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Mars Surface Systems Common Capabilities and Challenges for Human Missions

Larry Toups, NASA Johnson Space Center

Stephen J. Hoffman, Ph.D., Science Applications International Corporation

Kevin Watts, NASA Johnson Space Center

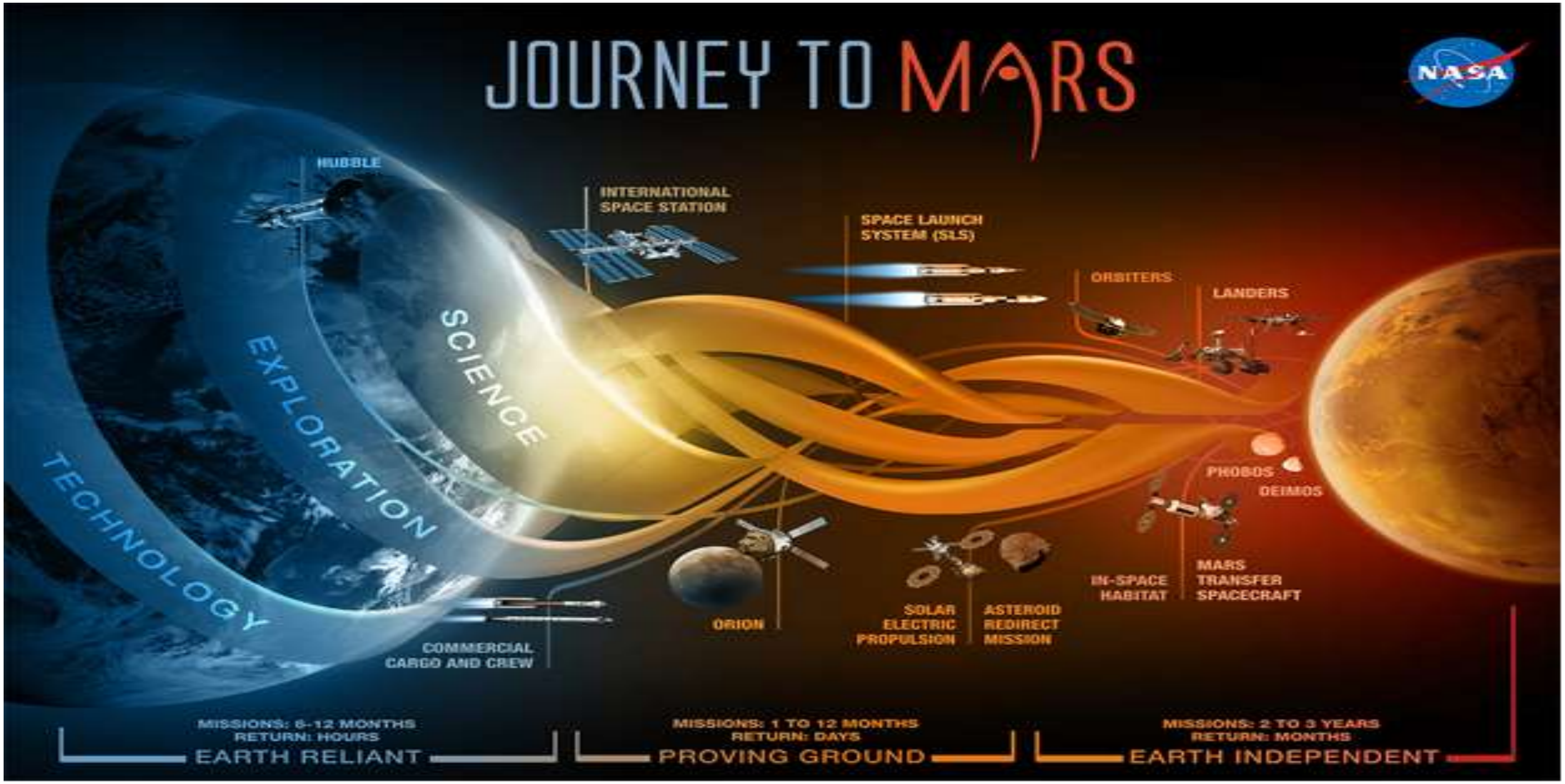
Agenda

- **How do we pioneer an extended human presence on Mars that is Earth independent?**

- **The Exploration Zone, Regions of Interest, and Mars Surface Field Station concepts**

- **Impacts of Mars Surface Field Station location on surface system commonality**
  - Traverse range and route impact on rover
  - Landing site topographic impact on Field Station layout

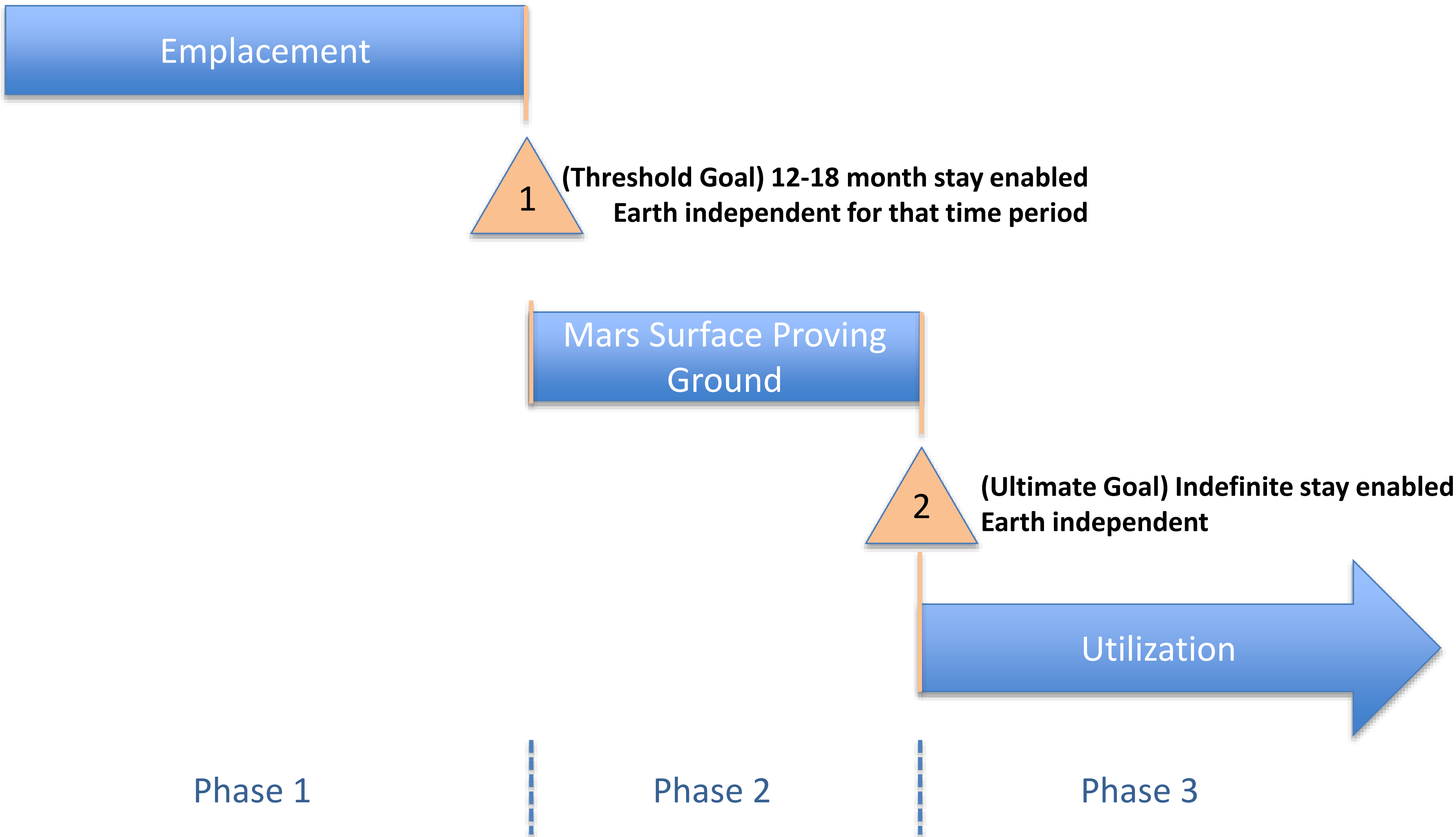
Key Questions for the Evolvable Mars Campaign



How do we pioneer an extended human presence on Mars that is Earth independent?

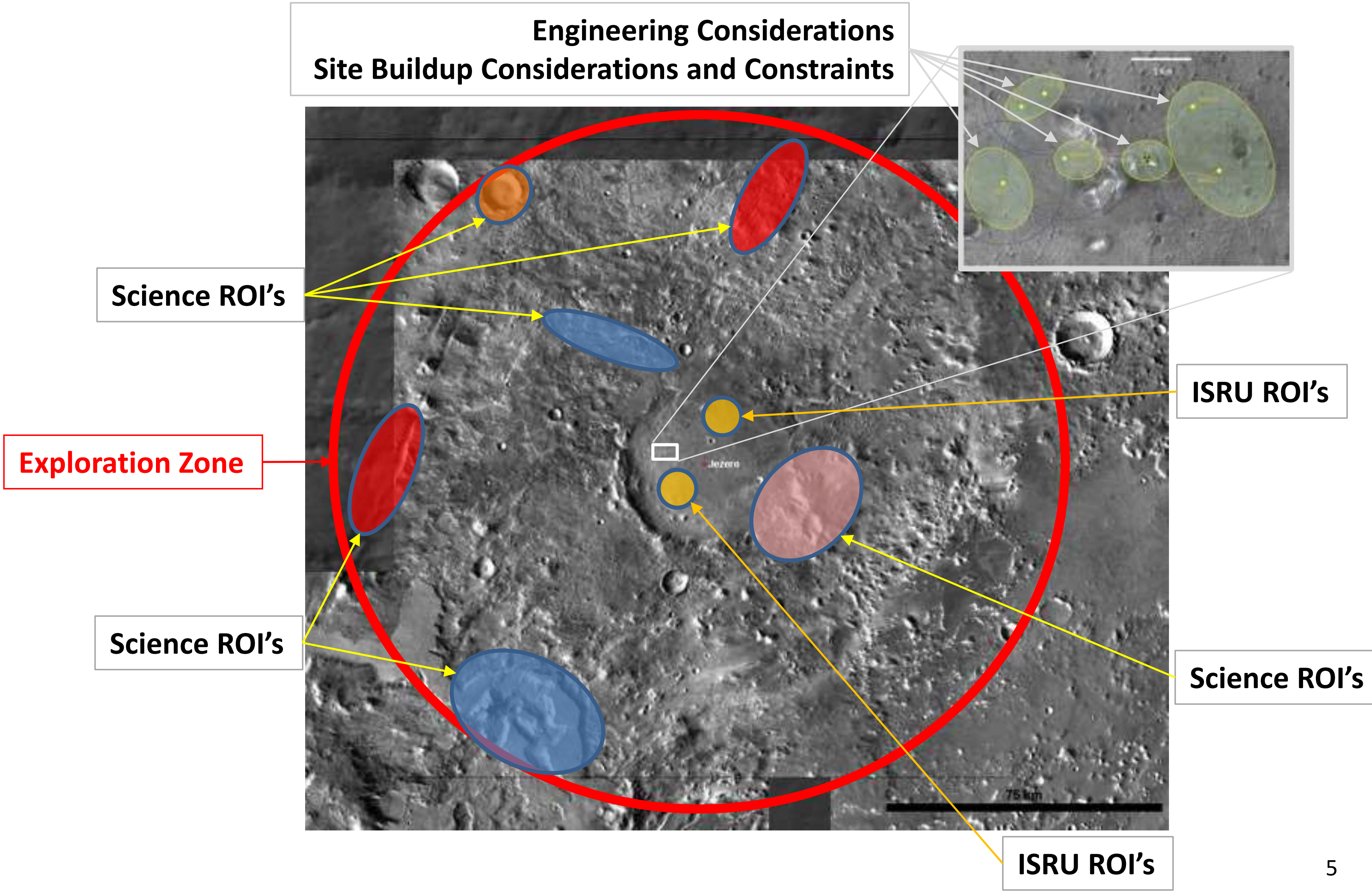
For the diverse range of Mars Surface Field Station locations being considered, how much commonality across surface systems can be expected?

