Mars, and beyond. He participated in many exploration planning activities, including NASA's Exploration Systems Architecture Study (ESAS), Global Exploration Strategy Workshop, Lunar Architecture Team 1 and 2, Constellation Lunar Architecture Team, the Global Point of Departure Lunar Exploration Team, and the NASA Advisory Council (NAC) Workshop on Science Associated with the Lunar Exploration Architecture. Mr. Gruener has also been an active member of the science team supporting NASA's Desert Research and Technology Studies (RATS).

A9 – Presentation of John E. Gruener

A notional example of understanding human exploration traverses on the lunar surface

[Slide 1] A notional example of understanding human exploration traverses on the lunar surface, John E. Gruener, NASA-JSC.

[Slide 2] Back in 2004 when the Vision for Space Exploration (VSE) was released and we started thinking about going back to the moon, we wanted to start thinking about not being limited to the local landing site like we were in Apollo. To do this we are going to need a traverse capability like you have been talking about today for Antarctica. So we need to expand from just an unpressurized capability to a pressurized traverse capability. Not just to support further distances from the land site, but also greater time away.

[Slide 3] Listed here are a number of different {science} groups, each with a different set of often conflicting requirements for their science on the moon. For example, the astrophysicists would like to be on the far side of the moon with a low-noise view of space, while the Earth scientists want the near side with a clear view of the Earth. So, we need to try and come up with an architecture or plan that makes everyone happy.

[Slide 4] We have been looking at the lunar South Pole for our reference missions. So we needed to see what science requirements we could meet using that location for an outpost. One way to increase the diversity of site to which we have access is long traverses. With traverses of 100 to few 100 kms, we can characterize the basins around the South Pole; get to locations with permanent views of Earth or permanent view of space away from Earth radio noise. The site also is advantageous for power as we have more consistent solar viewing than the 14-day day/night cycle at lower latitudes and that makes solar based power more practical.

[Slide 5] This is from a poster I put together for a NASA Advisory Council meeting in Tempe, AZ. It shows some of the more local locations to which we would want to traverses from the reference output location. These sites are not too far, but we would want to go there for days to weeks and work the field site.

[Slide 6] On a much larger scale, these are other basins and areas we could visit on traverses that are both further and longer in duration.

[Slide 7] Here I have laid out three different traverses that would provide us with a wide range of geological data.

[Slide 8] The data here shows the parameter space of how fast and how far we can travel under various assumptions. This data plus our EVA time at the sites will help define the logistics needed to support traverse activities.

[Slide 9] Applying the above data to the traverses I showed before, these are the sort of traverses that result. These may be a little optimistic. As you will notice, most of these traverses reference 14-day sequences; that is because of the day/night cycle. In order to go beyond 14 days, you need better power logistics.

[Slide 10] These are examples of some work done by other people in looking at the science we could do around the South Pole. The gray lines with purple points represent their traverse ideas with stops.

[Slide 11] Way before our current VSE thinking, there were ideas for long traverses across the surface of the moon.

[Slide 12] More recently, some other ideas for traverses not based on a South Pole outpost, but rather on a landing site with sufficient supplies for 45 days and 100 km of traverse capability. It was interesting to see how the two teams prioritized their science objectives. Each team also described the assumptions, basically their requirements, of what they needed to carry out their traverse.

[Slide 13] Assumptions of Team 1. The LRV-type soil sample was something done on Apollo. Without getting off of the rover, the astronauts would scoop up a sample. Both teams thought a good way to do this would be an improvement.

[Slide 14] Assumptions of Team 2. The second team had similar assumptions, but also included a cargo capability to drop of remote stations and carry small robots that would be used while the main vehicle was parked. This small robot would also be controllable from Earth as the astronauts rested.

