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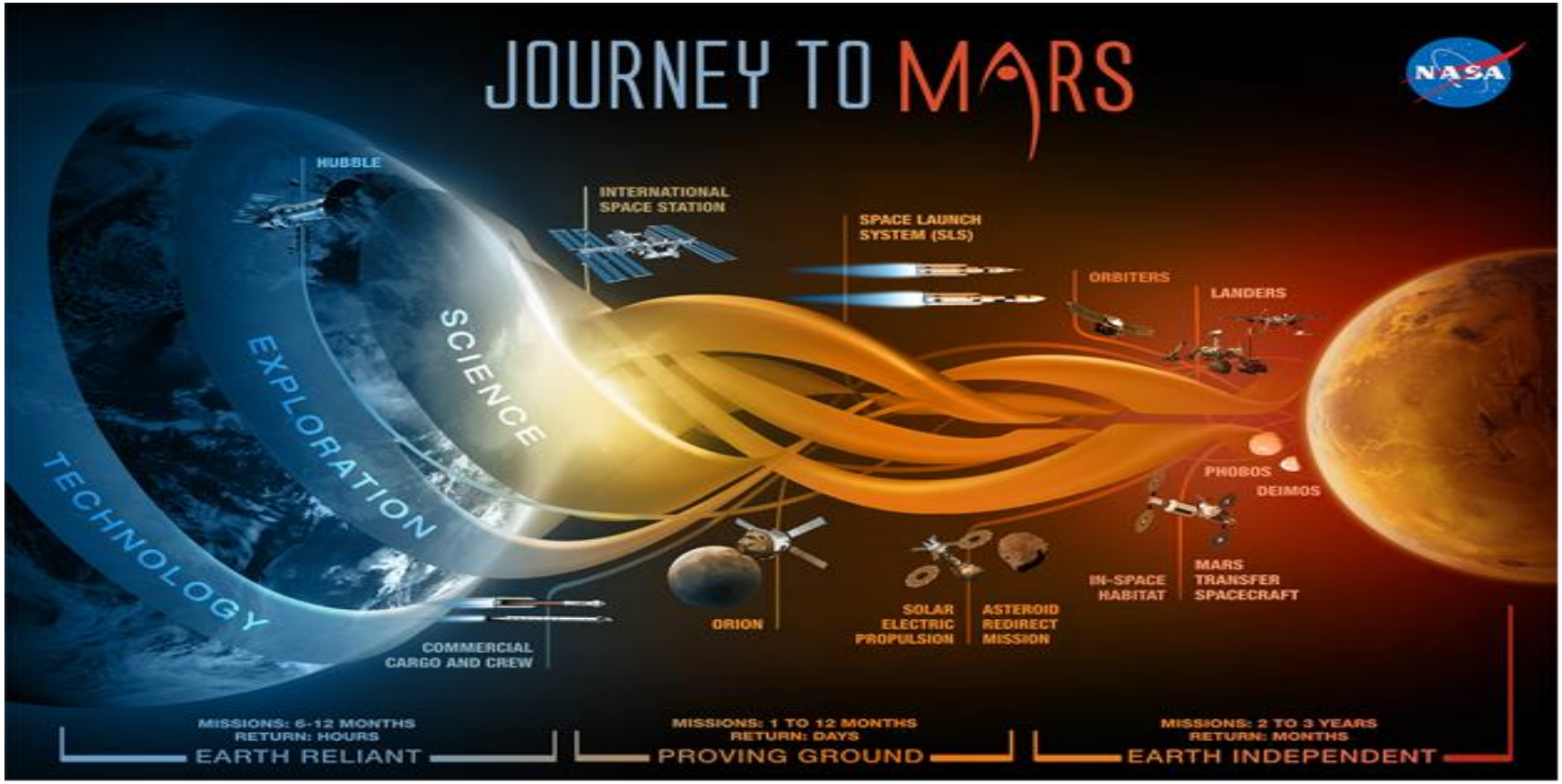
# Human Mars Landing Site and Impacts on Mars Surface Operations

Ben Bussey, Ph.D., NASA Headquarters
Stephen J. Hoffman, Ph.D., Science Applications International Corporation

# 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**
- **Factors that affect the selection of a location for the Mars Surface Field Station**
- **First EZ Workshop results**

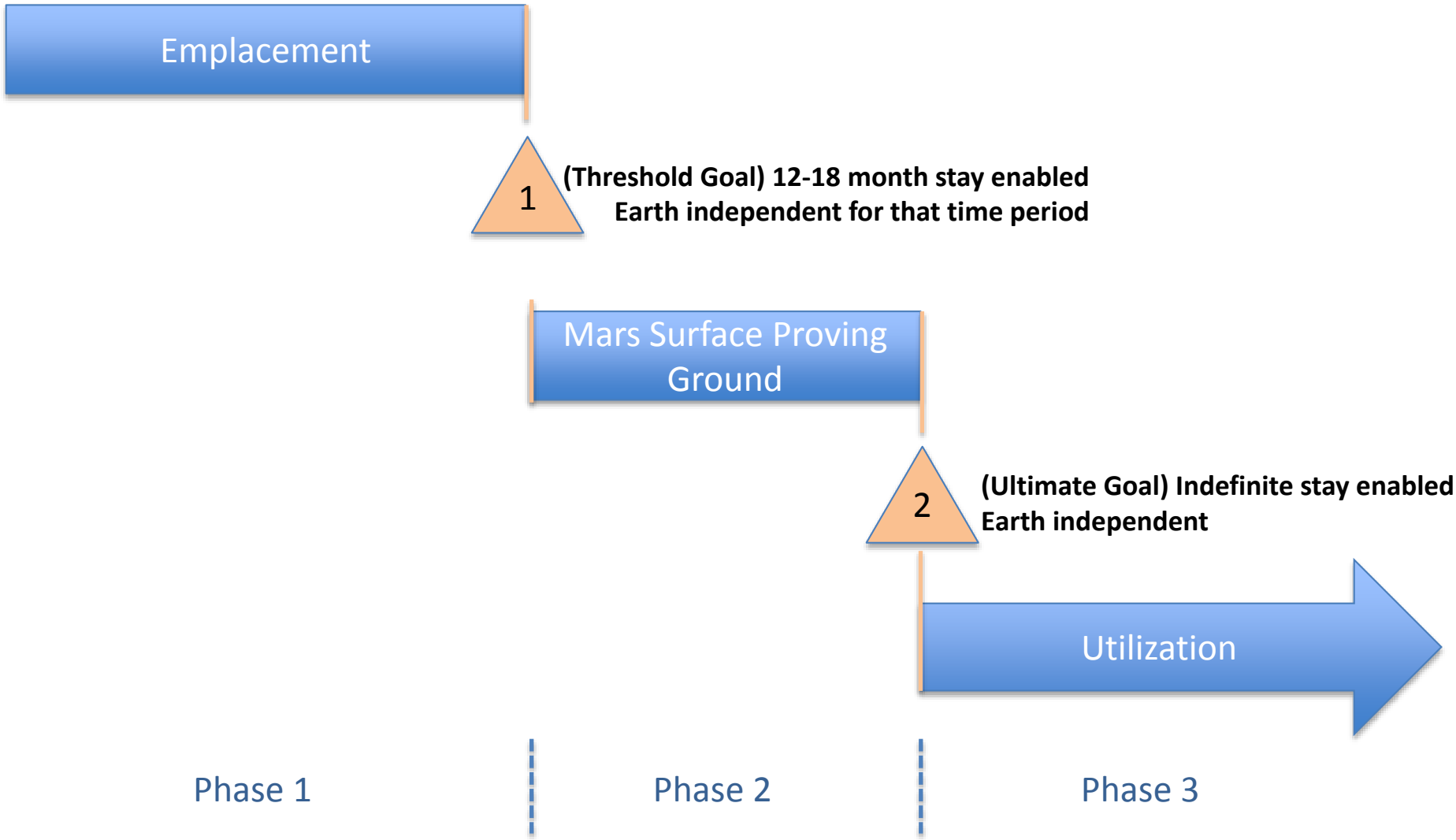
# Key Questions for the Evolvable Mars Campaign