Architecture Approach within the EMC – Mars Surface

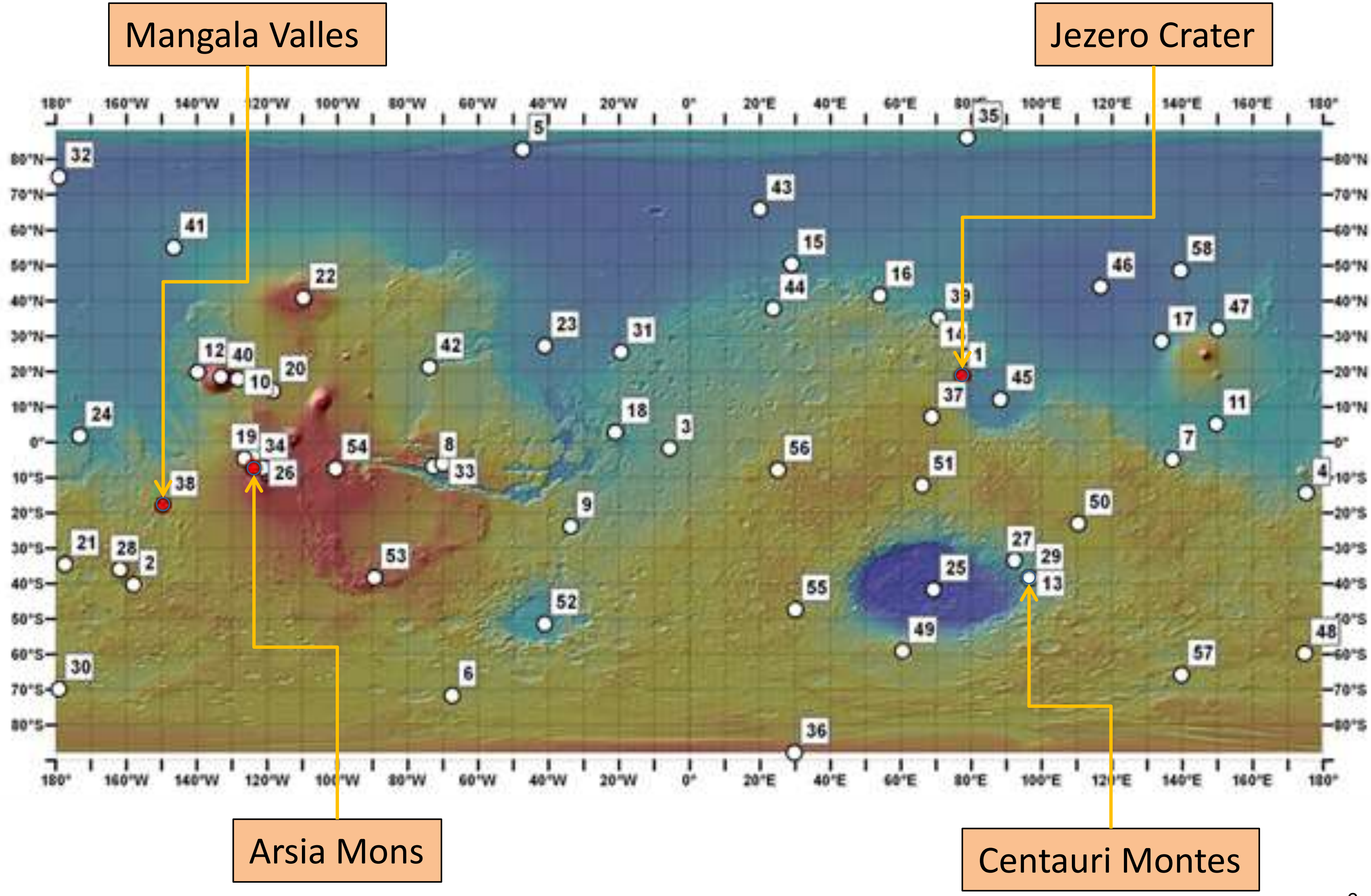


See Toups and Hoffman “Pioneering Objectives and Activities on the Surface of Mars,” AIAA Space 2015

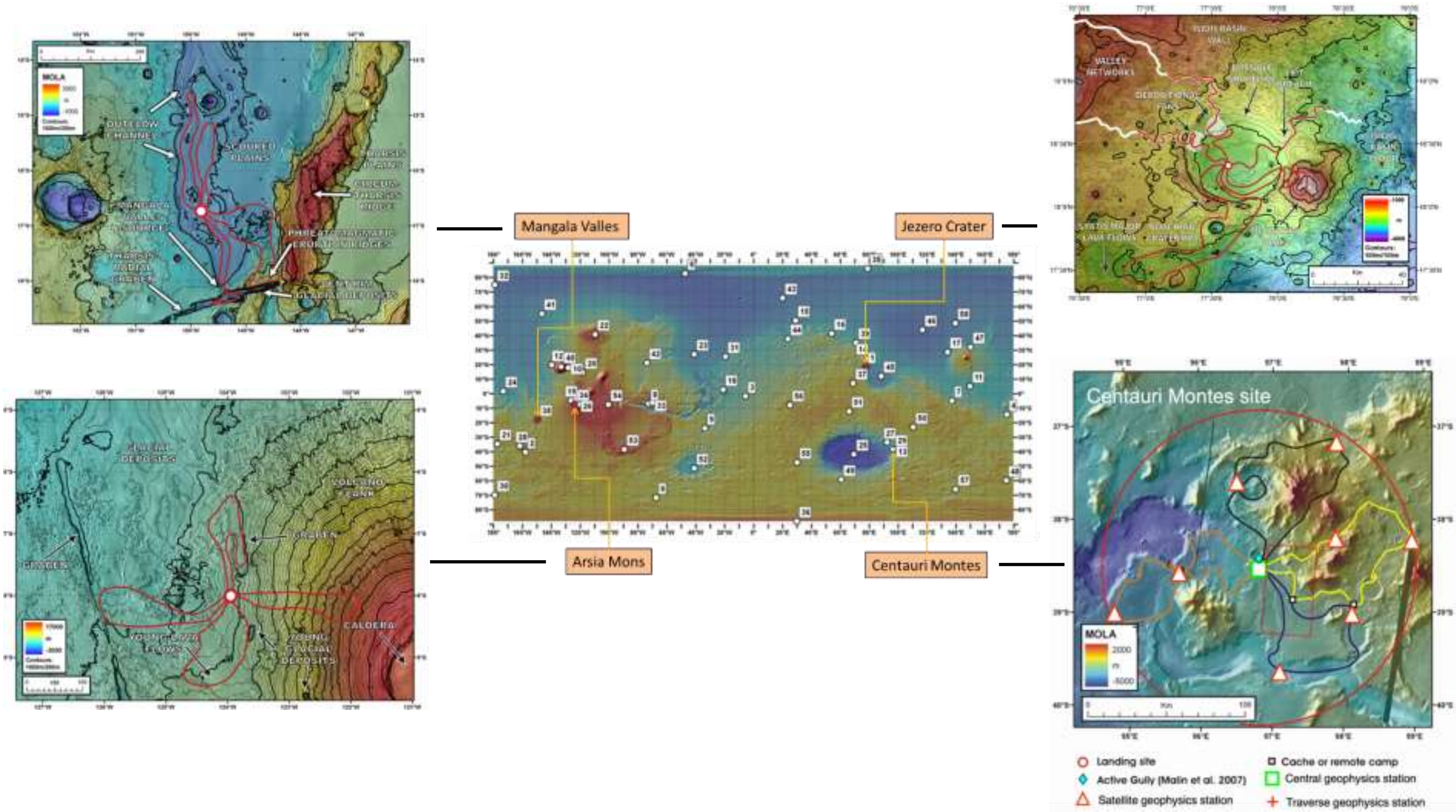
Example Mars Surface Field Station and Surrounding Regions of Interest (ROI's)



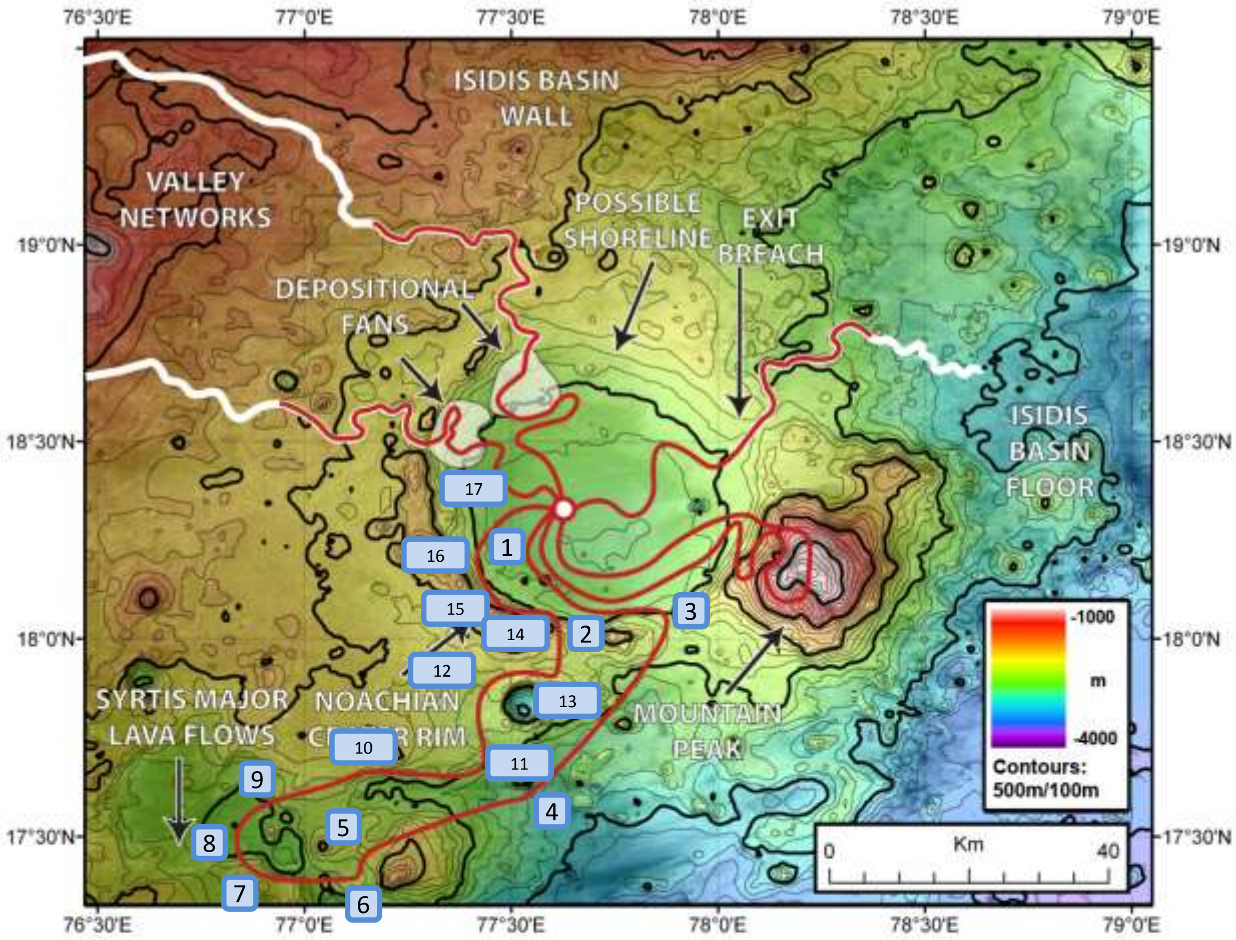
HEM-SAG Candidate Mars Landing Sites



Notional ROIs and Associated Traverse Routes at the Four HEM-SAG sites



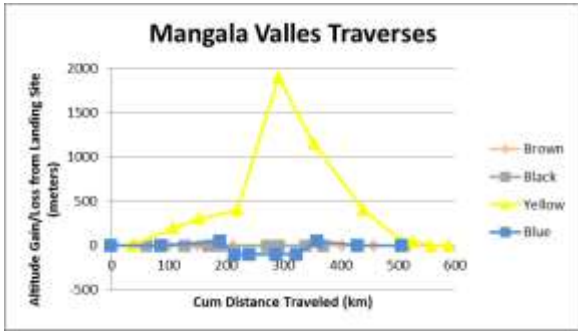
Example Traverse Distance/Elevation Estimate