A notional example of understanding human exploration traverses on the lunar surface

John E. Gruener
NASA-Johnson Space Center

1

Unpressurized Traverses

Very Apollo-like (i.e., lunar roving vehicle)

Astronauts wear space suits

Limited to local traverses (10-20 km from outpost site) and short periods of time (<10 hours)

Pressurized Traverses

Similar to current undersea exploration (i.e., pressurized submersibles)

Astronauts inside in 'shirt-sleeve' environment

Designed for long-duration traverses (i.e., many tens of km to low hundreds of km), and many days away from an outpost site

2

Basic Needs of the Scientific Communities

Planetary Science
Global access (e.g., crustal diversity)
Remote stations (e.g., control from earth)
On site sample analysis
Crew operations (e.g., field work, emplacement and maintenance)
Robotic operations (e.g., teleoperation)

Astrophysics
Far side (e.g., radio telescope)
Remote observatories (e.g., control from earth)
Crew operations (e.g., emplacement and maintenance)

Earth Science
Earth view (e.g., ideally near side)
Remote observatories (e.g., control from earth)
Crew operations (e.g., emplacement and maintenance)

Heliophyiscs
Sun and Earth view
Instruments in lunar orbit and on lunar surface
Remote observatories (e.g., control from earth)
Crew operations (e.g., emplacement and maintenance)

Life Science
Anywhere
Pressurized laboratory
Crew operations (e.g., research)

Planetary Protection
Anywhere
Crew operations (e.g., research)

3

Basic Needs of the Scientific Communities
Lunar South Pole- an example

Planetary Science
Shackleton crater possibly on South Pole-Aitken (SPA) basin inner ring
Malapert and Leibniz β possibly SPA basin rim
SPA terrane distinct from Apollo samples (e.g., Procellarum KREEP terrane)

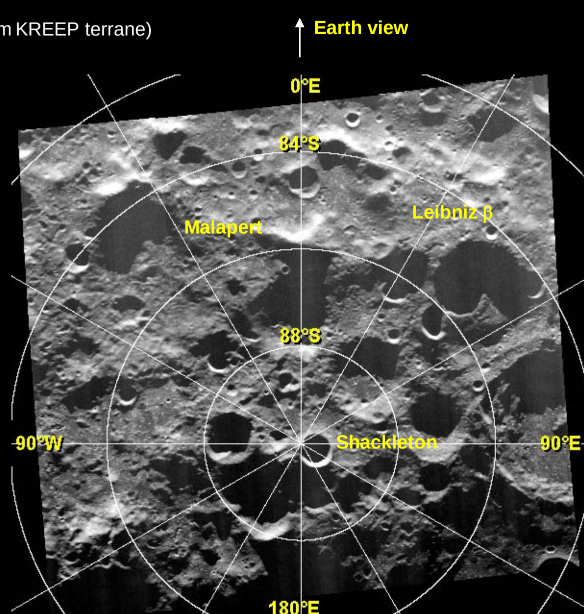
Astrophysics
Far side is accessible
Requires long range traverse, continuous power, and communications

Earth Science
Shackleton Outpost partial earth view
Malapert peak-continuous earth view
Requires long range traverse, continuous power, and communications

Heliophyiscs
Shackleton Outpost partial sun view
Malapert peak-continuous sun view likely
Requires long range traverse, continuous power, and communications

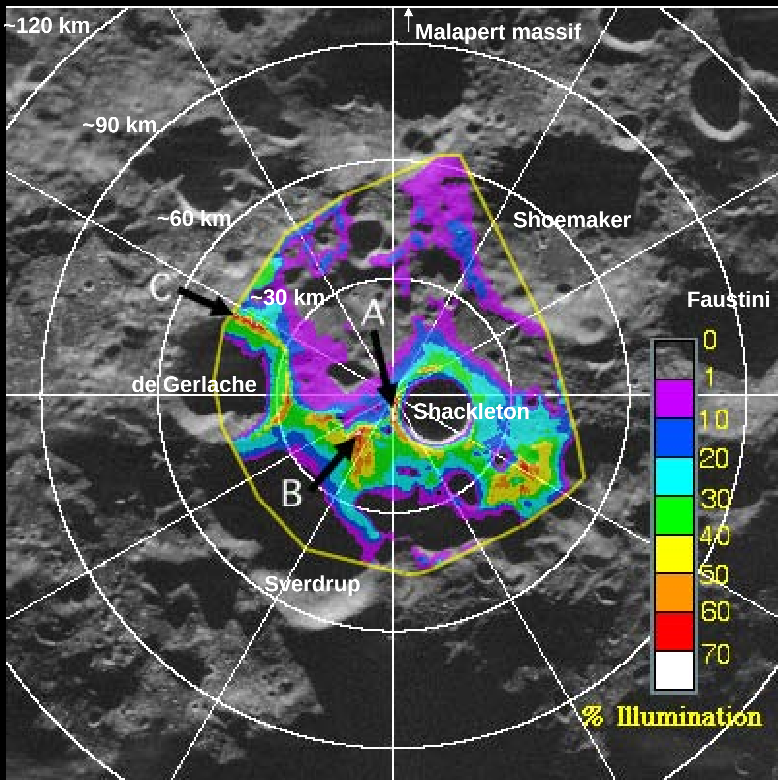
Life Science
At Outpost

Planetary Protection
At Outpost



(from Margot et al, 1999 and Bussey)