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

*Where on Mars is the "best" place to conduct these pioneering activities?*

# Architecture Approach within the EMC – Mars Surface

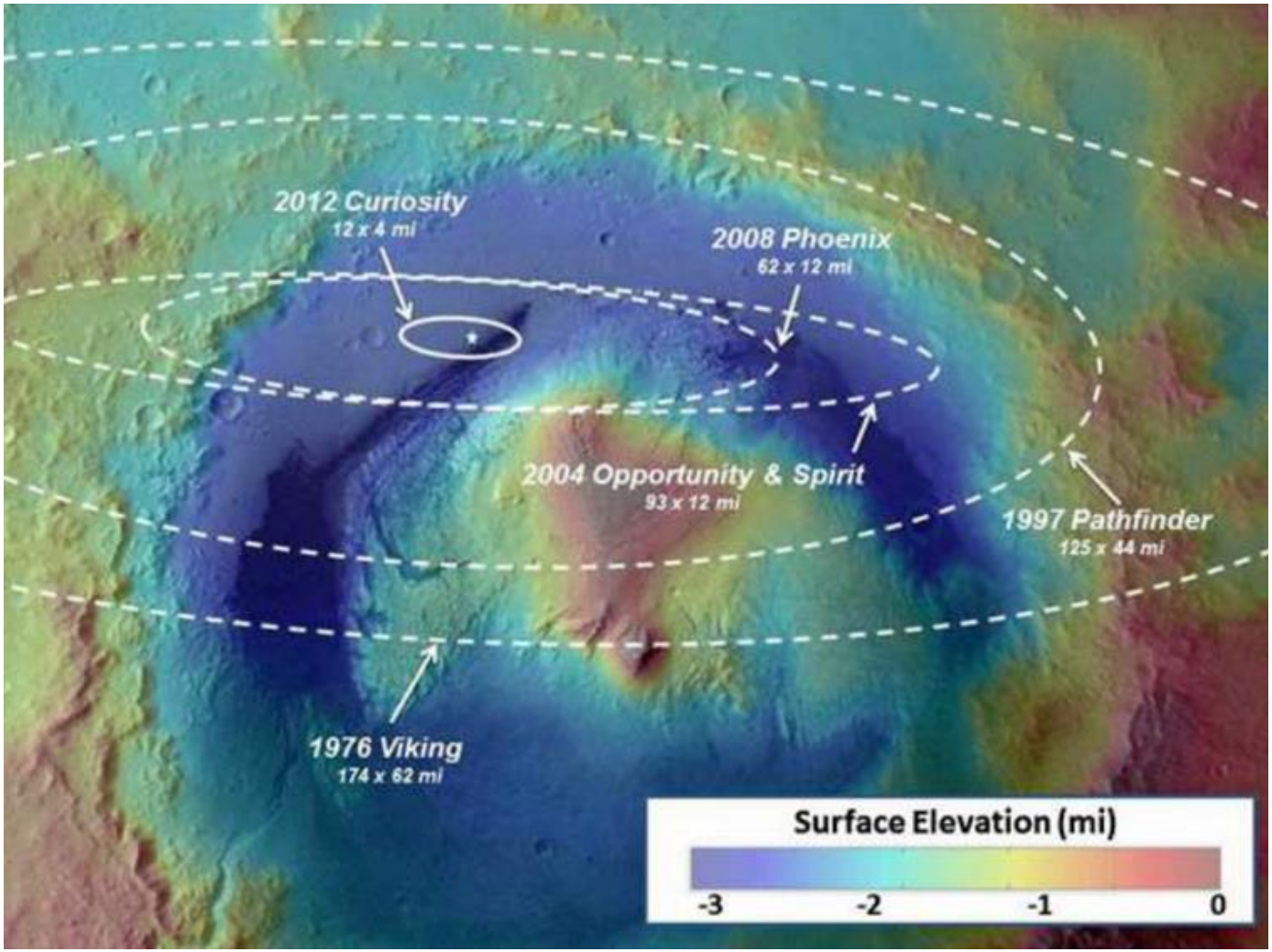



See Toups and Hoffman "Pioneering Objectives and Activities on the Surface of Mars," AIAA Space 2015