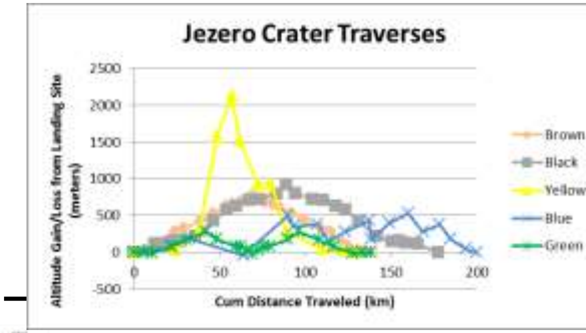


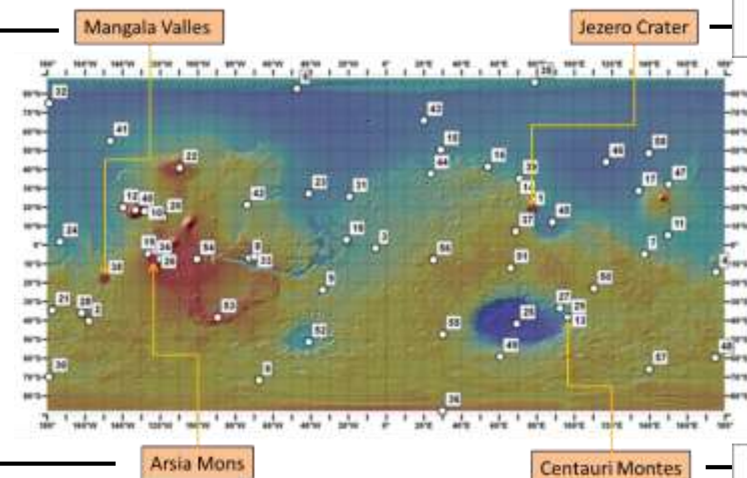
Blue Traverse

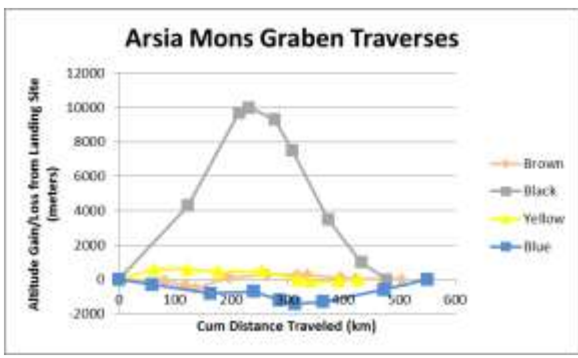
Blue Traverse		
Start point	End Point	Surf Dist (km)
0	1	9
1	2	13
2	3	11
3	4	31
4	5	26
5	6	3
6	7	14
7	8	6
8	9	10
9	10	14
10	11	1
11	12	11
12	13	11
13	14	9
14	15	10
15	16	6
16	17	9
17	0	6
	Total	200

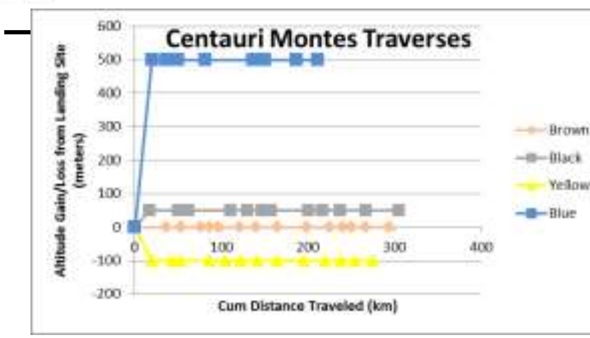
Summary of Traverse and Altitude Profiles at all HEM-SAG Sites







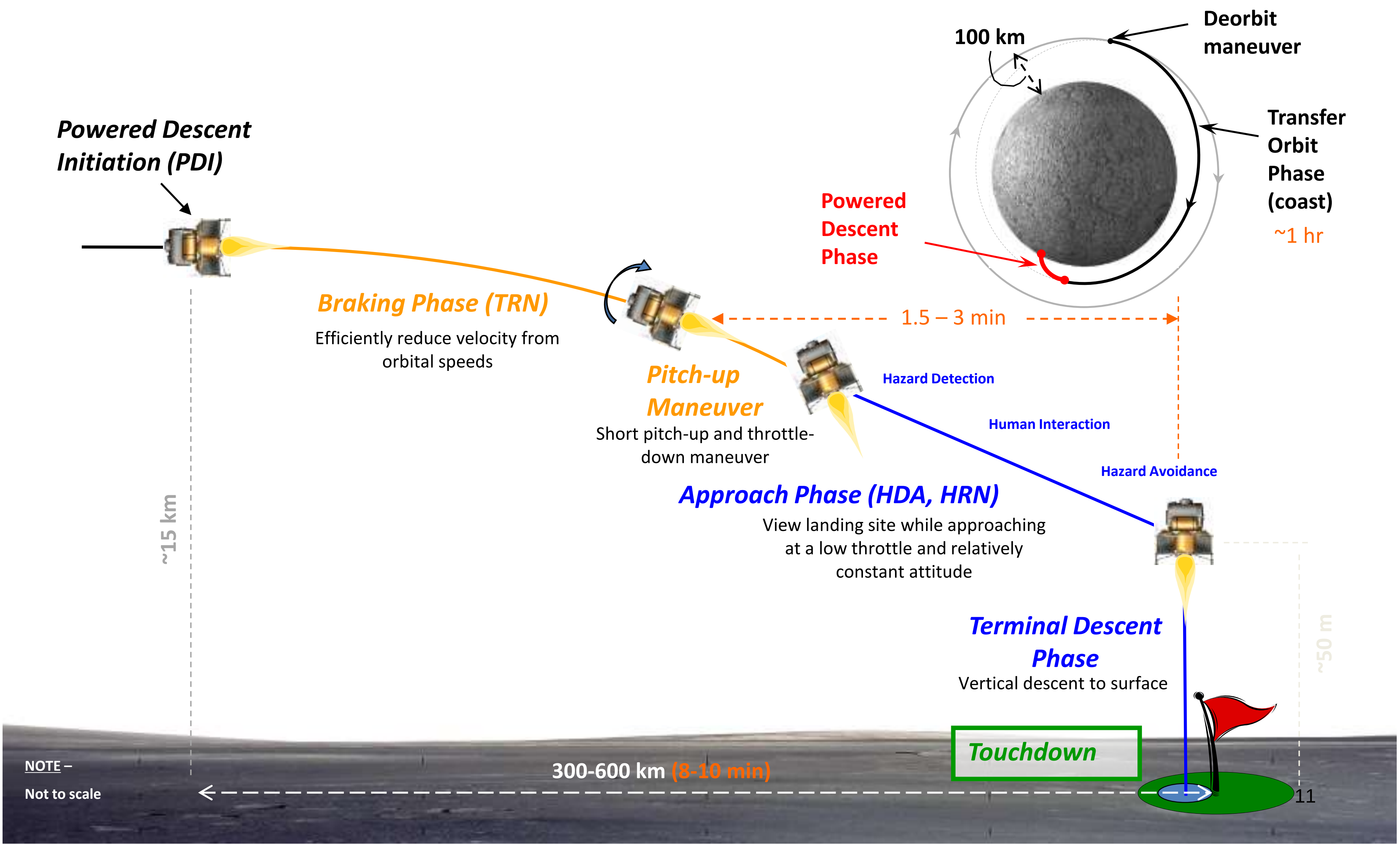




Small Pressurized Rover

- Two crew
  - capable of carrying four crew in a contingency
- Two week duration without resupply
- ~400 km "odometer" range
  - 200 km out, 200 km back
  - Factor of 2 for actual distance over straight line distance
  - ***Results in ~100 km straight line range from starting point***

ALHAT Technology Assumed for EMC Missions



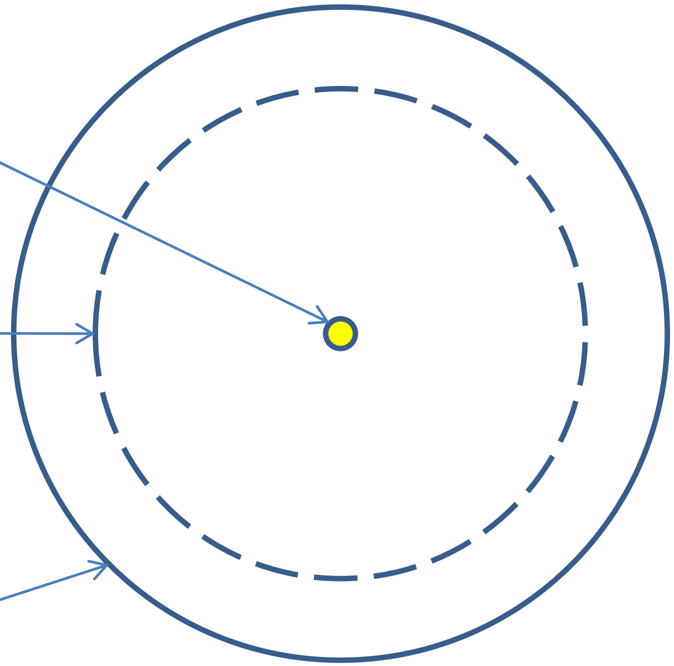
Landing Site Symbology

On the following pages this symbology will be used to indicate landing site factors discussed on the previous pages

