

A1 – Presentation of Stephen J. Hoffman

Antarctic Exploration Parallels for Future Human Planetary Exploration: Science Operations Lessons Learned, Planning, and Equipment Capabilities for Long Range, Long Duration Traverses

[Slides 2 – 3] The purpose for this workshop can be summed up by the question: Are there relevant analogs to planetary (meaning the Moon and Mars) to be found in polar exploration on Earth?

The answer in my opinion is “yes” or else there would be no reason for this workshop.

However, I think some background information would be useful to provide a context for my opinion on this matter. As all of you are probably aware, NASA has been set on a path that, in its current form, will eventually lead to putting human crews on the surface of the Moon and Mars for extended (months to years) in duration. For the past 50 – 60 years, starting not long after the end of World War II, exploration of the Antarctic has accumulated a significant body of experience that is highly analogous to our anticipated activities on the Moon and Mars. This relevant experience base includes:

- Long duration (1 year and 2 year) continuous deployments by single crews,
- Established a substantial outpost with a single deployment event to support these crews,
- Carried out long distance (100 to 1000 kilometer) traverses, with and without intermediate support
- Equipment and processes evolved based on lessons learned
- International cooperative missions

This is not a new or original thought; many people within NASA, including the most recent two NASA Administrators, have commented on the recognizable parallels between exploration in the Antarctic and on the Moon or Mars. But given that level of recognition, relatively little has been done, that I am aware of, to encourage these two exploration communities to collaborate in a significant way.

[Slide 4] I will return to NASA’s plans and the parallels with Antarctic traverses in a moment, but I want to spend a moment to explain the objective of this workshop and the anticipated products. We have two full days set aside for this workshop. This first day will be taken up with a series of presentations prepared by individuals with experience that extends back as far as the late 1940s and includes contemporary experience. The people presenting bring a variety of points of view, including not only U.S. but international, although most, if not all, have collaborated on international teams. The second day will consist of a series of small focused group interactions centered on those elements likely to be needed for traverse missions, such as mobility, habitation, and extravehicular activity (EVA, aka space suits). Our invited participants will be talking with people that specialize in these elements so that we can foster more direct interaction and exchange of experiences between these two exploration communities. After the workshop we will be preparing a report documenting these presentations and the essence of the focused interactions.

[Slides 5] Returning now to the exploration of the Moon and Mars in general and traverses in particular, this has been an active area of (non-science fiction) discussion going all the way back to the mid-1950s. Unfortunately, with the exception of Apollo, we have not gotten much closer to realizing them. What is different about the current situation compared to most of the past attempts at something similar is that these general objectives have been documented as public policy by the White House and codified into law

by the U.S. Congress. The first step in the current process – retiring the Space Shuttle and building its replacement – is already well under way.

A key difference in this environment is that future lunar and Mars missions will differ from what you probably remember from the Apollo missions in that they will last longer – from about a week to a couple of years (for reference the longest time spent on the lunar surface during an Apollo mission was about 72 hours). The lunar missions in this new era are likely to start with about a one-week duration and gradually grow to about 6 months between crew rotations at a single surface facility. Early lunar missions may visit different surface locations but the goal is to build up a single, continuously occupied facility, much as the International Space Station is continuously occupied now, with regularly scheduled crew rotations. Mars missions (i.e., the round-trip flight of a single crew of six people) on the other hand will last approximately 3 years in total duration, with about 18 months of that time spent on the surface. This is dictated by orbit mechanics and the current state of our rocket propulsion technology. Orbit mechanics also dictate that these launch opportunities occur at intervals such that it will not be possible for one crew to overlap on the surface of Mars with the next crew. But given that each crew will spend 18 months at a given site, current plans do not call for subsequent crews to return to the same location on the Martian surface, at least for the first several missions.

[Slides 6 – 7] The next two charts illustrate the similarity between the hardware elements needed for lunar and Mars exploration as we currently understand them. There is some reasonable rationale to sending human crews to the Moon before going on to Mars. This is driven in large part to building confidence in operations and equipment in smaller steps before taking some very large steps. Opportunities to launch crews to the Moon occur approximately once per month while opportunities to launch crews to Mars occurs approximately once every 26 months. Thus if there are reasons to delay a lunar mission the Program suffers a delay lasting just a few months compared to a minimum of 2-year delay for a missed Mars mission. Opportunities to return to Earth from the Moon are similarly more frequent. The specific interval is, again, orbit mechanics dependent but is no more than 1 month in duration. These factors allow equipment and operations to be tried in a similar situation and environment but without the multi-year commitment should any aspect of the equipment or operations be flawed.

