HUMAN MARS MISSION OVERVIEW AND DUST STORM IMPACTS ON SITE SELECTION. S. J. Hoffman[1], Aerospace Corporation, NASA Johnson Space Center, 2101 NASA Parkway, Houston, Texas 77058, stephen.j.hoffman@nasa.gov.

Introduction: NASA has begun a process to identify and discuss candidate locations where humans could land, live and work on the martian surface. This process is being carried out as a cooperative effort by NASA's Human Exploration and Operations Mission Directorate (HEOMD), responsible for future human mission preparations, and the Science Mission Directorate (SMD), responsible for the on-going Mars Exploration Program of robotic vehicles in orbit and on the surface of Mars. Both of these Directorates have a significant interest in this process, as these candidate locations will be used by NASA as part of a multi-year effort to determine where and how humans could explore Mars. In the near term this process includes: (a) identifying locations that would maximize the potential science return from future human exploration missions, (b) identifying locations with the potential for resources required to support humans, (c) developing concepts and engineering systems needed by future human crews to conduct operations within a candidate location, and (d) identifying key characteristics of the proposed candidate locations that cannot be evaluated using existing data sets, thus helping to define precursor measurements needed in advance of human missions.

At present NASA is assessing different options for conducting these future human missions to Mars by means of coordinated studies, the results of which are assembled into an end-to-end mission description collectively known as the Evolvable Mars Campaign (EMC) [1]. To guide studies associated with the EMC over the past several years, a set of ground-rules and assumptions were established to examine one particular approach to the human exploration of Mars. Principle among these ground-rules and assumptions that are relevant to EMC activities was a choice to concentrate all of the surface assets needed to support human exploration at a single location and then send future crews to this site for subsequent missions. This contrasts with the scenario considered in Design Reference Architecture 5.0 (DRA 5.0) [2] in which a campaign of three missions would send crews to different locations on Mars. One outcome of the choice to concentrate all surface assets at a single location is the concept of an Exploration Zone (EZ), describing the features of a surface location where the activities of the human crews will take place (Figure 1) [3]. An EZ is a collection of Regions of Interest (ROIs) that are located within approximately 100 kilometers of a centralized landing area. ROIs are areas that are relevant for scientific investigation and/or development/maturation of capabilities and resources necessary for a sustainable human presence. The EZ also contains multiple landing sites within the centralized landing area, as well as a habitation area that will be used by multiple human crews during missions to explore and utilize the ROIs within the EZ. The "First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars," held on 27-30 October 2015, discussed 47 proposals for EZs and ROIs based on a set of criteria developed for our current understanding of both scientific and operational objectives for human missions [2]. Figure 2 shows the locations of these 47 proposed EZs.

Dust as a site selection factor: Dust will be one of several important factors considered when choosing from among proposed EZs: both the dust that is resident at the centralized landing sites and habitation zone when surface facilities are first established, and the potential for dust storms to originate or move through the site over time.

Each crew sent to the selected EZ will require several large landers to support their surface mission. Current EMC studies estimate three to four landers for each crew, depending on length of stay and equipment delivered [4]. Based on modeling of rocket plume interaction with surface materials (personal communication P. Metzger 2015), dust and other small, loose debris will be lofted by the terminal descent rocket engines of these landers, creating a surface hazard for other nearby assets. Depending on a number of factors, this surface material can achieve very high velocities and can be thrown several hundred meters from the lander. Consequently, it will be necessary to separate landing sites for all of the landers supporting a crew by a significant distance. Until better data is available, the working assumption for this separation distance is 1000 meters; yet it is also desirable to have all of these landers as close together as possible at the centralized landing site. Figure 3 illustrates how several potential landing sites could be arrayed around a specific surface location, taking this separation distance into account. Some of these landing sites will be used one time (e.g., delivering a surface habitat) and some can be reused once all useful material has been removed from a preceding lander. Figure 4 illustrates how the landing sites portrayed in Figure 3 could be transformed into a multi-use surface field station [4].