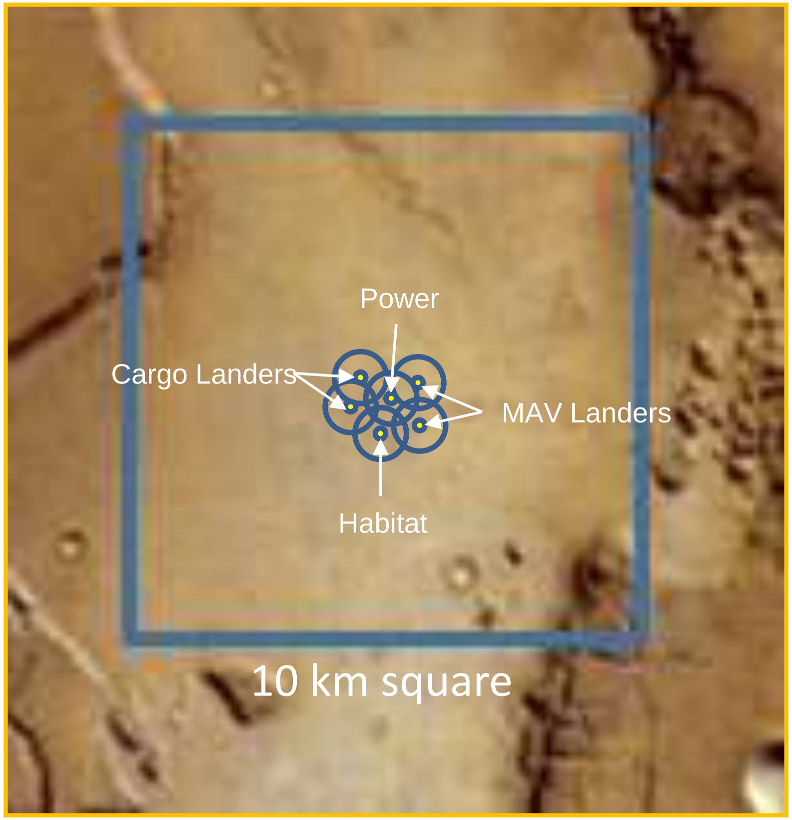
100 meter diameter circle inside of which the ALHAT system is targeting for delivery of a lander

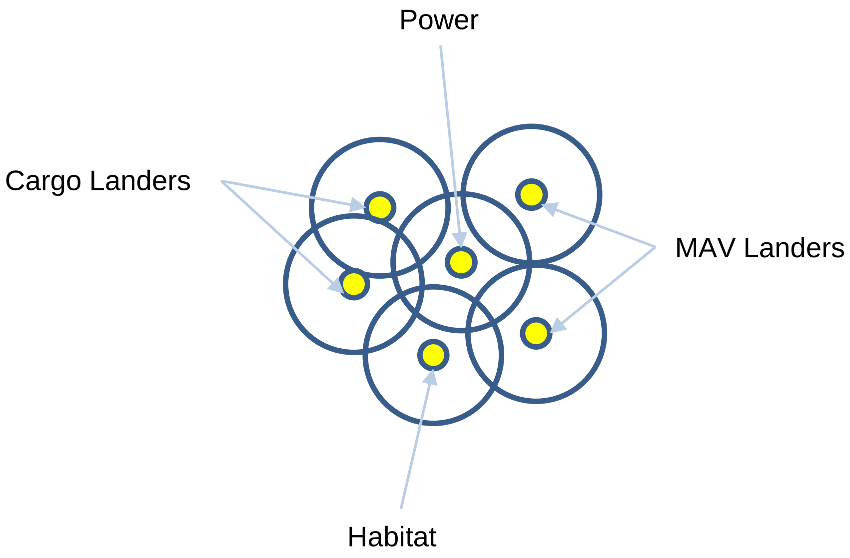
700 meter diameter circle that analysis indicates will be the maximum range of debris lofted by a large terminal descent thruster

1000 meter diameter circle outside of which an element of surface infrastructure should be safe from terminal descent thruster debris



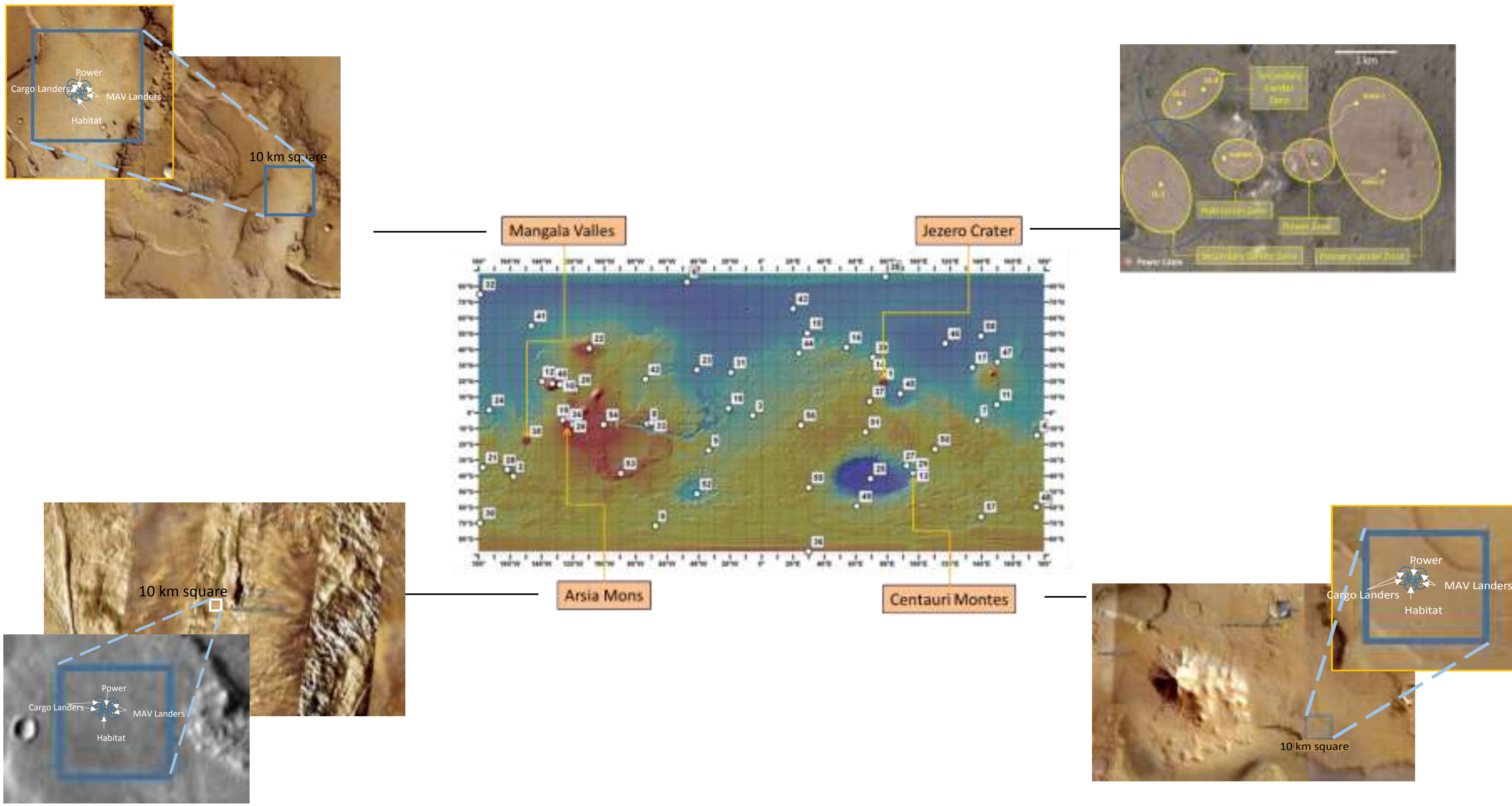
Notional "Common" Field Station Layout



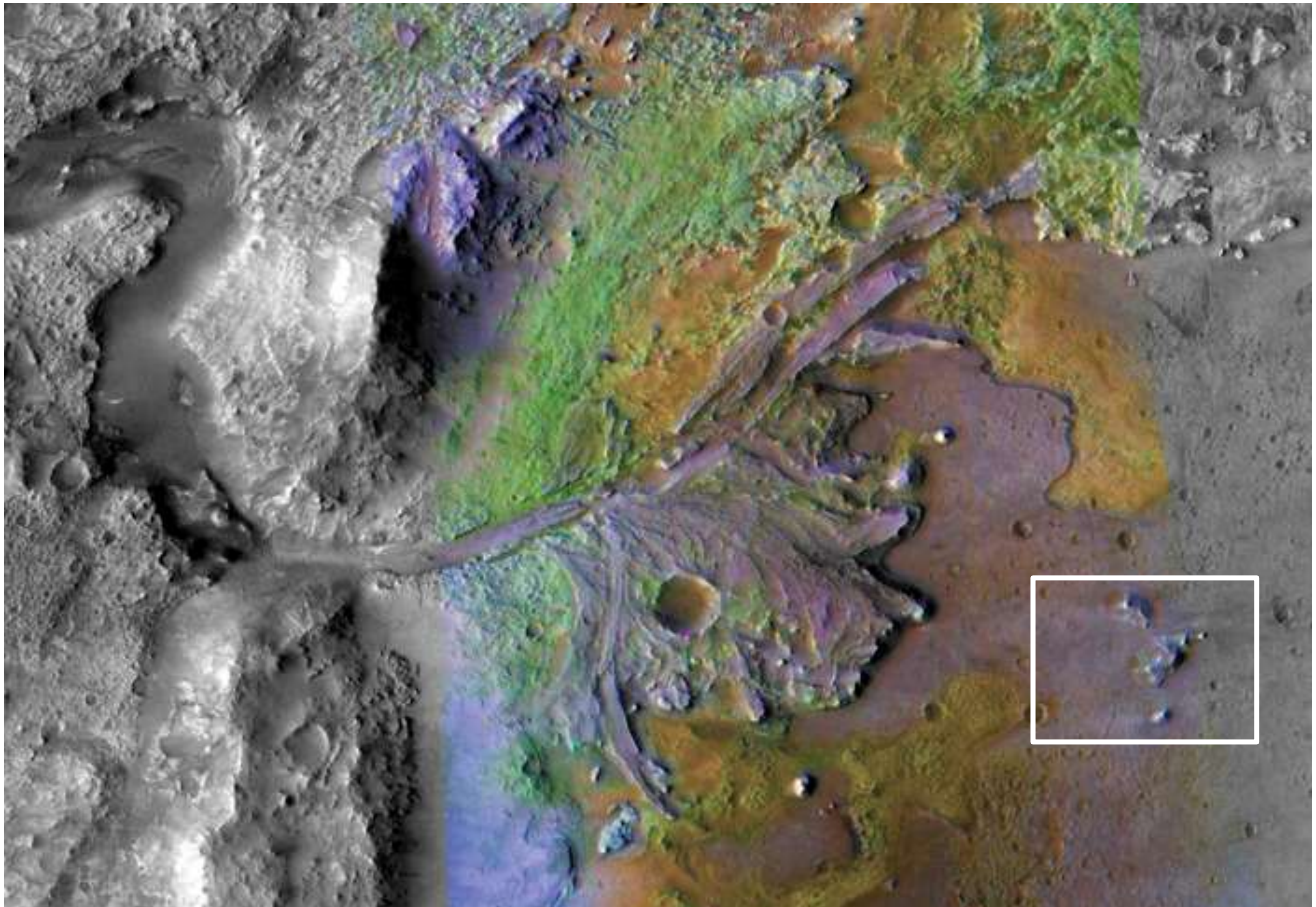


- "Wagon Wheel" configuration
  - Minimizes distance between elements
  - Minimizes power cable length