For both lunar and Mars missions it is anticipated that both crew and robotic equipment, which could arrive on different vehicles, will land in a fairly benign location. But “benign” can also translate into “uninteresting” from a scientific or exploration perspective, resulting in the crew exhausting the scientific potential of a particular site before returning to Earth. This is especially true for Mars mission crews who will spend 18 months at a given location. This is not to imply that missions cannot land at more interesting, but also more challenging, landing sites; Apollo missions evolved from the very flat Apollo 11 site to the relatively challenging sites for Apollo’s 15, 16, and 17. But providing a capability to move long distances across the surface removes the need to risk a landing at a more challenging surface location. Hence the interest in a surface traverse.

[Slides 8 – 10] These next three charts illustrate the kinds of ranges and types of features that we may wish to explore from one of these “benign” landing sites on the Moon and Mars.

[Slide 11] There is one other aspect of future lunar and Mars missions that has an extensive experience base in Antarctic traverse – drilling. There is limited experience with this exploration tool during Apollo (and some Soviet robotic) mission and, so far, none on Mars. Exploring the subsurface of both the Moon and Mars will be a key feature of these future missions. Most of our invited Antarctic speakers have direct experience with this exploration tool.

[Slides 12 – 13] So what kind of Mars mission are we talking about? These two charts show the ground rules and study results from the most recent effort by a NASA team to capture the desires of the science/exploration community and translate them into a technically feasible approach. This can be considered the large end of the scale for future human missions: 6 crew spending almost 18 months on the surface of Mars.

[Slide 14] There are several Antarctic cases that are analogous to this – we have several speakers here today that have lived through those experiences, including the Norwegian-British-Swedish expedition (NBSX) of 1949 – 1952. Here is a comparison of several of the key features of these missions.

[Slides 15 – 16] There are also Antarctic cases that are at the small end of the scale, one of which is called ANSMET. These two charts describe this Antarctic mission and provide a comparison with Apollo activities on the Moon.

[Slide 17] And finally, the long traverse. Several nations currently active in the Antarctic regularly use long, unsupported traverse to achieve a variety objectives in this environment. These are the type of experiences we plan to discuss in this workshop.

[Slide 18] This should give you an idea of the “playing field” we are working in and the general evolution of the thinking of the NASA community that I work in, namely that: (a) Mars missions will be relatively infrequent and very long duration (by NASA standards) with no opportunity for resupply or for relief should something go wrong; (b) the Moon provides an equally challenging situation in which to build confidence in equipment and operations but over shorter durations while still accomplishing important scientific investigations; and (c) surface traverse offers a means to investigate many interesting sites from a single, “safe” landing site.

So NASA has embarked on planning for these surface bases and for a key capability of traversing across the surface for potentially long distances and extended periods of time from the landing site. It is my opinion, reinforced by the workshop we did in 2001 (NASA/TP–2002–210778, [Antarctic Exploration Parallels for Future Human Planetary Exploration: A Workshop Report](#)), that the accumulated experience exploring the polar regions is something that NASA should mine for the guidance it can provide in this new planning process. So what I called "lessons" in my workshop invitation are most likely things our invited speakers do not spend any time thinking about any more, things they just do because they know they work. There is probably not a one-to-one correspondence between what the invited speakers have done and what NASA is attempting to do on the Moon and Mars but a dialog about the invited speakers' experience and what NASA is thinking about doing on these planets should help these NASA folks figure out what should be their best course of action.

This chart shows the agenda we have set up for the remainder of today and will be the starting point for our dialog between these two exploration communities.



Antarctic Exploration Parallels for Future Human Planetary Exploration: Science Operations Lessons Learned, Planning, and Equipment Capabilities for Long Range, Long Duration Traverses

4 August 2009

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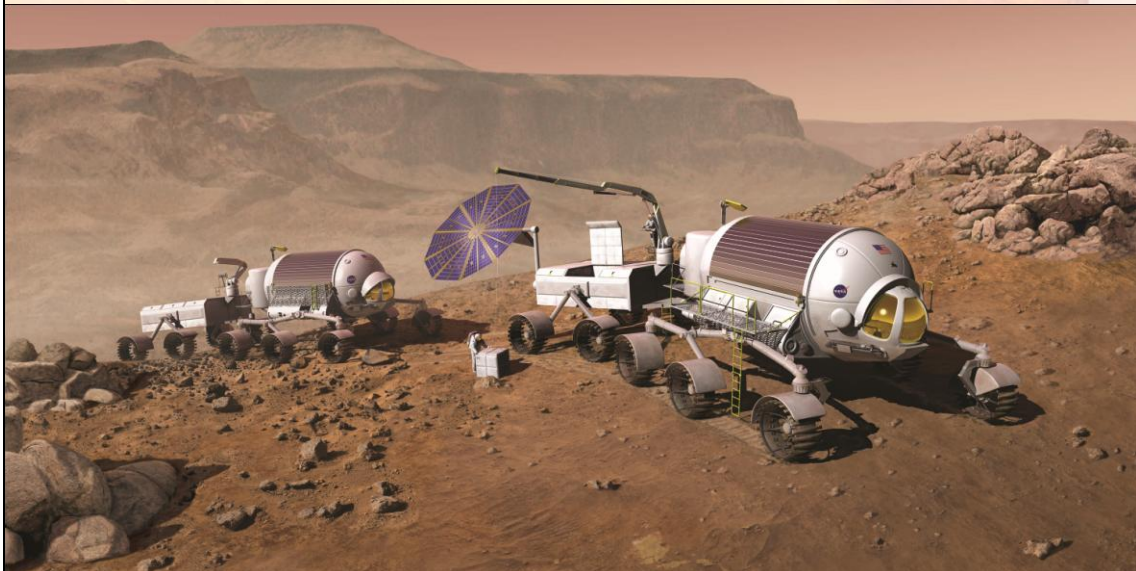
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Are There Relevant Analogs to Planetary Science Traverses in Polar Exploration?