4



From Bussey, et al., 1999

Lunar Outpost at South Pole

Local traverses could be used for:

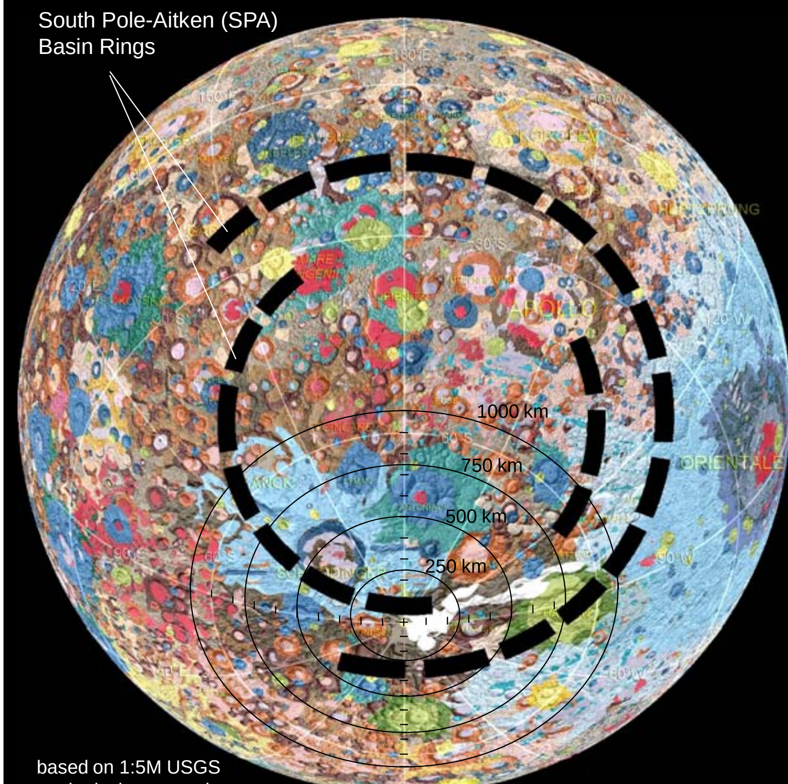
Infrastructure Emplacement
Point A to Point B ~10 km
Point A to Point C ~47 km
Point B to Point C ~43 km

Exploration Science
(distances from outpost to center of crater)
Shackleton crater ~10 km
de Gerlache crater ~50 km
Shoemaker crater ~60 km
Faustini crater ~90 km
Malapert massif ~120 km

Resource Development
Shackleton crater floor (19 km dia)
Shoemaker crater floor (50 km dia)
de Gerlache crater floor (30 km dia)
Points A, B, and C (illumination)

5

South Pole-Aitken (SPA) Basin Rings



based on 1:5M USGS geological maps and Wilhelms, 1987

Lunar Outpost at South Pole

Within 100 km
Interior SPA basin materials
SPA basin ring massifs
Malapert massif
Shackleton & Shoemaker craters

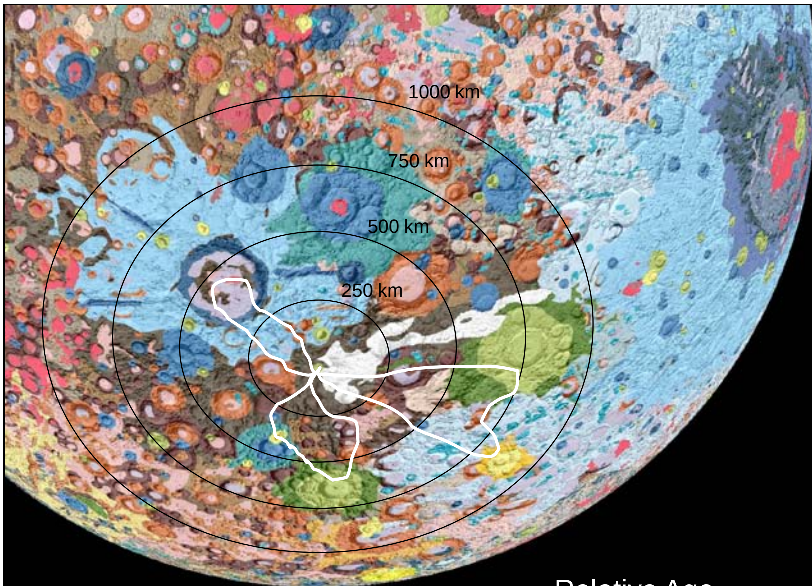
Within 250 km
Amundsen & Cabeus craters
Schrödinger basin ejecta
Drygalski crater ejecta