# Considerations and Constraints for Locating the Mars Surface Field Station

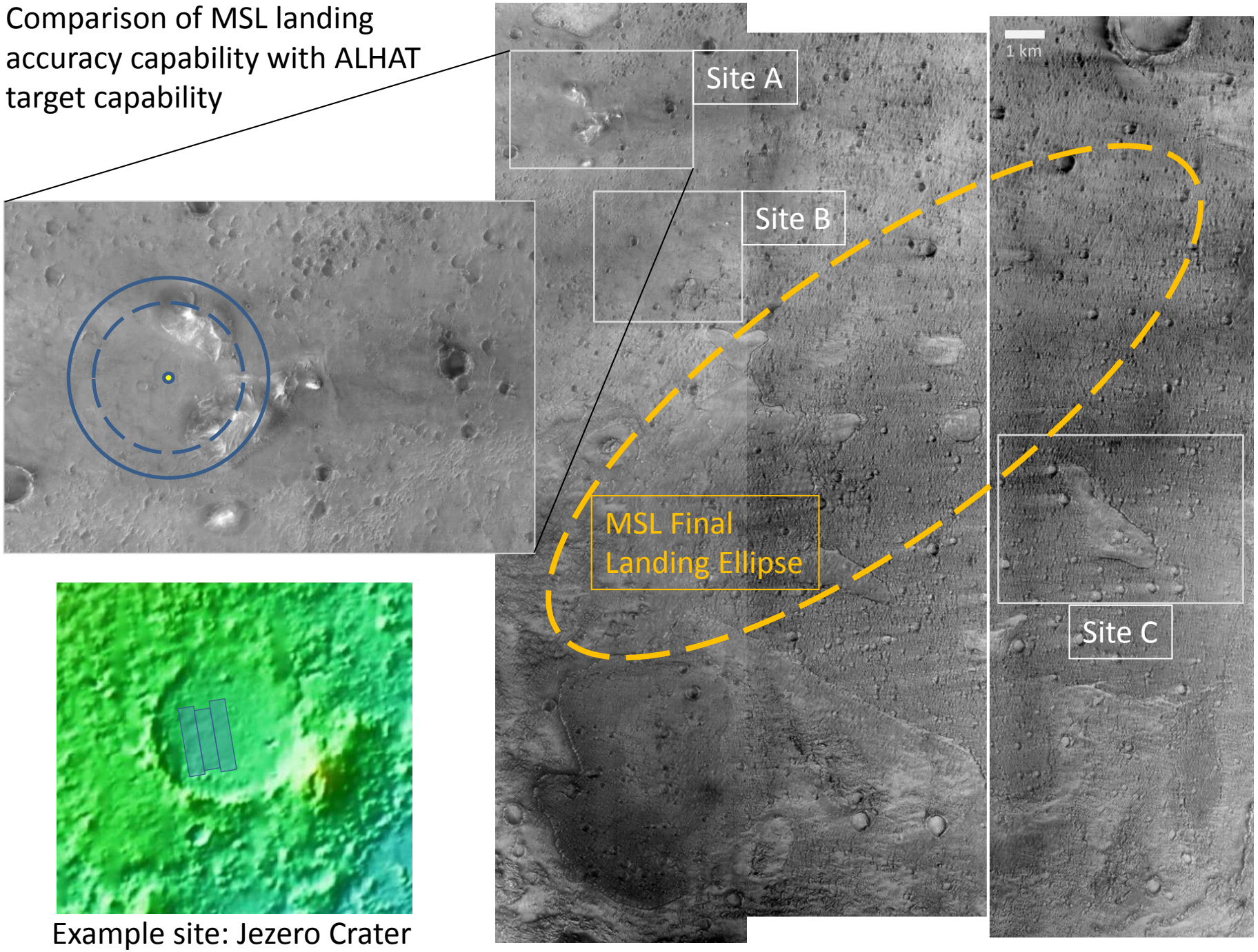
- **Mission objective areas**
  - Human (and eventually plant) physiology in the Martian surface environment
  - Basic exploration of Mars – comparable to MEPAG Goals I – III
  - Applied exploration of Mars – in situ resource utilization (ISRU) and civil engineering
- **Trajectory options allow for surface 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

# Mars Landing Accuracy Improvements to Date




Example site: Gale Crater

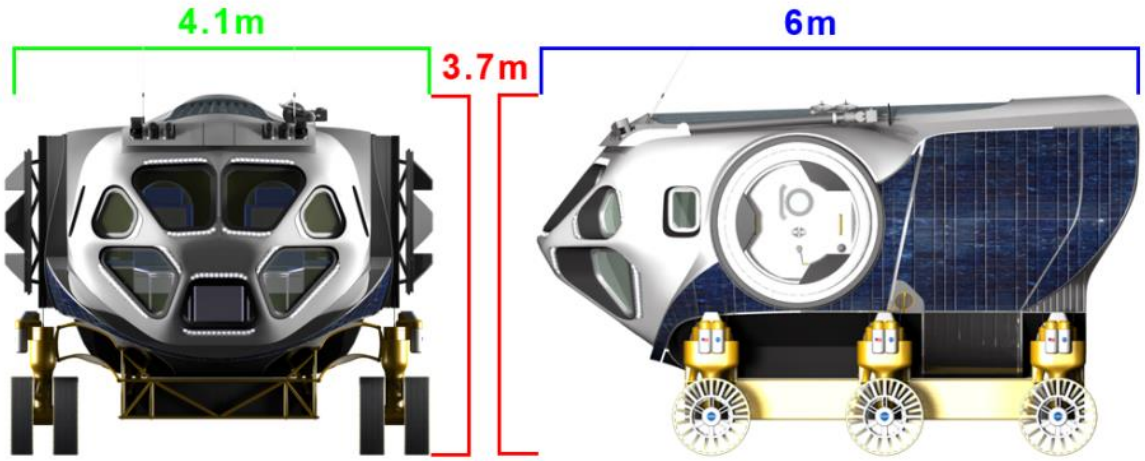
Comparison of MSL landing accuracy capability with ALHAT target capability