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There Are Relevant Analogs in Polar Exploration

- **Antarctic exploration has accumulated 50+ years of experience that is an excellent analog for lunar and Mars missions**
 - Long duration (1 yr and 2 yr) deployment
 - Established outposts with a single deployment
 - Long distance (100 – 1000 km) traverses
 - Built on evolved processes and lessons learned
- **Prior NASA Administrators have on more than one occasion compared planetary exploration to Antarctic exploration**

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Objectives and Products

- **Workshop Objective:**
 - **Present an overview of 50+ years of Arctic and Antarctic scientific traverse experience and discuss the relevance to the NASA Constellation Program planning and testing activities**
 - Lessons learned in science operations, traverse planning, and logistics
 - Evolution of what can and cannot (should not) be accomplished on traverse
 - Implications of equipment and crew capabilities on science operations during traverse
 - **External presentations provided by**
 - Several consultants with experience extending back to Antarctic traverses in the 1950s
 - NSF Office of Polar Programs personnel and contractors
 - Army Corps of Engineers/Cold Regions Research and Engineering Laboratory (ACE/CRREL) personnel
 - Canadian Space Agency personnel
- **Products**
 - **Workshop report documenting science operations lessons learned from Arctic and Antarctic traverse experience**
 - **Document interaction between science operations objective, equipment capabilities, crew capabilities and logistics for use by LSS and any Mars-forward planning**

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A Bold Vision for Space Exploration, Authorized by Congress

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration



NASA Authorization Act of 2005

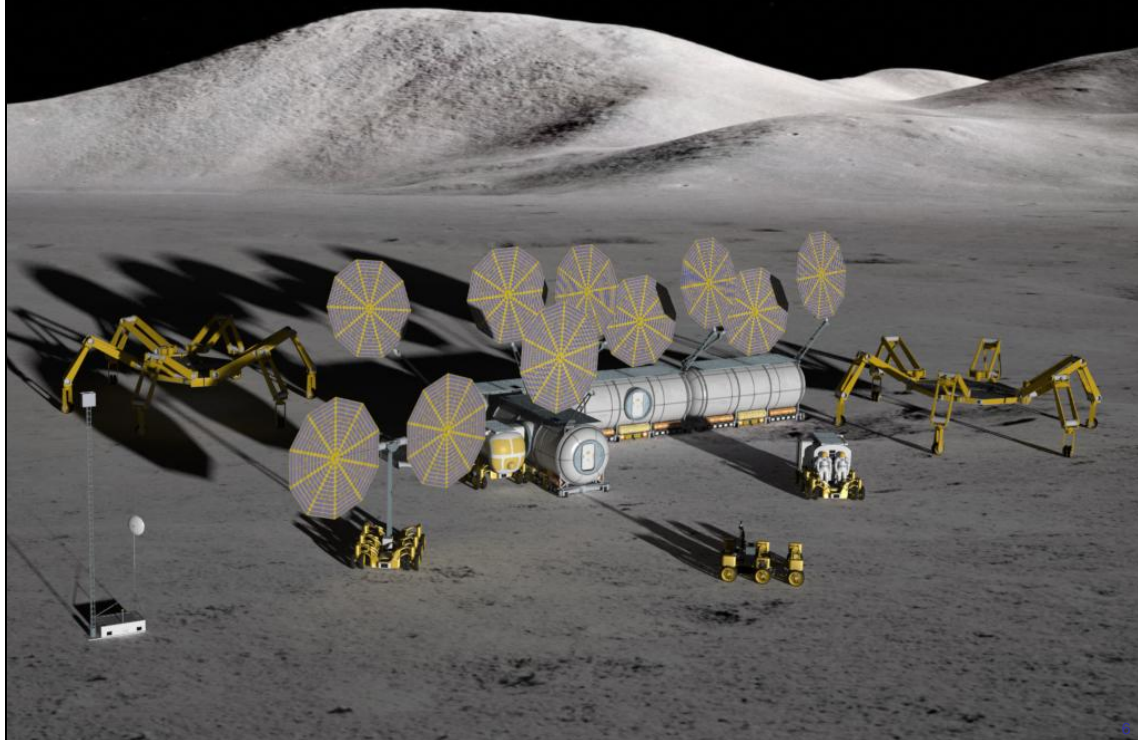
The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