Within 500 km
Schrödinger basin; dark halo (pyroclastic) crater on floor
Orientale basin ejecta
Drygalski, Zeeman, Schomberger, Scott, Hale, and Demonax craters

Within 750 km
Orientale basin ejecta
Antoniadi, Lyman, Hausen, Moretus, Boussingault, and Neumayer craters
Mare fill in Antoniadi

Within 1000 km
Planck & Poincaré basins
Mare Australe & SPA maria
Cryptomaria near Schiller basin
Fizeau, Petzval, Zucchius, and Clavius craters

6



Lunar Outpost at South Pole

The basic idea for long range traverses is to:

Visit major features

large impact craters or basins
basin rim massifs
resource deposits

Or

Visit as many 'colors' as you can

Characterize the heterogeneity in age and composition within a local geologic unit.

Characterize and sample maximum diversity in age and composition across many geologic regions.

Relative Age

Youngest

Yellow = Copernican System
Green = Eratosthenian System
Blue/Red = Imbrian System/mare materials
Orange/Tan = Nectarian System
Brown = Pre-Nectarian System

Oldest

7

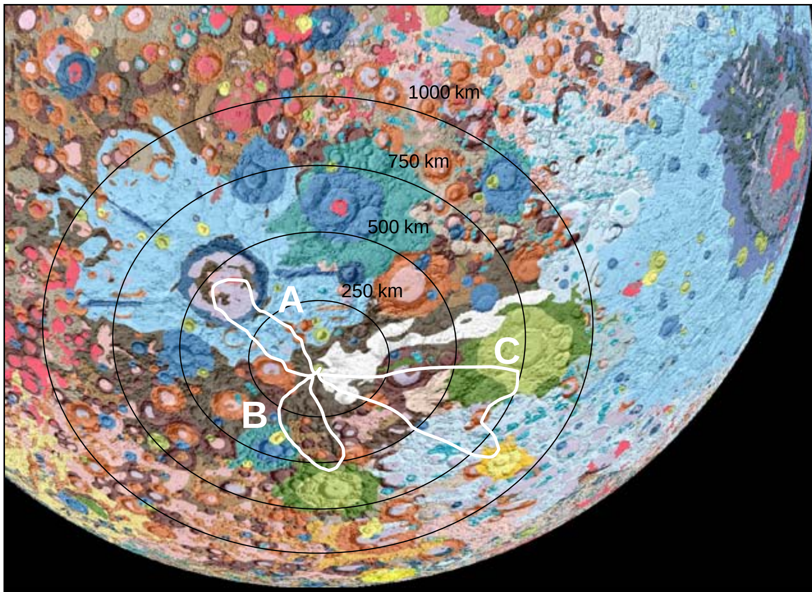
Human pressurized rover long-range roving traverse distances from a lunar outpost at the South Pole

	Average Driving Speed					
	10 km/hr		8 km/hr		5 km/hr	
	Total (km)	Radius (km)	Total (km)	Radius (km)	Total (km)	Radius (km)
14 days, 10 hrs roving /day	1400	700	1120	560	700	350
12 days, 10 hrs roving /day	1200	600	960	480	600	300
10 days, 10 hrs roving /day	1000	500	800	400	500	250
14 days, 5 hrs roving /day*	700	350	560	280	350	175
12 days, 5 hrs roving /day	600	300	480	240	300	150
10 days, 5 hrs roving /day	500	250	400	200	250	125

*This can be used as a proxy for using half of the days for driving, and half of the days for extravehicular activity (EVA)

Apollo Lunar Roving Vehicle (LRV) traverse data

	Average Driving Speed (km/hr)	Average % of EVA spent driving
Apollo 15	8.9	17
Apollo 16	8.2	16
Apollo 17	8.2	19