Example site: Jezero Crater

# Small Pressurized Rover

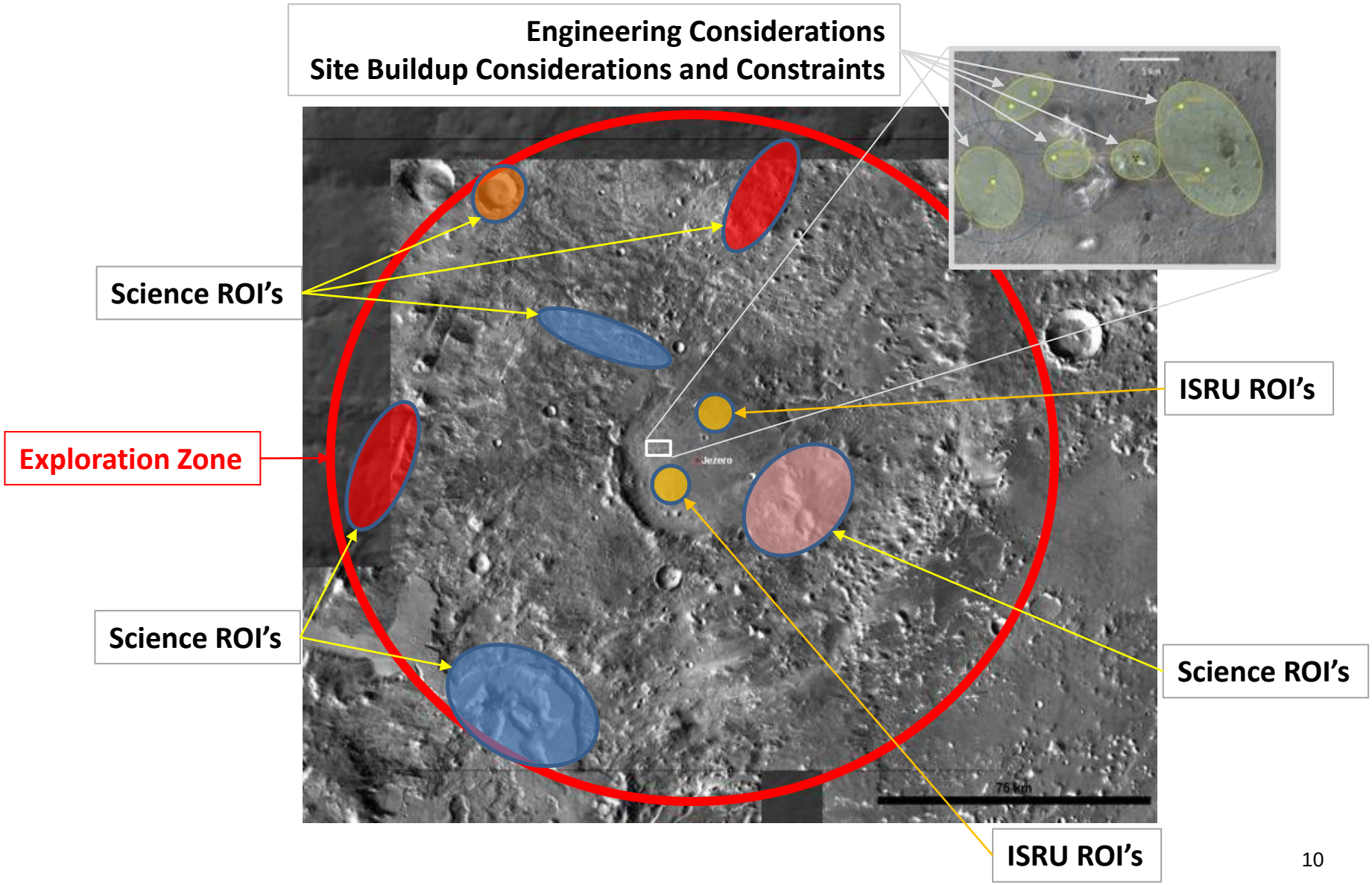



- Two crew
  - capable of carrying four crew in a contingency
- Two week duration without resupply
- ~400 km “odometer” range
  - 200 km out, 200 km back
  - Factor of 2 for actual distance over straight line distance
  - ***Results in ~100 km straight line range from starting point***

# EZs, ROIs, and Boundaries

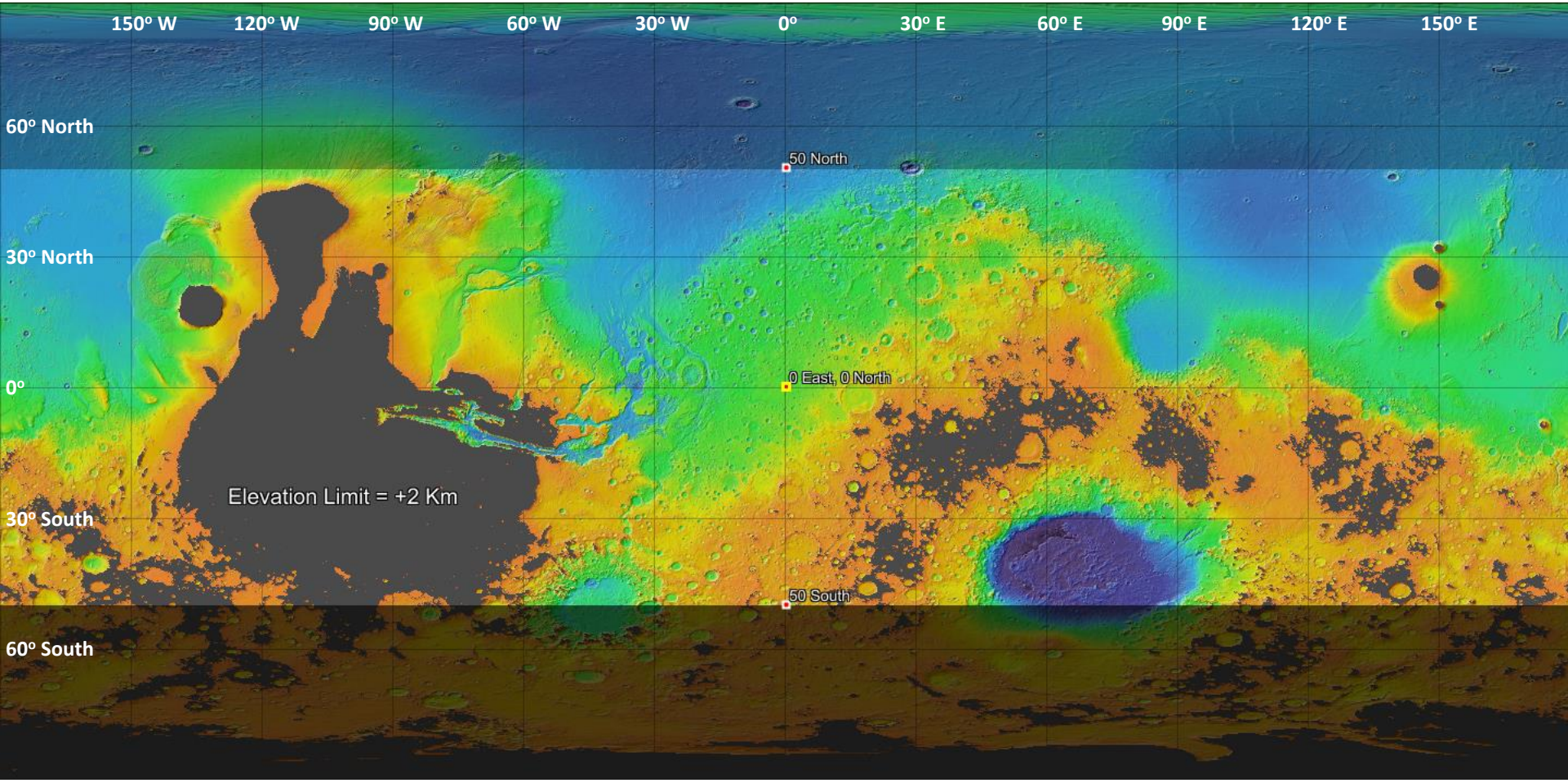
- **Exploration Zone**
  - A collection of Regions of Interest (ROIs) that are located within approximately 100 kilometers of a centralized landing site
- **Region of Interest**
  - Areas that are relevant for scientific investigation and/or development/maturation of capabilities and resources necessary 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)