In addition to dust already resident at the site, site selection consideration must also be given to dust storms that could originate at or pass over the EZ. Dust storms over the centralized landing sites could delay the arrival of landers or the departure of the crew at the end of their surface mission. In addition, dust storms during the surface mission could impact the operation of surface equipment (discussed later by M. Rucker) or surface operations, such as EVAs or rover operations by the crew away from the central habitation zone. The lower portion of Figure 5 shows the frequency and duration of regional dust storms for several martian years [5]. The central portion of Figure 5 shows the duration of three different surface mission opportunities for two different propulsion types (a "hybrid" propulsion system and a "split" propulsion system). The message of this chart is that the orbit mechanics of getting to and from Mars will cause some crews to spend most or all of their surface mission on the ground during the most active dust storm season of a martian year. Figure 6 shows the pathways taken by the majority of these regional dust storms as they grow and/or move across the surface [5]. Figure 7 indicates where individual dust storms, regardless of size, have formed without necessarily moving away from these formation locations [5]. Overlaying Figures 6 or 7 with Figure 2 provides an initial indication of the dust storm potential at any one of these proposed EZs.

Conclusion: NASA is in the process of defining where and how human crews sent to Mars will land, live and work on the martian surface. Current assumptions presume a single site to which multiple crews will be sent during the course of an exploration campaign. Many factors will go into selecting this single site, but a significant factor will be the dust that either resides at or is brought to this site by local environmental conditions. Understanding dust and dust storms will inform how to incorporate dust into site selection criteria.

References

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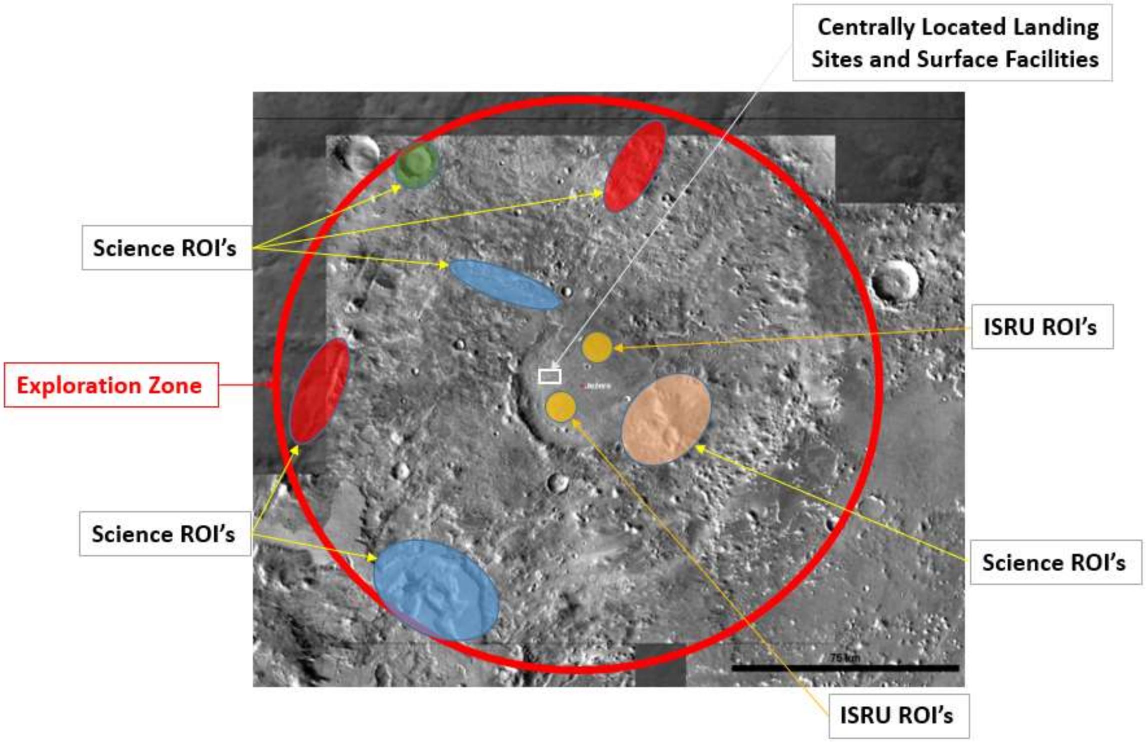

Figure 1. Example Mars Exploration Zone Containing Several Regions of Interest (ROI's) [3]