Lunar Outpost at South Pole

Human Pressurized Rovers

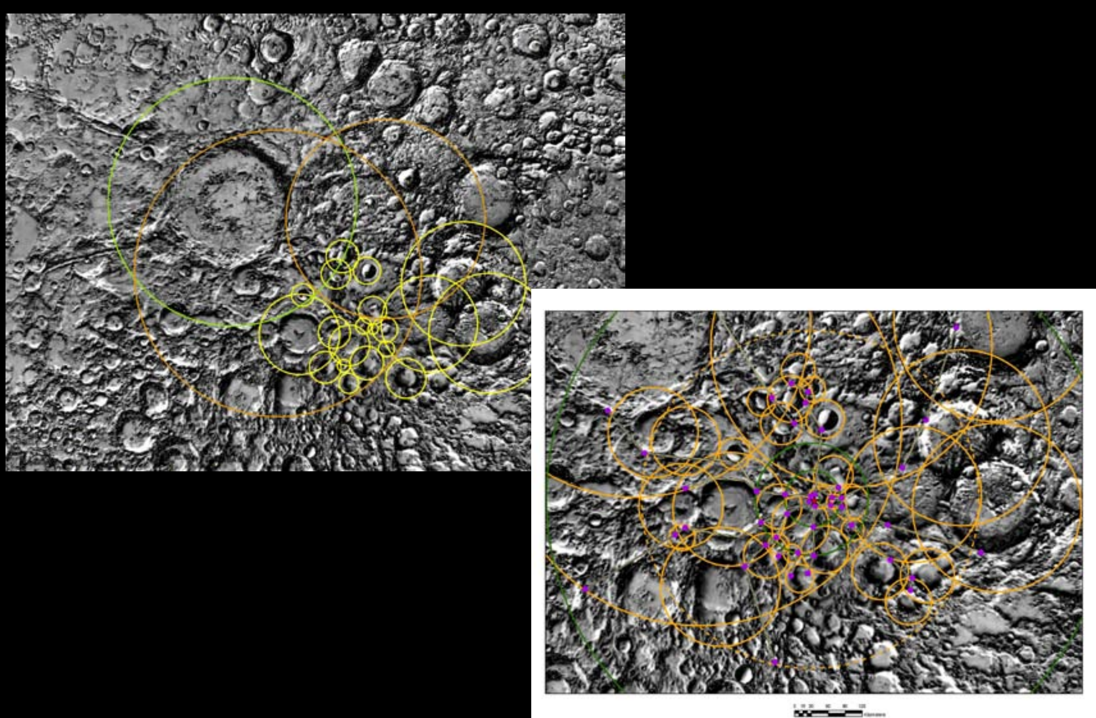
A. Long range traverse mission to Schrödinger basin:
< 500 km radius
12-14 day total mission
10 km/hr avg. driving speed
2-4 days in Schrödinger area

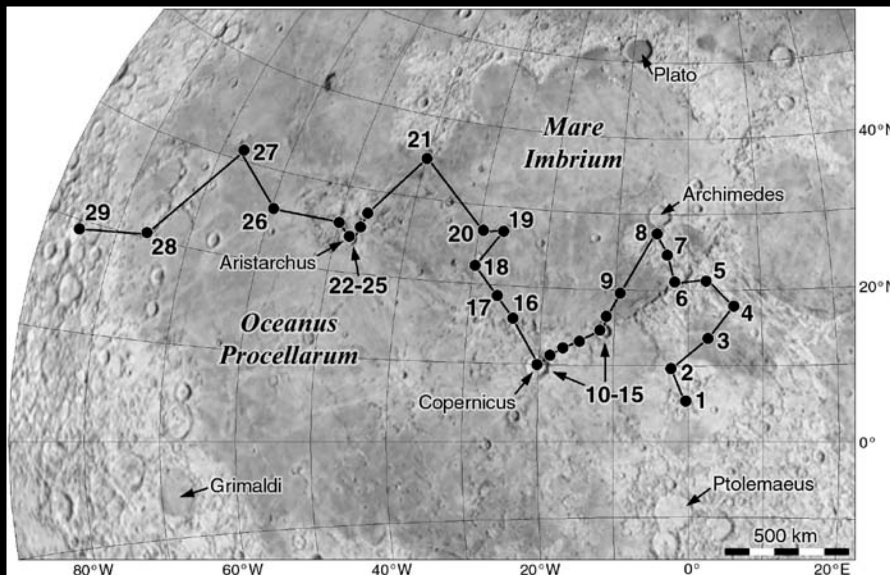
B. Visit as many 'colors' as you can
≤ 500 km radius
14 day total mission
10 km/hr avg. driving speed
1-2 days in Schomberger area
1 day in Moretus area
1 day in Newton area