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



# Preliminary Mars Surface Location Constraints for EZs

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

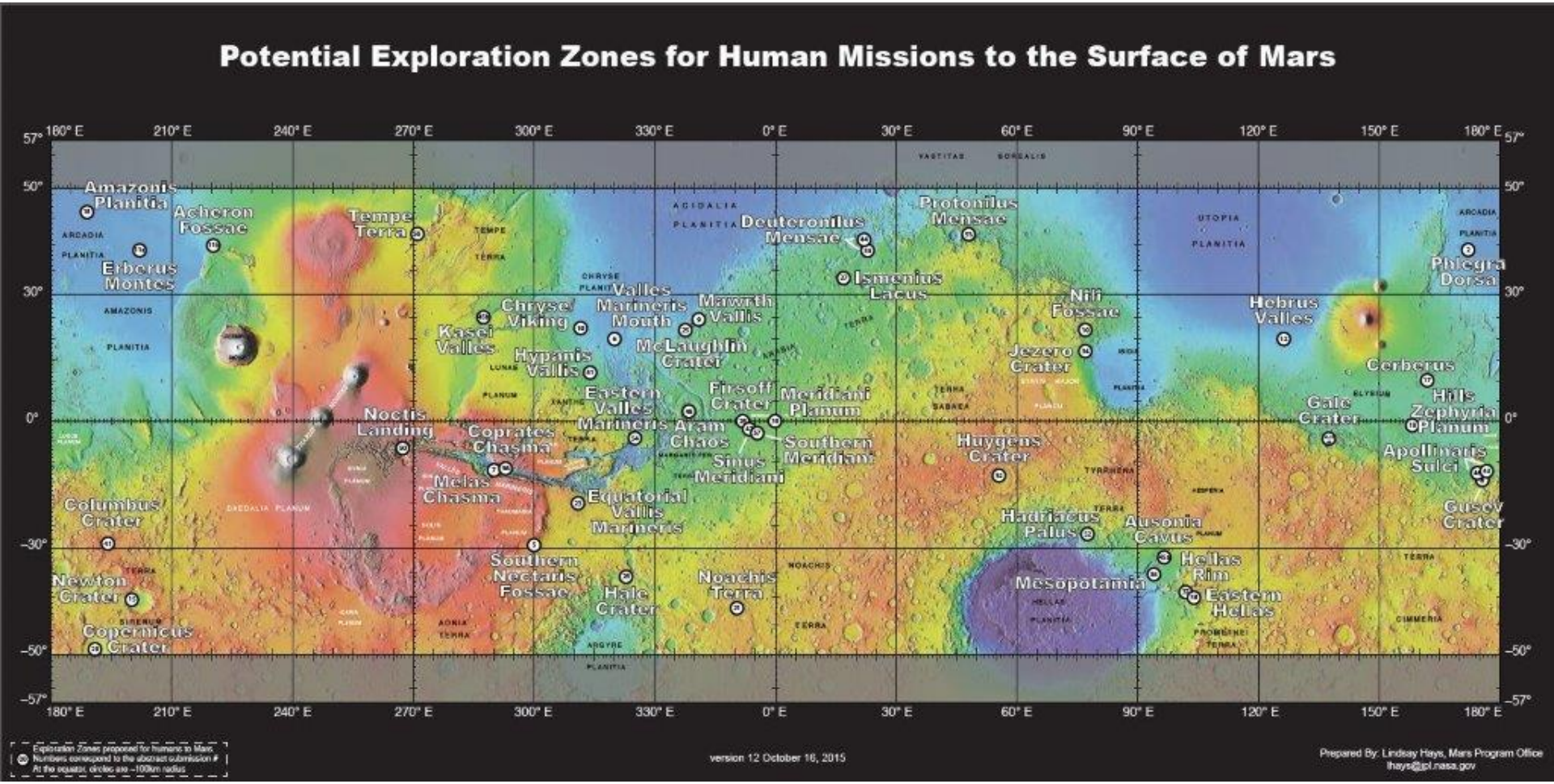



MOLA Color Legend

# First EZ Workshop

- **A joint HEOMD and SMD steering committee organized a workshop to discuss EZ locations**
- **Selection criteria for science and ISRU/CE ROIs was prepared and distributed**
  - These criteria are in an appendix to the Bussey Hoffman paper
- **Forty-five individuals or teams proposed 47 EZs**
- **Video of each presentation, along with the presentation materials used, have been posted for future reference**
  - URLs for videos and presentation materials are in the Bussey Hoffman paper