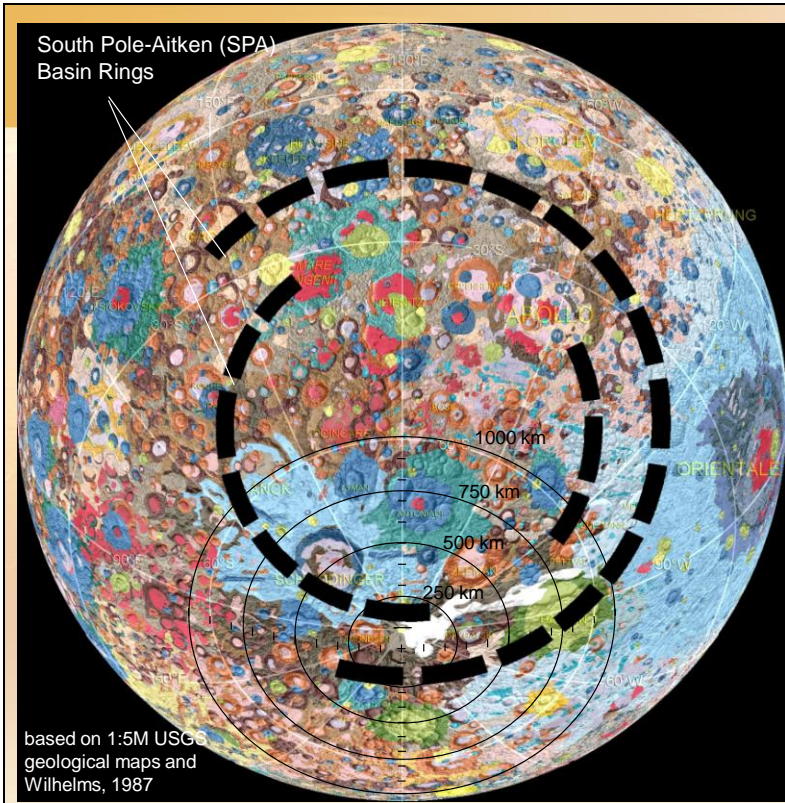
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Lunar Surface Architecture





Example Outpost at Lunar 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 Demanox 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, Zucchi, and Clavius craters

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EXAMPLE REGIONAL SCALE GEOLOGICAL STUDIES INVOLVING CONTINUOUS ROVING*

- Sample early crustal rocks to understand the development of the magma ocean, formation of the crust and mantle, timing of anorthosite formation and other large intrusive magmatic events, size and composition of the lunar core
- Measure bulk chemical composition of the Moon to constrain the processes by which elements were partitioned in the Earth-Moon system at the time of formation
- Use the Moon's craters as a natural laboratory to study the large impact process, including the origin and mechanism of central peaks and basin ring development, excavation dynamics and dimensions, and the mechanics of ejecta emplacement

FOR EACH GEOLOGIC UNIT:

- Determine and map the lateral extent of major lithologies and landforms
- Define and sample ejecta blankets from major pre-imbrian impacts
- Map the major structures associated with various size impact craters
- Collect samples that will date major geologic events, including impacts and magmatic events

CAPABILITIES REQUIRED:

- Pressurized rove capability with a minimum radius of ≈1000 km
- A campaign of multiple long roves
- 100s to 1000s of EVA crew days