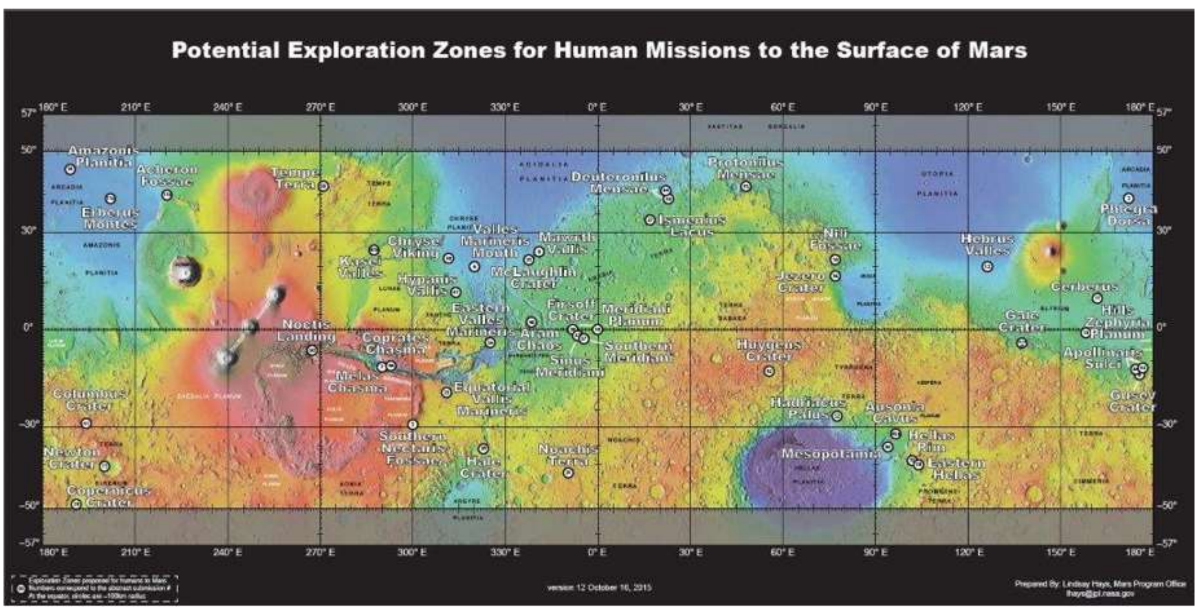

Figure 2. Exploration Zones Proposed at First EZ Workshop [3]