# Exploration Zones Proposed at First EZ Workshop




This map is posted at http://www.nasa.gov/sites/default/files/atoms/files/exploration-zone-map-v10.pdf

# 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.**

# Summary

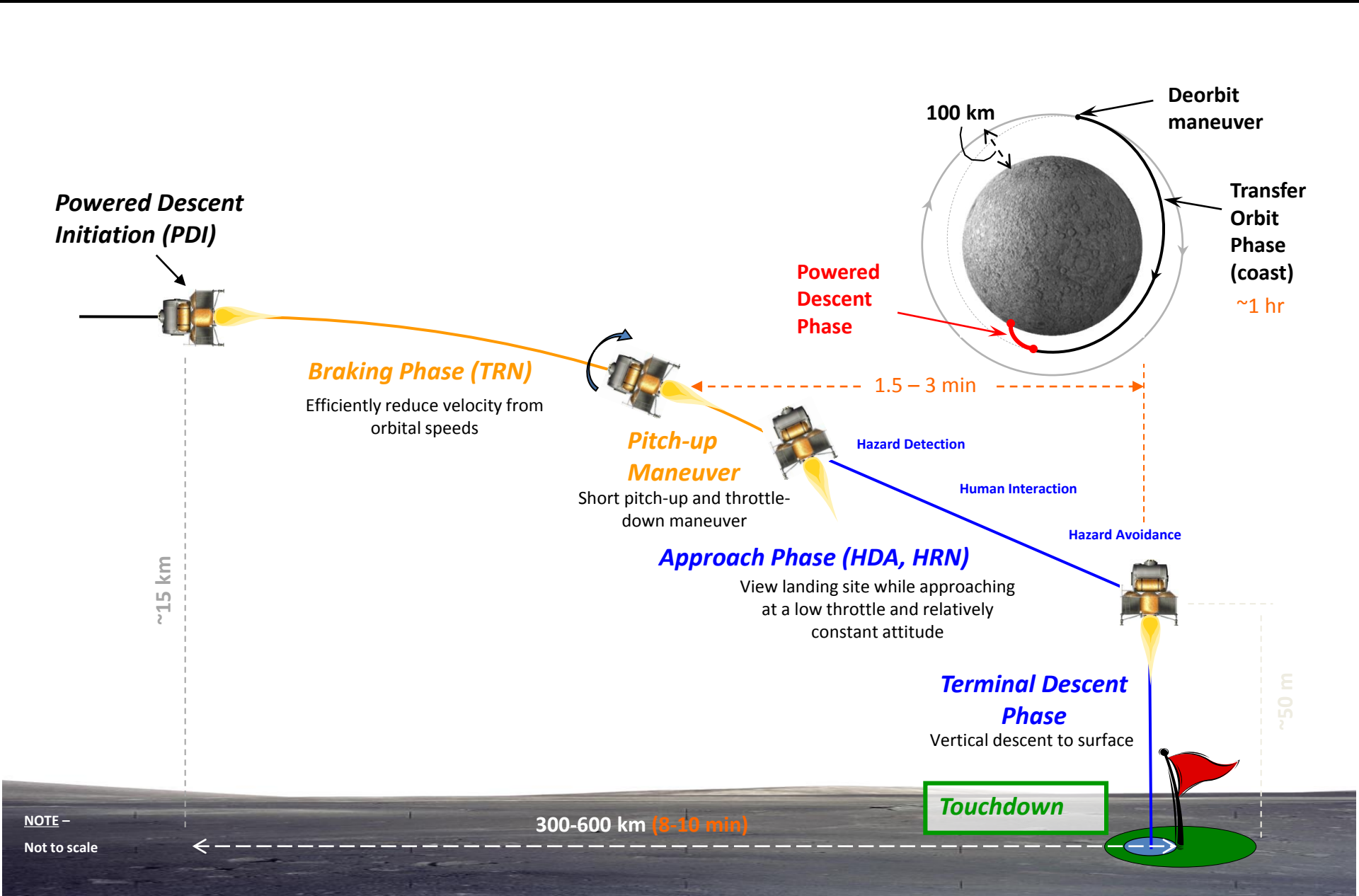
- Recent work on the Evolvable Mars Campaign has started a process to identify a location on Mars where crews will land and explore
- Specific criteria have been documented and used to propose several Exploration Zones
- HEOMD is using these results to refine studies of EMC options
- SMD is supporting requests to gather EZ data using existing NASA assets at Mars
- Additional workshops focused on several relevant topics are in work