Summary of Field Station Placement at all HEM-SAG Sites



Terrain Considerations in Field Station Placement



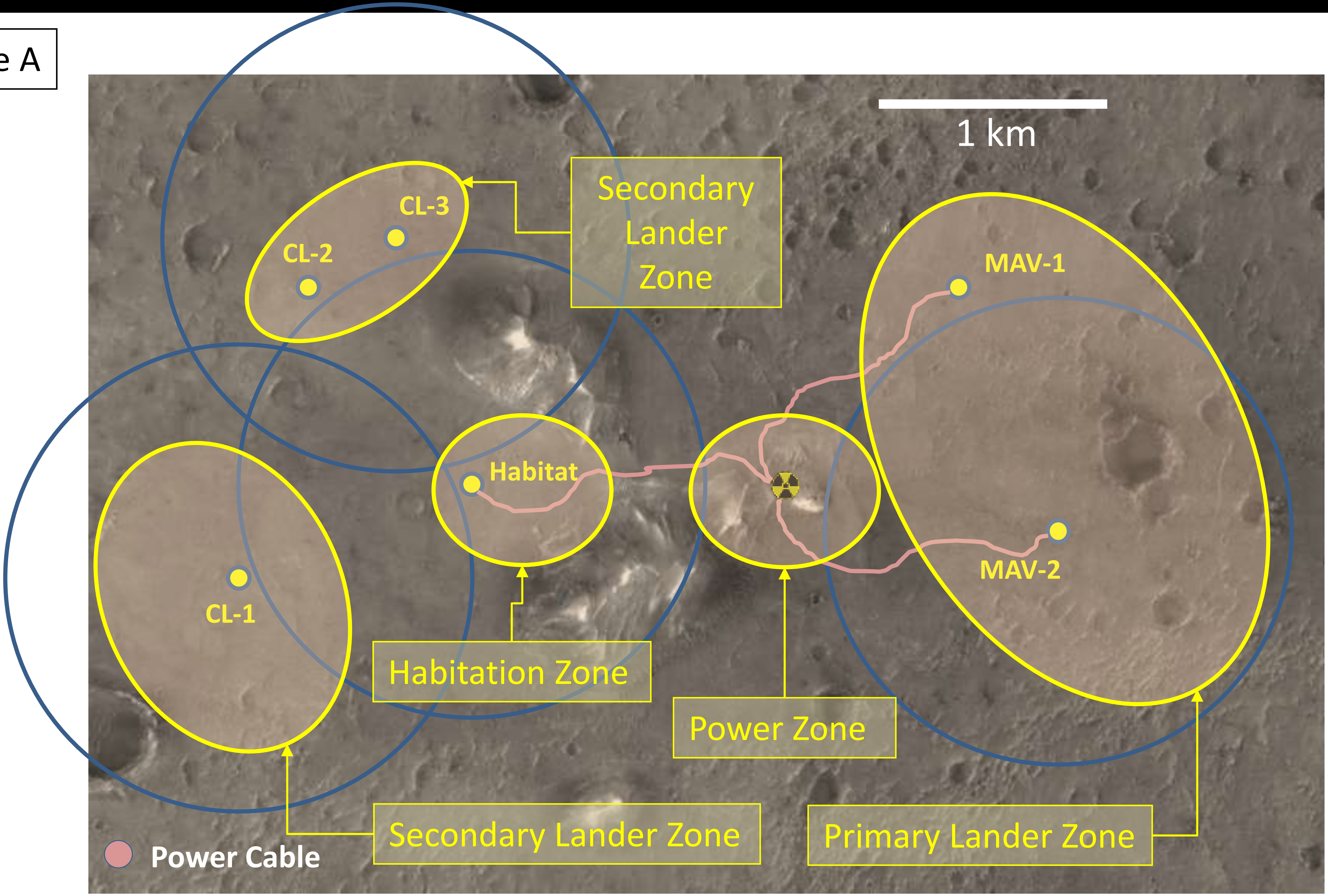
Site A

Jezero contains Fe-Mg smectite clay indicative of multiple episodes of fluvial/aqueous activity on ancient Mars, elevating the potential for preservation of organic material.
(Green = phyllosilicates, orange = olivine, purple = neutral/weak bands.)

Landing Site ‘A’ Within Jezero Crater

Example of Field Station Layout with Specific Utilization Zones Identified

Site A



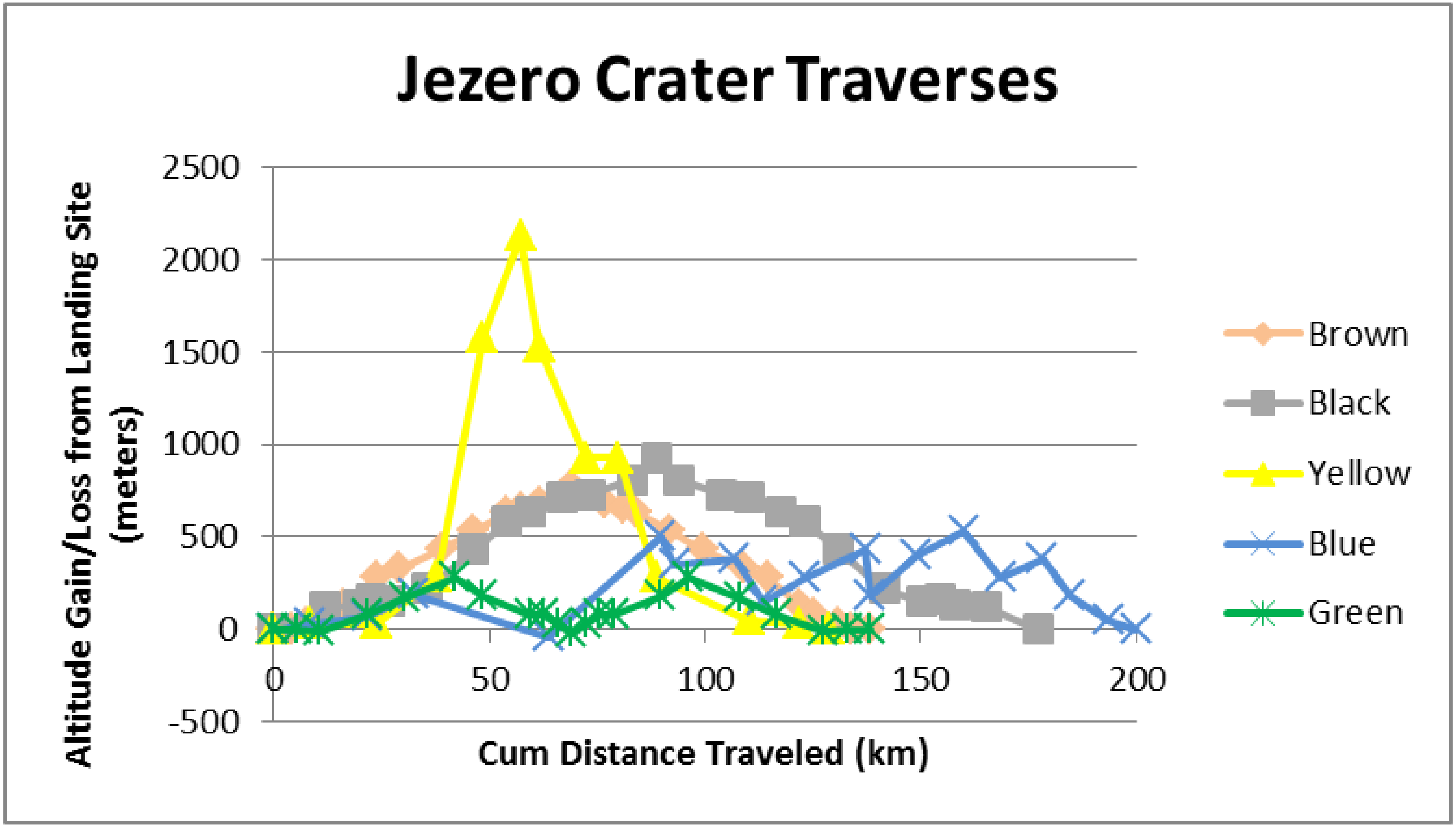
Landing Site 'A' Within Jezero Crater

Summary

- **For the diverse range of Mars Surface Field Station locations being considered, how much commonality across surface systems can be expected?**
  - Initial focus on traverse range needs and Field Station layout
- **While much more work still needs to be done, several important findings have emerged from these preliminary assessments:**
  - All of the proposed traverses appear to be feasible for the small pressurized rover currently envisioned for these surface missions.
    - At the level of analysis conducted to date, range and topography do not appear to be obstacles for the kinds of traverses envisioned at this relatively diverse set of HEM-SAG EZs.
      - With the possible exception of a long, steep climb to the top of Arsia Mons.
  - At each of the four HEM-SAG sites there was a 10 km x 10 km area at or near the proposed landing site within which it is reasonable to set up a landing site and habitation site consistent with the needs of a Mars Surface Field Station.
  - At each of these 10 km x 10 km sites it is possible to set up a central location for a common power system and locate the landing and habitation zones in a radial “wagon wheel” configuration around this power system location.
  - The concept of supporting multiple crews with a designated “cargo landing zone” and a “MAV landing zone” that is used by multiple landers that can all land close to other surface field station infrastructure appears to be reasonable and achievable based on this sampling of four diverse locations.