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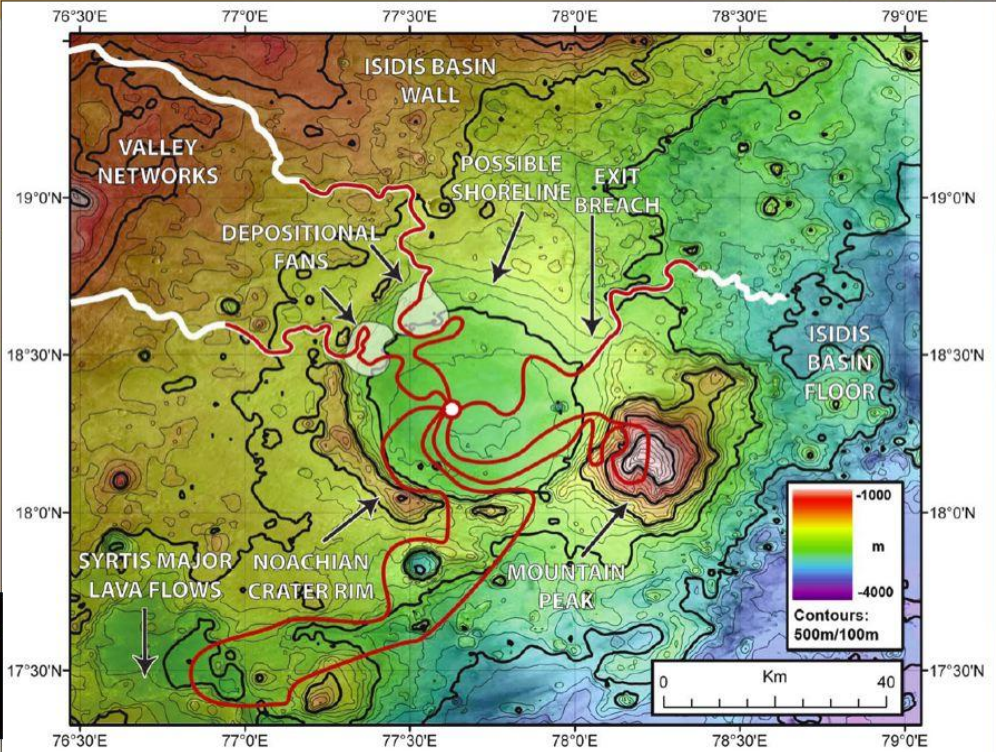
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LEAG BASS, SAT Report, 2009



RESULT: Human surface mobility on Mars (for science) should facilitate ~100 km long traverses, on the basis of Human Science Reference Mission (HSRM) Case Studies conducted by the HEM-SAG.

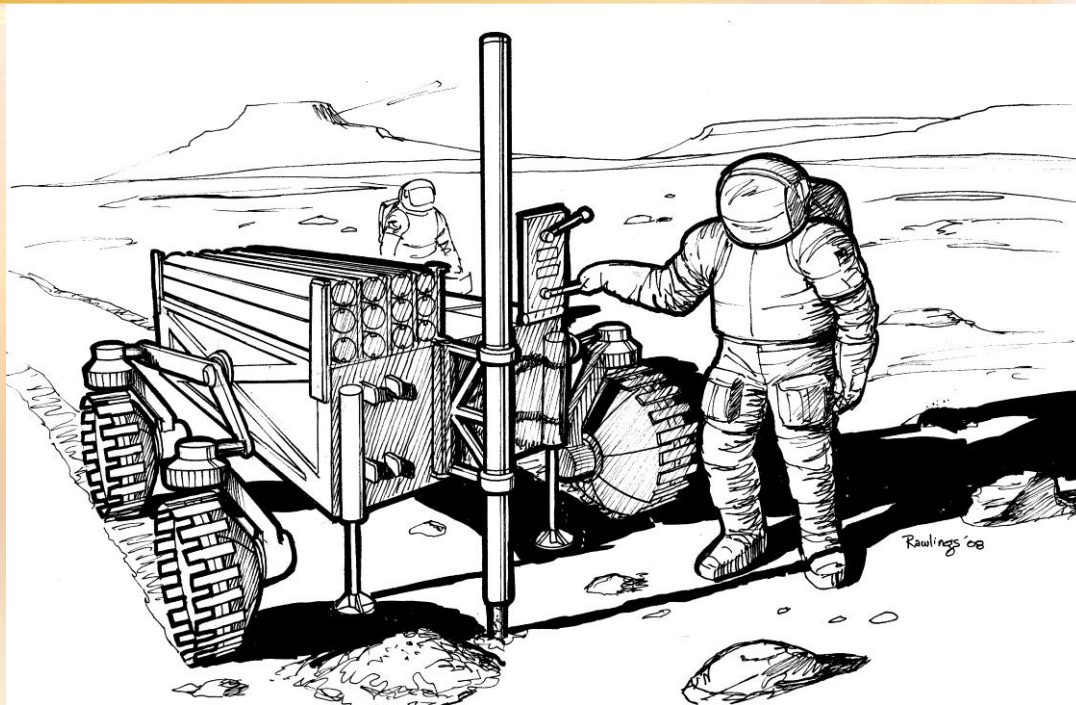
Ancient impact Basin and Early Crust HSRM Case Study Site



RED line indicates a set of science traverses (work in progress)



Subsurface Drilling



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Mars Surface Mission Assumptions

- **Assumptions based on previous studies (adopted here) or from completed MAT Decision Packages**
 - **Six crew**
 - All land on the surface together
 - **Long-Stay mission profile**
 - Nominal surface mission lasts approximately 500 sols
 - **Pre-Deploy transportation strategy**
 - Two cargo flights sent one opportunity prior to crew, one of which lands at the designated surface site shortly after arrival at Mars
 - **ISRU plant functioning at the surface site**
 - Quantities are TBD
 - Commodities include (nominally): oxygen, methane, water, buffer gases
 - **Mass allocation for surface activities**
 - (nominally) 100 kg for returned samples
 - This includes samples of all types: geologic, atmospheric, biological, medical, etc.
 - (nominally) 1000 kg for surface science experiments and equipment
 - Specific science experiments and equipment would be selected based on the objectives for the site being visited and thus will likely be different for each mission