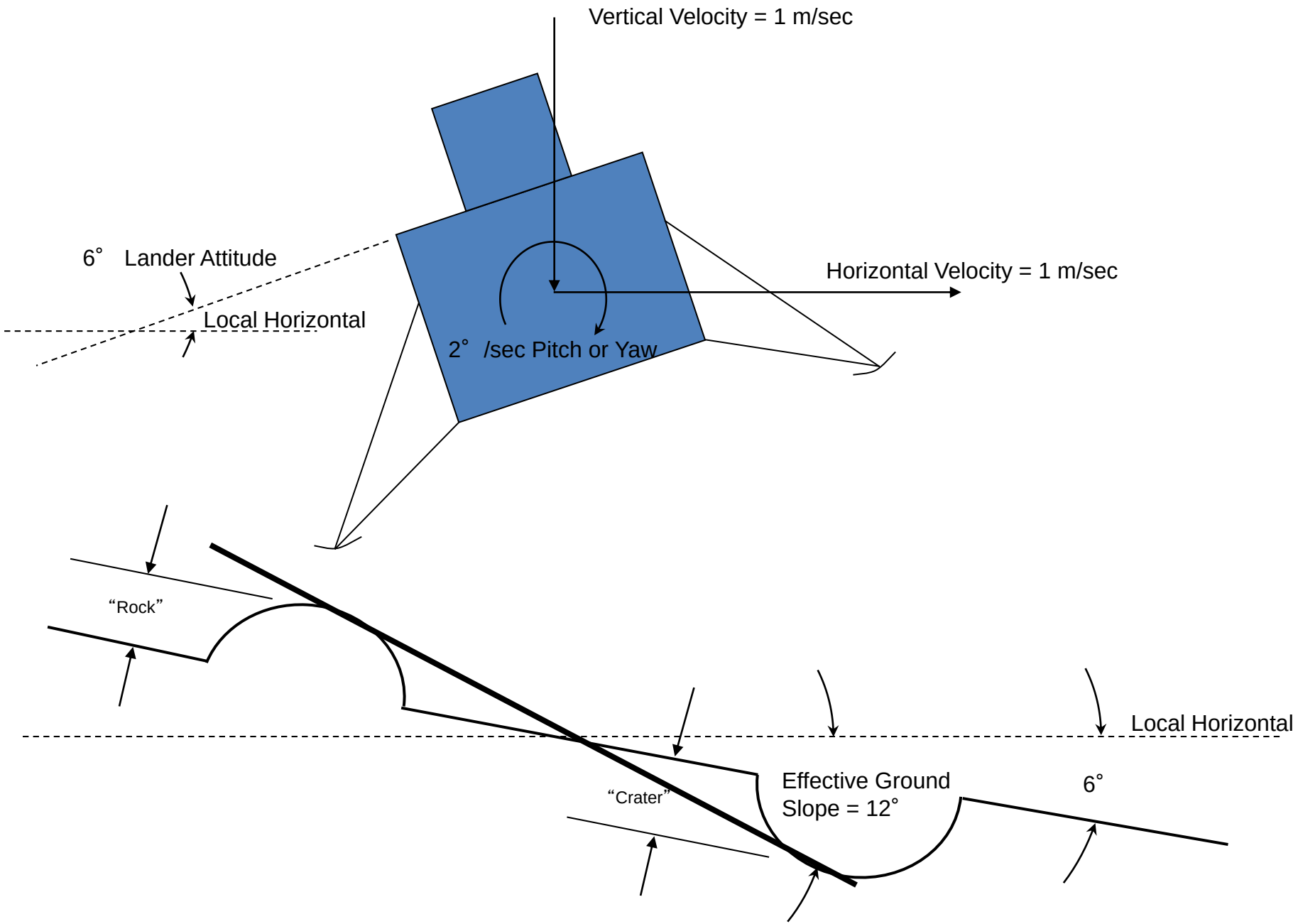
# Backup

# ALHAT Requirement 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**

# DESCENT & LANDING PHASES USING ALHAT




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°

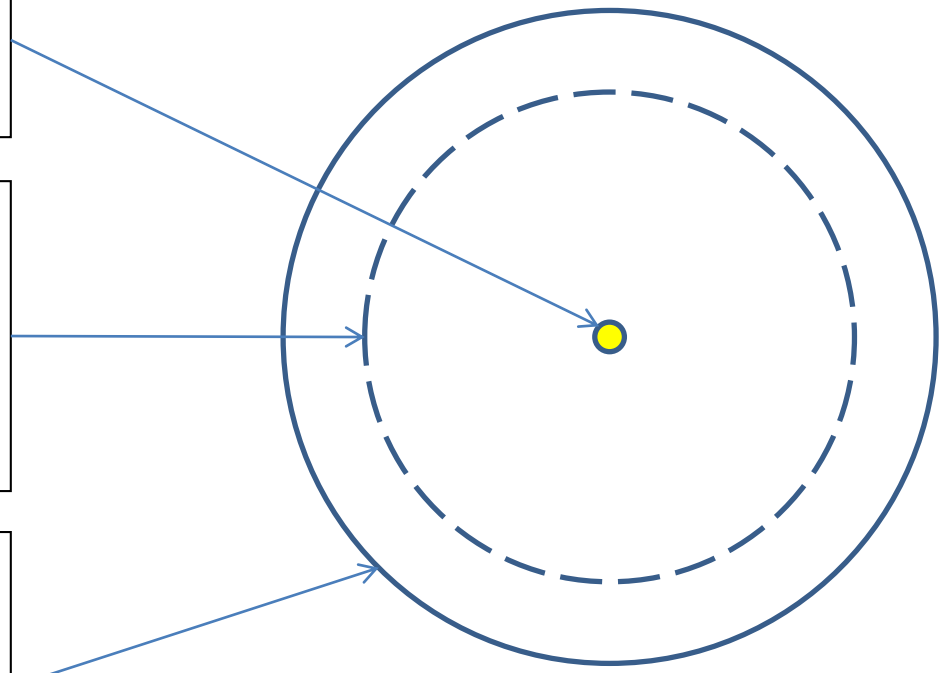
# Landing Site Symbology

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

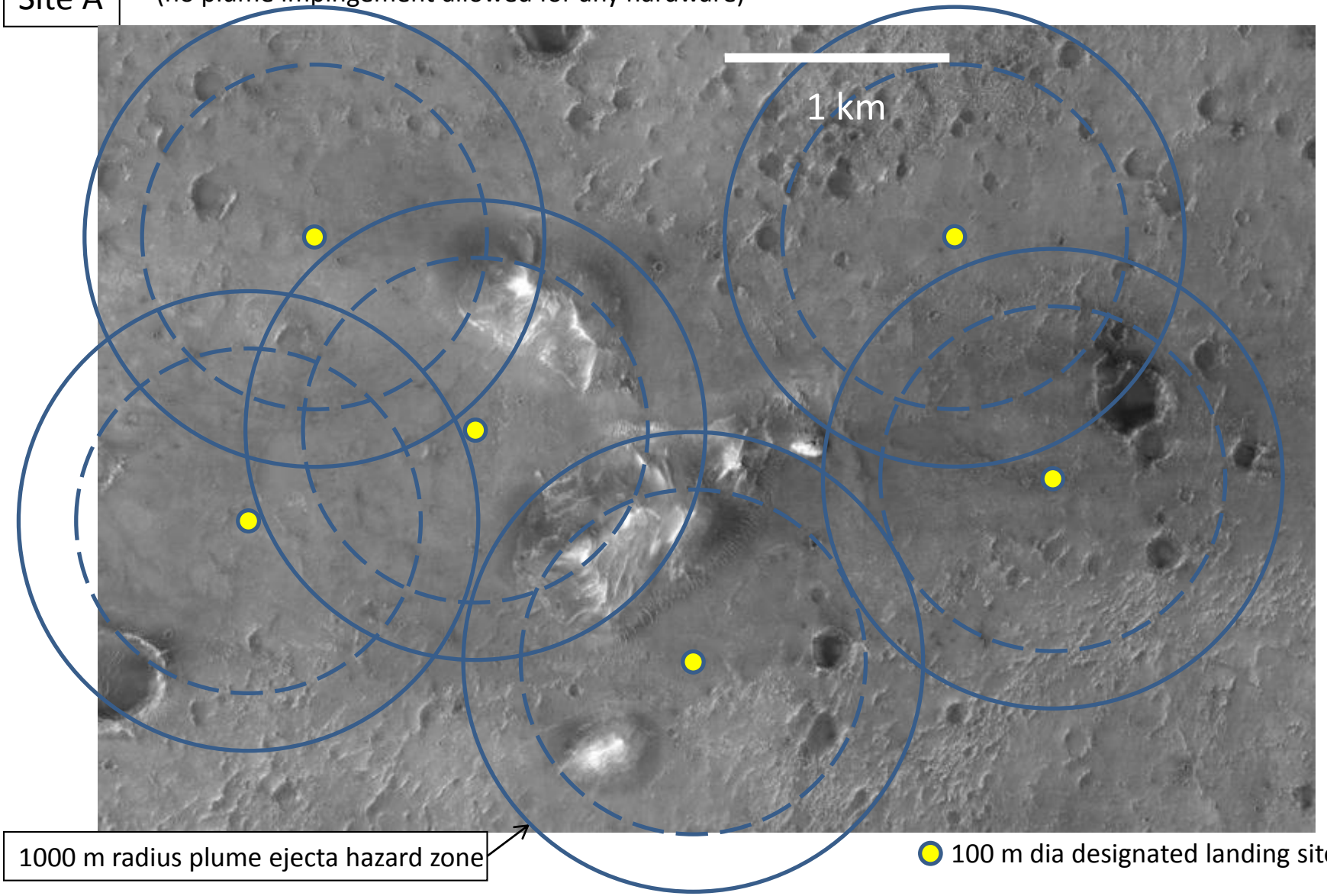