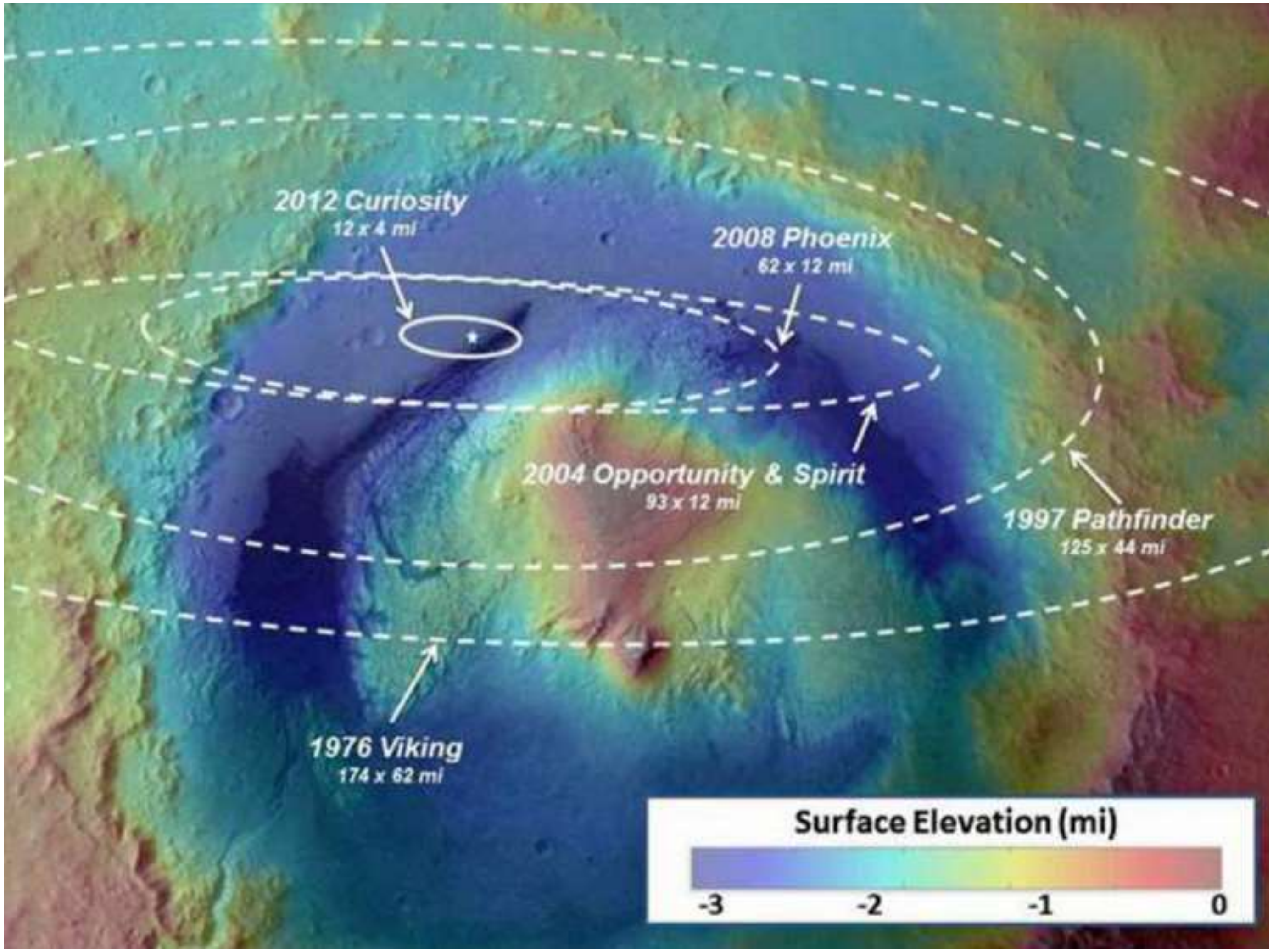
Backup

Traverse and Altitude Profiles at Jezero Crater



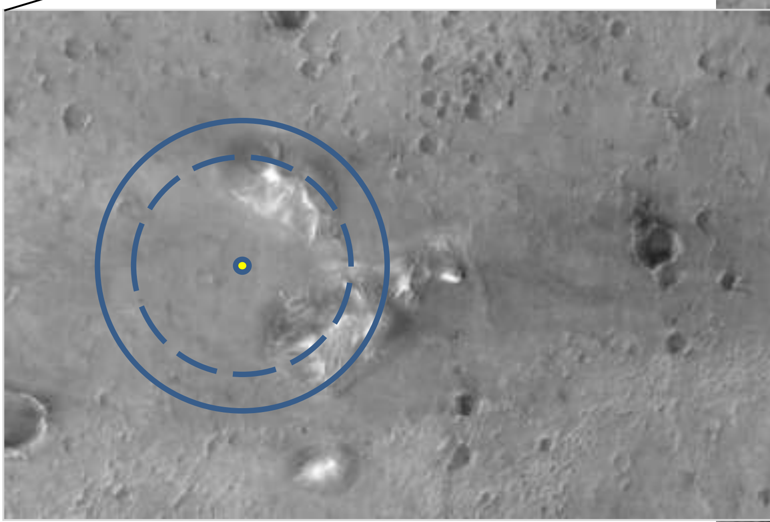
Similar summaries for other HEM-SAG sites can be found in the Toups-Hoffman-Watts paper

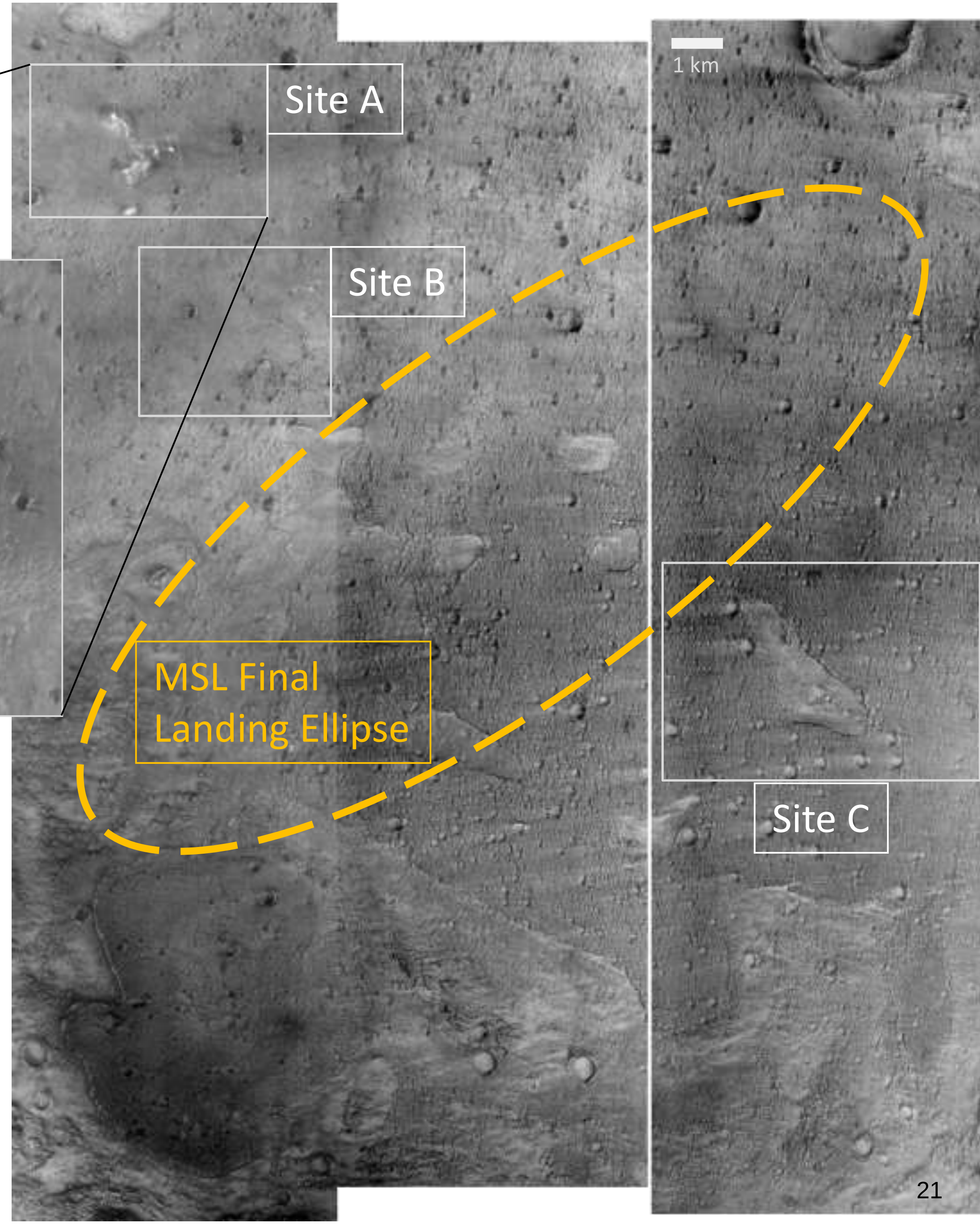
Landing Accuracy Improvements to Date

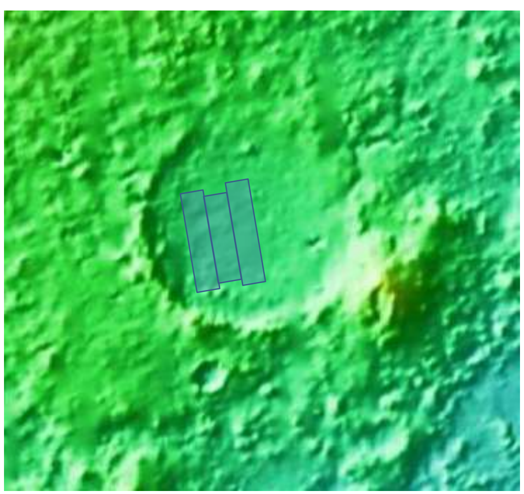


Example site: Gale Crater

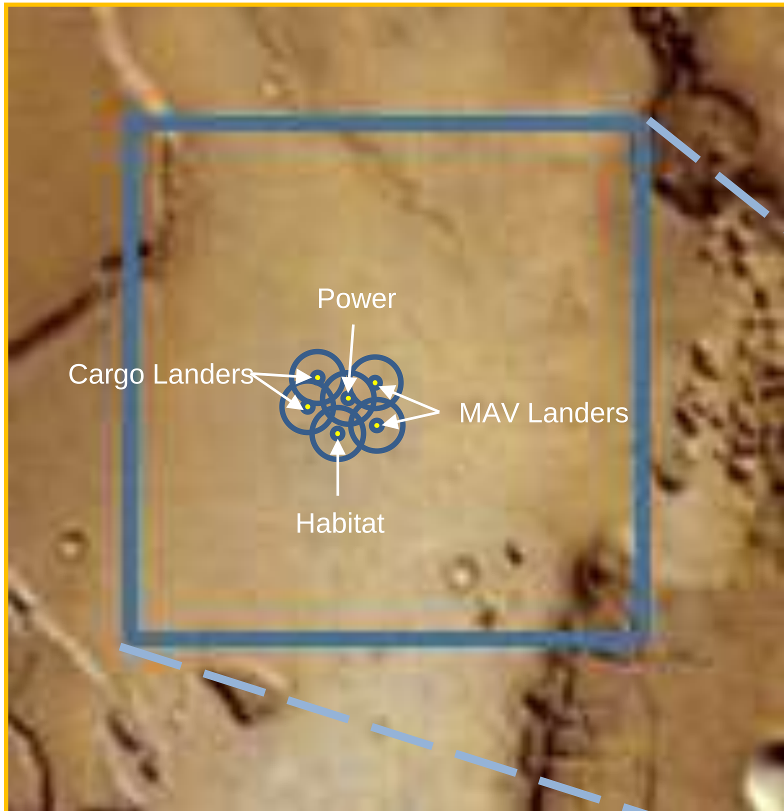
Comparison of MSL landing accuracy capability with ALHAT target capability