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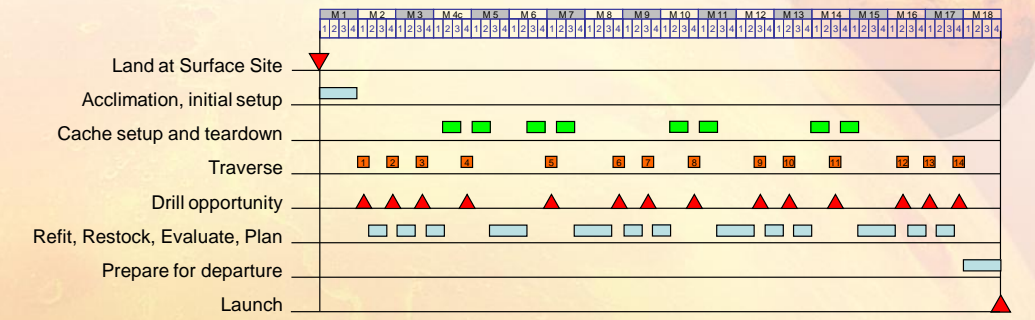
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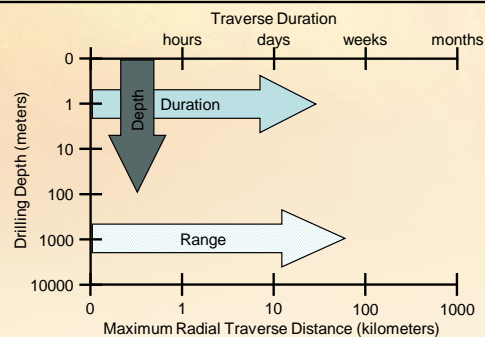
Surface Mission Strategy Option 2: “Commuter”

Notional Surface Mission Activities



Surface Assets

Item	Mass
Primary Habitat	15 MT (est)
Sm. Press. Rover x 2	6 MT (est)
Crew Consumables	7.5 MT (est)
Drill	1 MT (est)
Science Equipment	1 MT (allocation)
ISRU and Power Plant	2 MT (est)
Robotic Rovers x 2	0.5 MT (allocation)
Total	33 MT



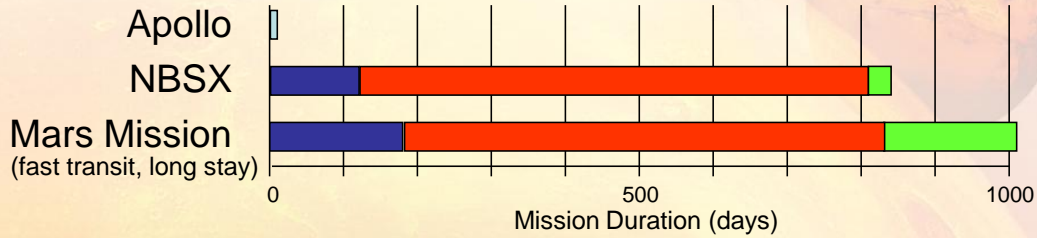
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Different Comparative Views



Personnel



Apollo



NBSX



Mars Mission (?)

Surface Cargo and Facilities



4.8 MT
(no propellant)



450 MT



Approximately 80 MT
(no propellant, aeroshell, parachutes)

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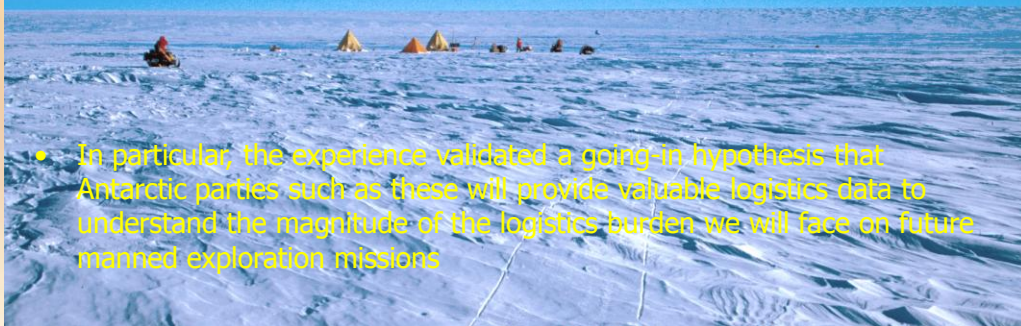
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ANtarctic Search for METeorites (ANSMET)