C. Visit as many 'colors' as you can (extended)
> 500 km radius
>14 day total mission
10 km/hr avg. driving speed
mission extends into lunar night
major objectives: Zucchius, Hausen

9

Clark et al. (2008), Unraveling bombardment history of South Pole Region: Traversing Crater Ejecta Blanket 'Spheres of Influence'





Cintala, Spudis, Hawke (1985), Advanced Geologic Exploration Supported by a Lunar Base: A Traverse Across the Imbrium-Procellarum Region of the Moon

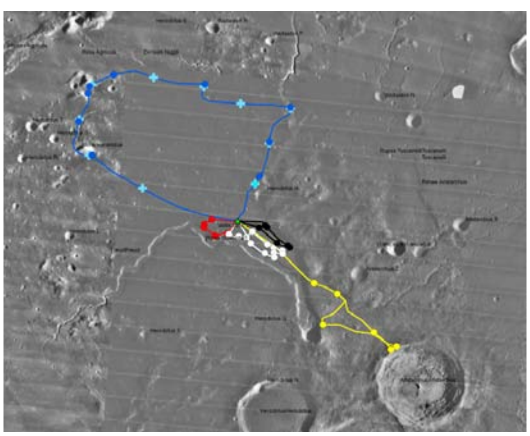
11

CONSTELLATION

Recent CxP Sponsored Workshop (2009)
45-day Exploration of Aristarchus Plateau

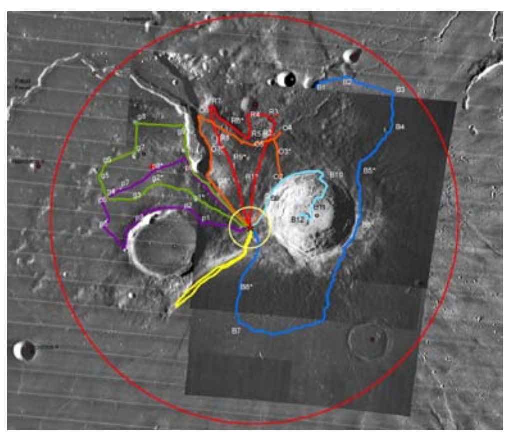
NASA

Team 1



D. Carrier, B. Garry, J. Hagerty, P. Spudis

Team 2



B. Banerdt, L. Gaddis, S. Mest, J. Plescia, R. Zeigler

System Assumptions -Team 1

- Operations
  - No walk-back requirement (LERs back up each other), so trip out to max range first and work back not necessary (but not excluded)
  - Traverse routes and stops are *suggestions*; crew needs to use geological judgment to pick final sampling/field work sites
- Additional field equipment
  - HDTV on rovers documents traverses, site geological settings
  - Multi-spectral mapping camera (imaging spectrometer)
  - Small rock drill to collect oriented bedrock samples (few cm)
  - Traverse geophysics (gravity, GPR, magnetics, active seismic)
- LER requirements
  - Need to collect "LRV"-type spot soil samples during traverses (~300-500 g scoop)
  - Manipulator arm
  - Pull or carry robotic rover (RR) during LER traverses
  - Winch and tether; pull-points mounted on LER, RR, suits
  - Capable of being teleoperated from Earth for after mission activities (bulldozer blade, others TBD)

Field Remote Sensing et al. – Team 2

- Hand-held
  - Camera
  - XRF/XRD
- Rover- mounted
  - Arm / scoop for sample acquisition
  - Radon m/s
  - Multispectral (VNIR) – mast mounted – panorama
  - GPR (penetration into the regolith, dielectric?)
  - Gravimeter
  - Magnetometer
- ALSEP-like station – deployed in three locations
  - Broad-band seismometer
  - Superconducting gravimeter
  - EM sounding
  - Heat flow probe (5-10 m)
  - Radon detector
  - Retroreflector (only at 1 station)
- FIDO Deployed from the LER
  - Operated from LER / Earth
  - Local recon while LER is parked
  - Collect samples
  - Imaging system (HDTV)