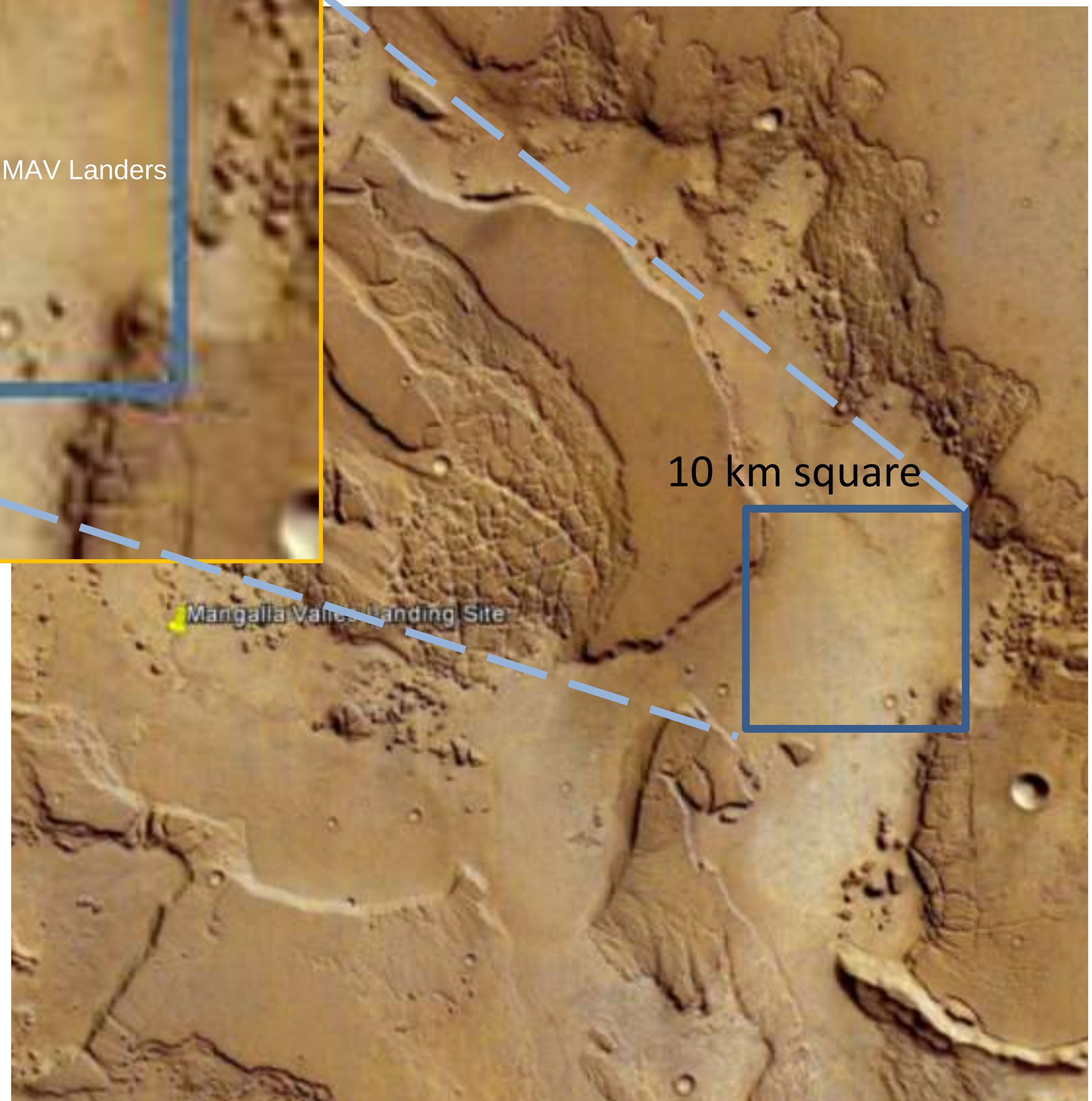






Example site: Jezero Crater

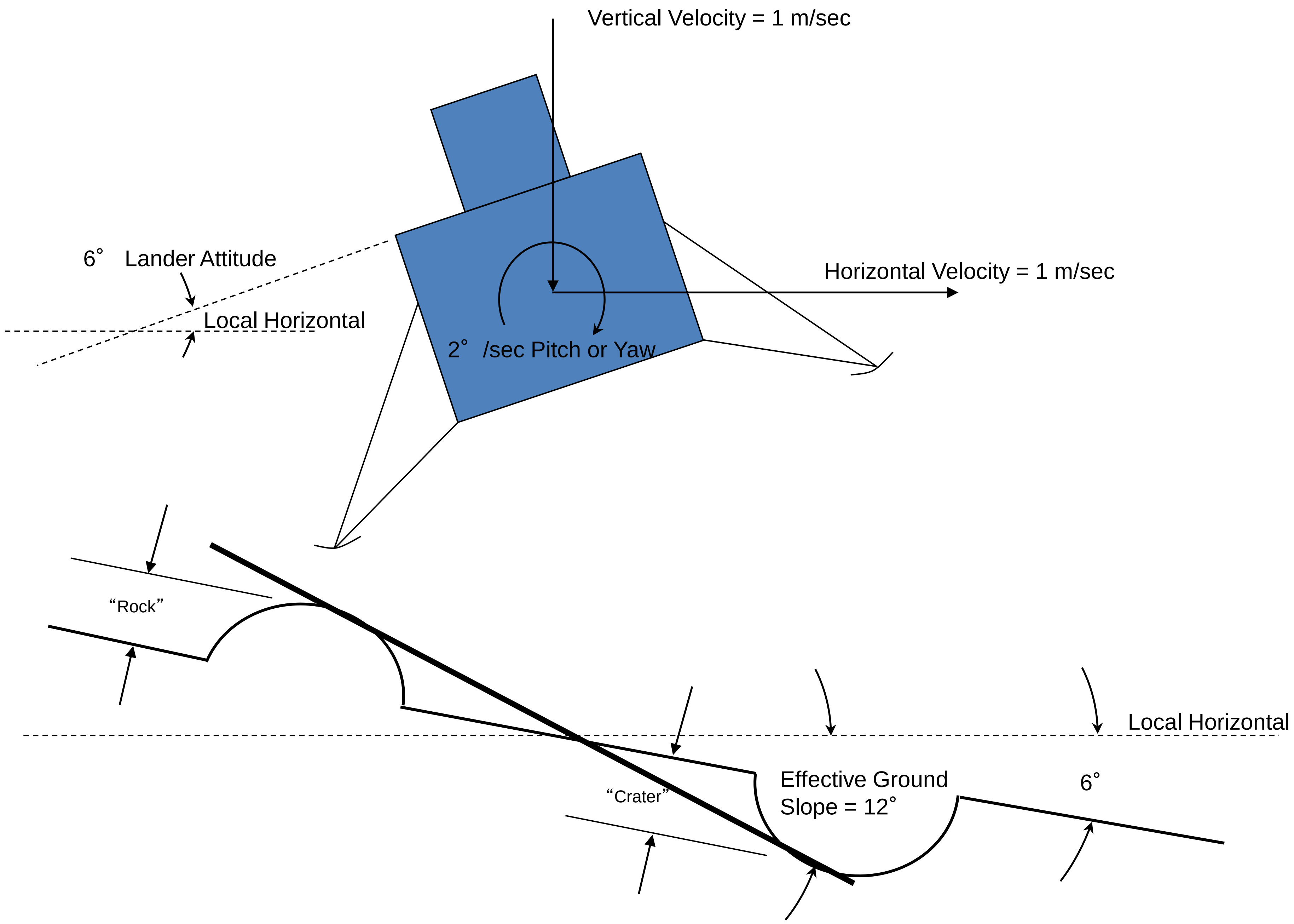




Example landing site at Mangalla Valles

ALHAT REQUIREMENTS DRIVERS

- **Requirement to go essentially anywhere on the (lunar) surface**
  - Global precision – Land within 100 meters (3-sigma) of a pre-mission defined landing location
  - Local precision – Land within a few meters of the center of a safe area determined in real-time
    - Pre-positioned active or passive beacons/markers enhance this capability but are not required
- **Hazard detection and avoidance**
  - Avoid 30 centimeter hazards and 5 degree slopes
- **Global planetary access also requires the ability to land under a wide variety of lighting conditions. Conservative approach is to require capability under any lighting conditions**
- **Guidelines are for utilization of terrain sensing technology systems for precision landing and hazard detection and avoidance**

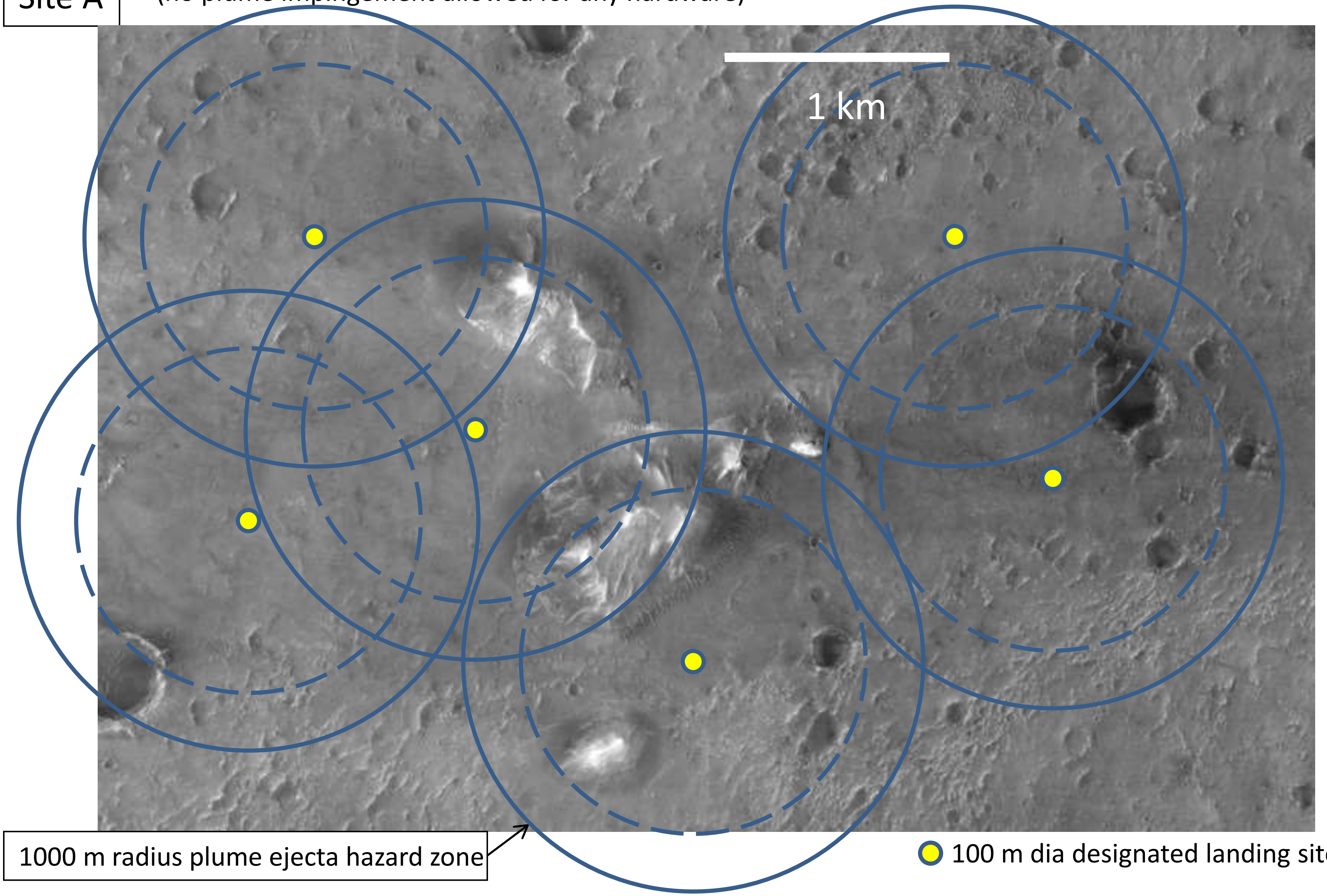


Vertical Velocity = 1 m/sec
6° Lander Attitude
Local Horizontal
Horizontal Velocity = 1 m/sec
2° /sec Pitch or Yaw
"Rock"
Local Horizontal
"Crater"
Effective Ground Slope = 12°
6°

Non-Interfering Landing Zones at Site A

Site A

(no plume impingement allowed for any hardware)



1000 m radius plume ejecta hazard zone

100 m dia designated landing site

Architectural Field Station Analog – McMurdo Station Antarctica

Emplacement

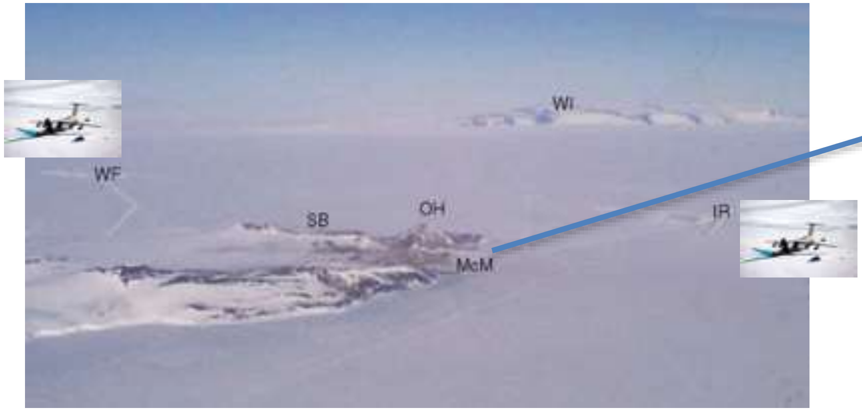
British National Antarctic Expedition 1902
R.F. Scott's "winter quarters hut." Used for both local scientific research and as a logistical base for traverses inland.