- In November 2002, ANSMET deployed a four person reconnaissance team to investigate a series of poorly explored blue ice fields southeast of the Weddell Sea and ≈ 200 miles north of the South Pole
- Over the course of the season, this team's operational experience became a good analog for the operations and logistics requirements that might be incurred on a manned exploration mission
- During 5 1/2 weeks of activity, we were able to collect a wealth of logistics and traverse data, part of which is presented here



- In particular, the experience validated a going-in hypothesis that Antarctic parties such as these will provide valuable logistics data to understand the magnitude of the logistics burden we will face on future manned exploration missions

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ANSMET also studied as Small Team Analog

- Comparison Data is between Apollo and ANSMET programs is very close at this level of granularity.
- We expect similar scalable math with larger field camp, small station and medium station numbers in future Analog work.

	Time, hrs	% On Surface Time
APOLLO 15		
Total Time on Surface	66.9	100%
Utilization Time	14.5	22%
Logistics Time	30.2	45%
Sleep Time	22.2	33%
APOLLO 16		
Total Time on Surface	71.0	100%
Utilization Time	14.6	21%
Logistics Time	29.1	41%
Sleep Time	27.5	39%
APOLLO 17		
Total Time on Surface	75.0	100%
Utilization Time	15.1	20%
Logistics Time	33.2	44%
Sleep Time	26.6	35%
ANSMET '02-'03 RECCE TEAM		
Total Time in Field	872.5	100%
Utilization Time	113.8	13%
Logistics Time	353.5	41%
Sleep Time	342.3	39%
Weather downtime	63.0	7%

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And, lest you think these surface traverses are hard to do ...



- NSF is moving to an operational resupply of South Pole Station from McMurdo Station. Early proof of concept tests included:
 - Eight crew
 - 1654 kilometers (1023 miles) one-way; no resupply enroute (including at South Pole)
 - 2900 meter (9300 foot) elevation change
 - Approximately 40 days one-way (average 1.5 km/hr although periodic stops are built in)
 - Delivers a net 100 tonnes of supplies
 - Already planning for robotic vehicles to reduce crew size
- Russians and French have performed similar resupply for years

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Agenda

- 8:30 – 9:00 Introductions: Steve Hoffman and Dr. Wendell Mendell
- 9:00 – 9:45 Dr. Charles Swithinbank (Scott Polar Research Institute) - observations from the Norwegian- British- Swedish Expedition (NBSX) of 1949-52
- 9:45 – 10:30 Dr. Charles Bentley (University of Wisconsin) - the first of two perspectives on the International Geophysical Year and the evolution that followed
- 10:30 – 10:45 a short break
- 10:45 – 11:30 – Dr. Richard Cameron - the second of two perspectives on the International Geophysical Year and the evolution that followed
- 11:30 – 12:15 – Dr. Friedrich Horz and/or Dr. Gary Lofgren - the Apollo lunar traverses and the associated planning
- 12:15 – 1:15 Lunch
- 1:15 – 2:00 Dr. Marie-Claude Williamson (Canadian Space Agency) - contemporary science traverses in the Arctic
- 2:00 – 2:45 Dr. Mary Albert (Dartmouth) - contemporary science traverses in the Antarctic
- 2:45 – 3:00 a short break
- 3:00 – 3:45 John Gruener (NASA) - NASA's plans for potential traverses on the lunar surface in the next era
- 3:45 – 4:15 Johan Berte (International Polar Foundation) - overview of the Belgian Princess Elizabeth Antarctica research station and its development
- 4:15 – 5:00 open discussion with all presenters and attendees

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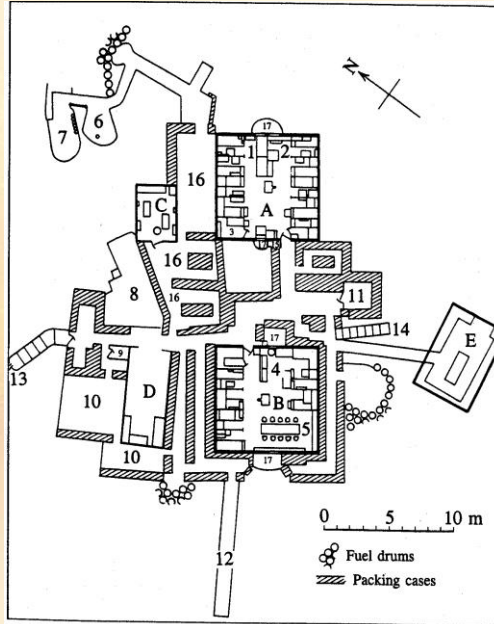
Automated Drill as part of Rover Testbed