1000 meter diameter circle outside of which an element of surface infrastructure should be safe from terminal descent thruster debris



# Non-Interfering Landing Zones at Site A

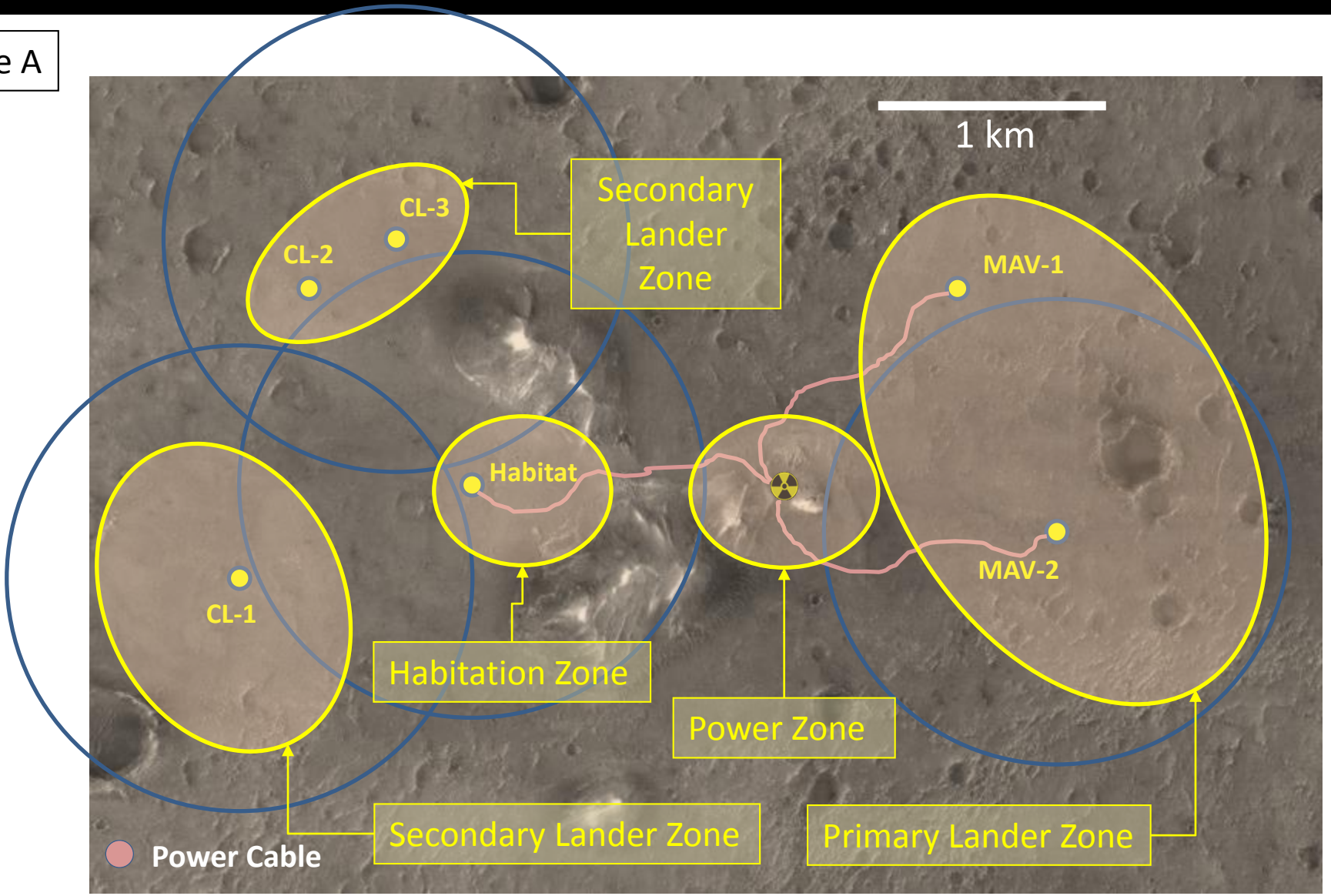
Site A

(no plume impingement allowed for any hardware)



# Example of Field Station Layout with Specific Utilization Zones Identified

Site A




(plume impingement *allowed* for any "dead" hardware)

# 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