Permanent occupation - 1955
Naval Air Facility McMurdo part of "Operation Deep Freeze" to support the International Geophysical Year. A collection of semi-permanent structures (e.g., tents, Jamesway huts)

Mars Surface Proving Ground

McMurdo Station Today
Antarctica's largest community and a functional, modern-day science station, including a harbour, three airfields (two seasonal), a heliport, and more than 100 permanent buildings

Utilization



Considerations and Constraints for Locating the Mars Surface Field Station

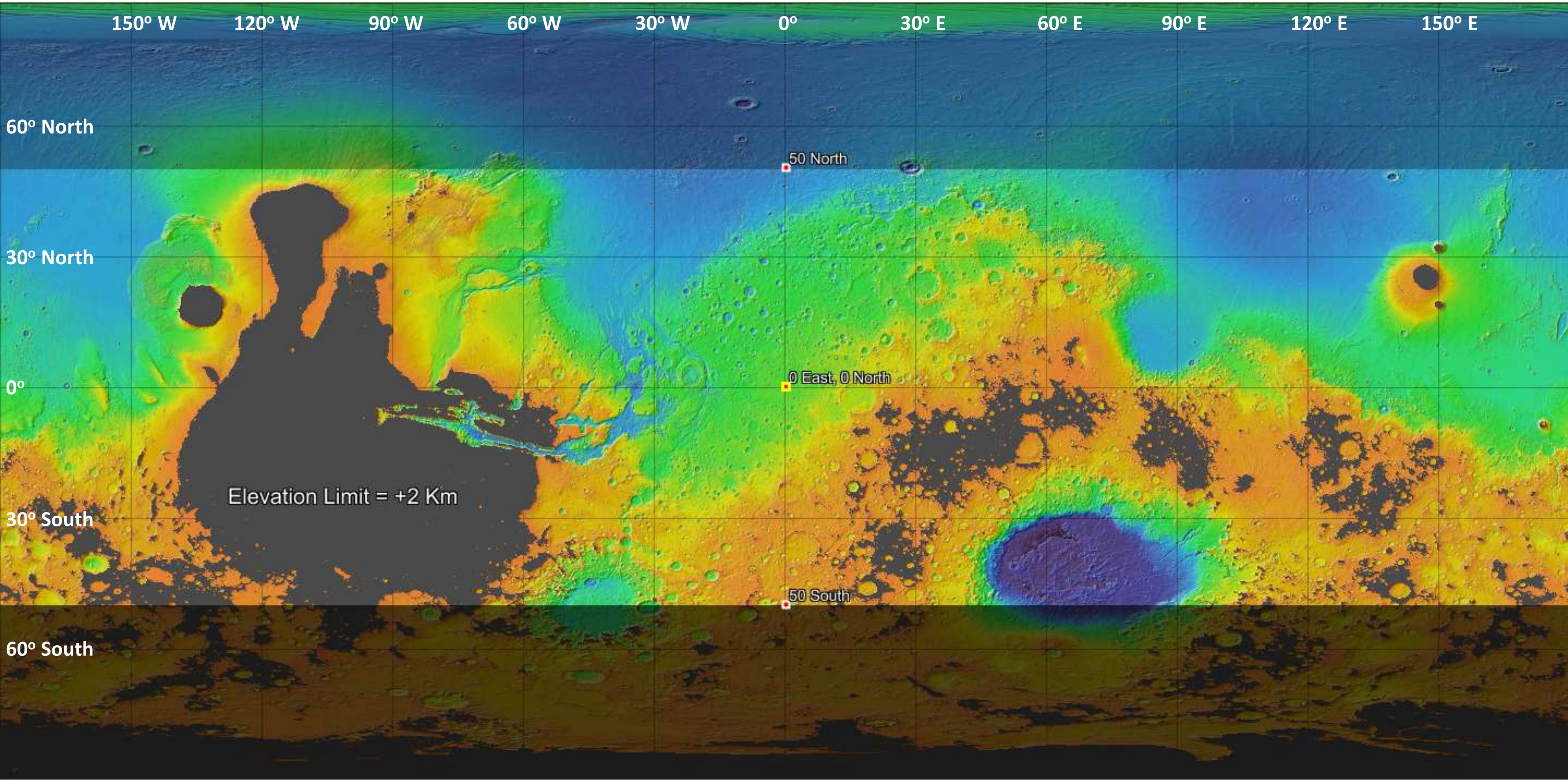
- **Mission objective areas**
  - Human (and eventually plant) physiology in the Martian surface environment
  - Basic exploration of Mars – comparable to MEPAG Goals I – III
  - Applied exploration of Mars – in situ resource utilization (ISRU) and civil engineering
- **Trajectory options allow for surface missions as long as 300 – 500 sols**
  - Activity scope and duration should make meaningful use of available crew time
- **Surface infrastructure will be built up at a single location**
  - Surface systems can be augmented or changed by subsequent missions/crews
- **Technology and system improvements incorporated**
  - Landing accuracy within 100 meters of designated location
  - Surface traversing capability out to 100 km radius and 2-week duration

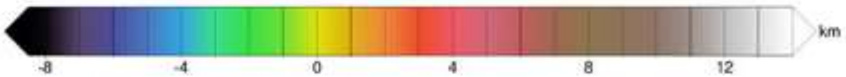
EZs, ROIs, and Boundaries

- **Exploration Zone**
  - A collection of Regions of Interest (ROIs) that are located within approximately 100 kilometers of a centralized landing site
- **Region of Interest**
  - Areas that are relevant for scientific investigation and/or development/maturation of capabilities and resources necessary for a sustainable human presence
- **Latitude and Elevation limits**
  - Landing and ascent technology options place boundaries on surface locations leading to a preference for mid- to low- latitudes and mid- to low- elevations
  - Accessing water ice for science and ISRU purposes is attractive, leading to a preference for higher latitudes
  - Preliminary latitude boundaries set at +/- 50 degrees
  - Preliminary elevation boundary set at no higher than +2 km (MOLA reference)

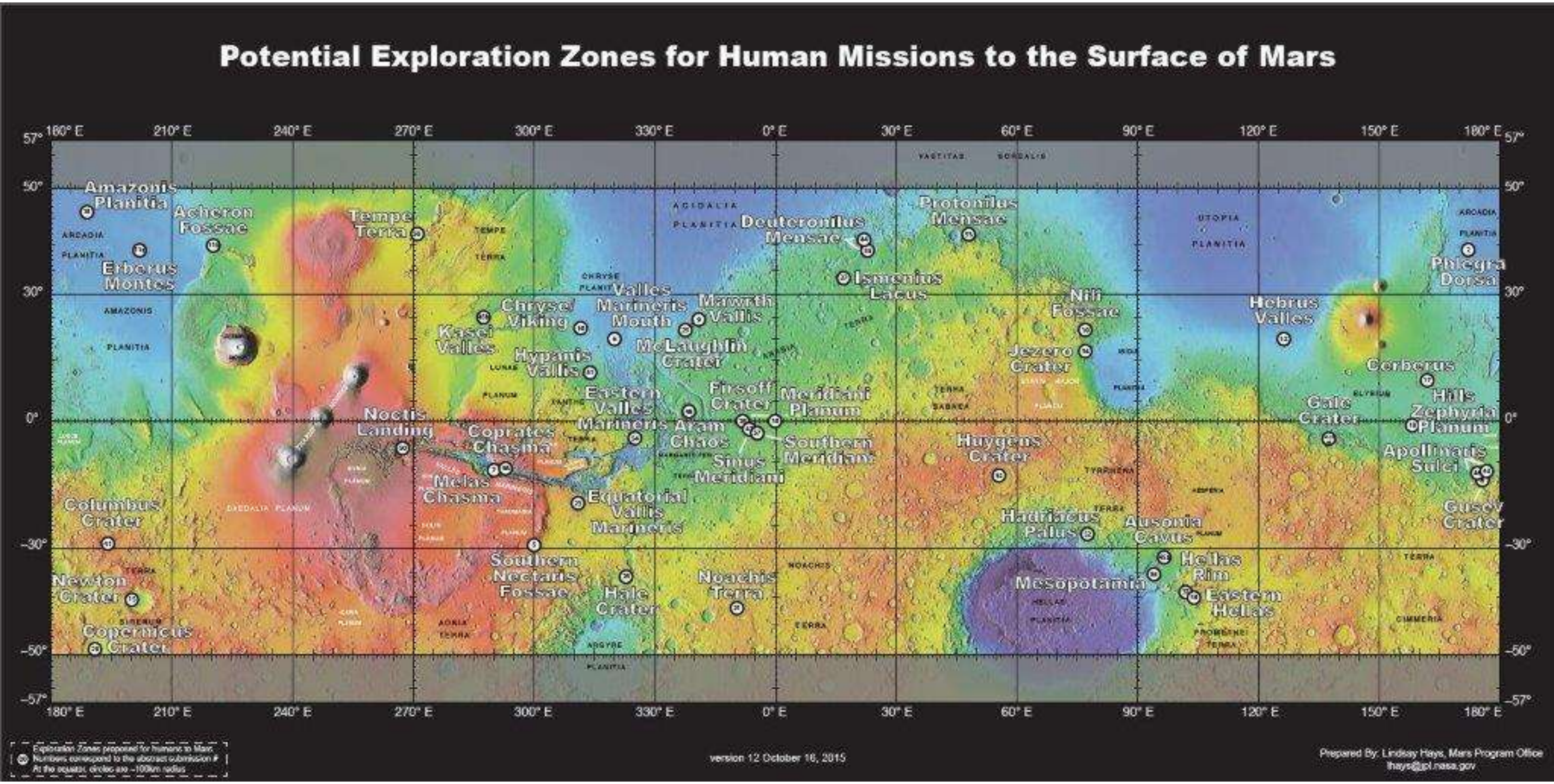
Preliminary Mars Surface Location Constraints for EZs

Elevation Limit = +2 km   Latitude Limits = +/- 50º





Proposed Exploration Zones



EZ Workshop Findings

- **FINDING #1: There was strong consensus that, at a scale of 100 km (radius), multiple places on Mars exist that have both sufficient scientific interest to sustain multiple crews of exploring astronauts, AND potential resource deposits for ISRU. There is no rationale (at least at this point in the EZ selection process) to change this figure (e.g. to 150 km radius).**
- **FINDING #2: Very few sites were proposed poleward of 45 degrees, even though by the rules of this Workshop, sites up to 50 degrees both north and south were allowed.**
- **FINDING #3: There was agreement that new data types (needed for more definitive analysis of EZs) argued strongly for a new orbiter mission, and possibly one or more surface missions, to obtain these data.**
- **FINDING #4: Workshop participants strongly endorsed the concept of an Announcement of Opportunity to support more detailed analyses of EZs as described by the Workshop organizers.**
- **FINDING #5: There was general consensus that this Workshop was an excellent start to identifying a place where future human missions to Mars can productively explore this planet and learn to live and work there for the long term. The participants expressed a strong desire to maintain the momentum started by this Workshop, which was understood to include more extensive analyses of the EZs presented and building the community of science and resources/engineering interests that came together to carry out these EZ analyses.**