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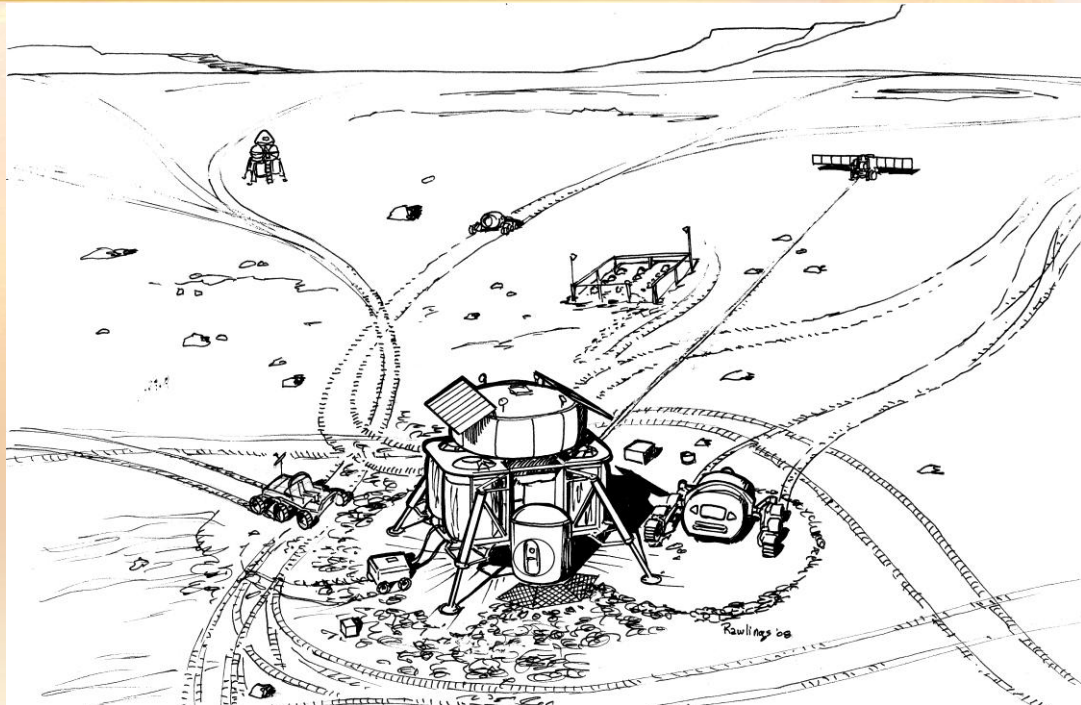
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Surface Mission Strategy Option 2: “Commuter”



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Mars Surface Environment

Surface temperature

Height above Surface (feet)	Day (F)	Night (F)
5	15	-105
0	65	-130
(Antarctica)	-15	-82

- Surface pressure: 7 -10 millibars (Earth surface pressure is 1000 millibars)
- Length of day: 24 hours 37 minutes
- Length of year: 687 days (the “long stay” surface mission is approximately 500 to 600 days long)
- Surface area: 145 million square kilometers (the same as all of the dry land on Earth)

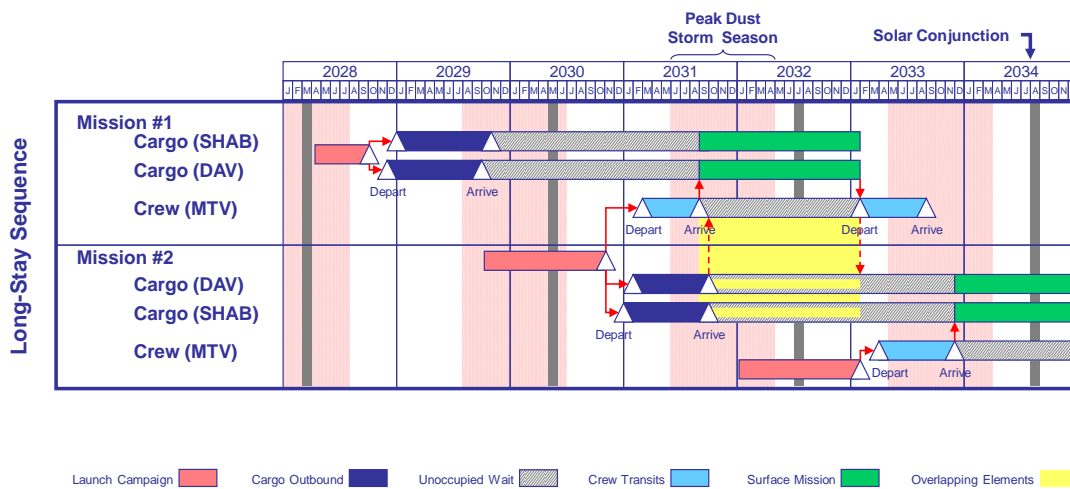
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Long Stay Mission Sequence Pre-Deploy Option



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