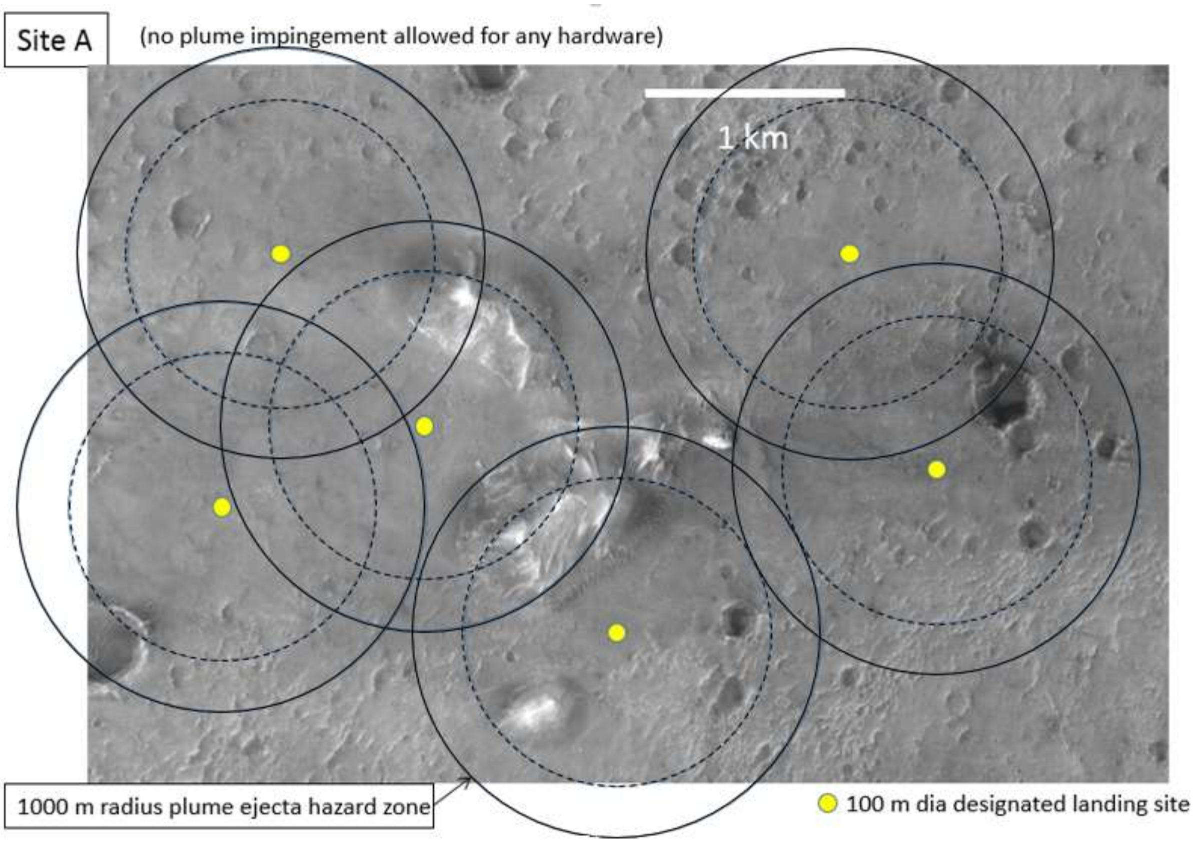

Figure 3. Example of Non-Interfering Landing Zones [4]

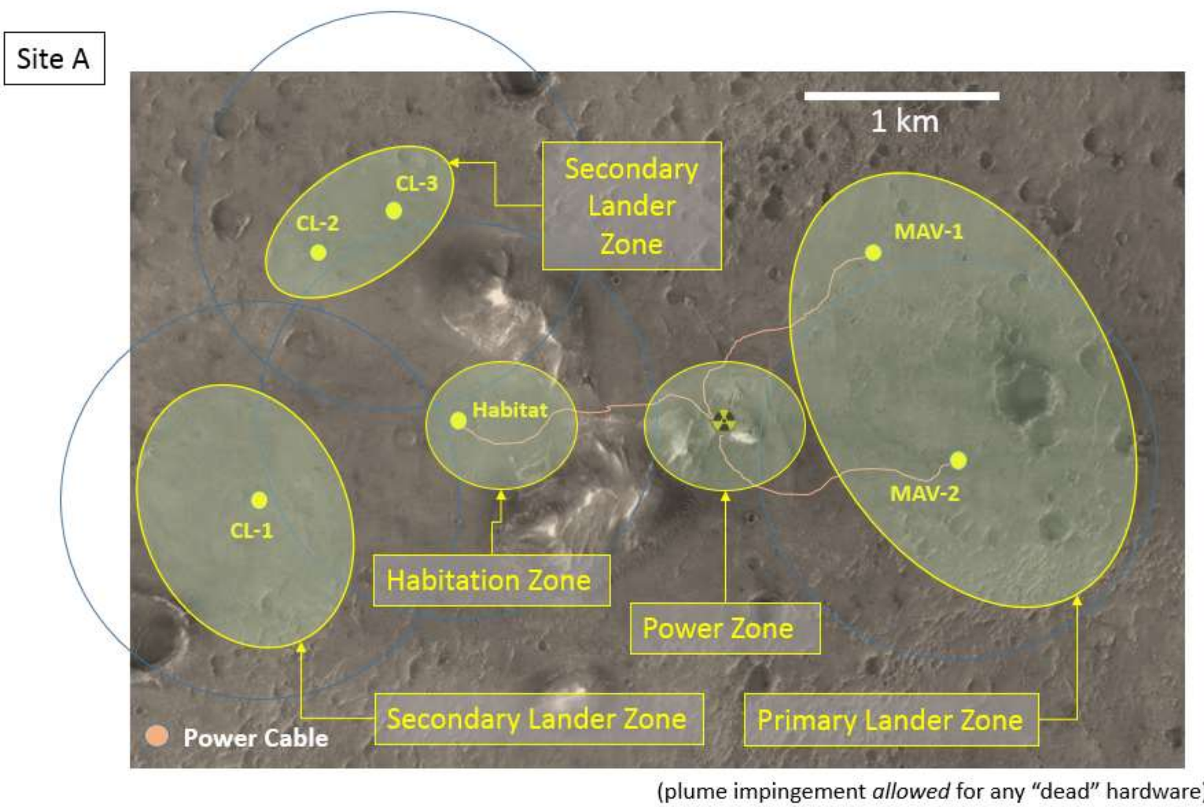

Figure 4. Example of Field Station Layout with Specific Utilization Zones Identified [4]

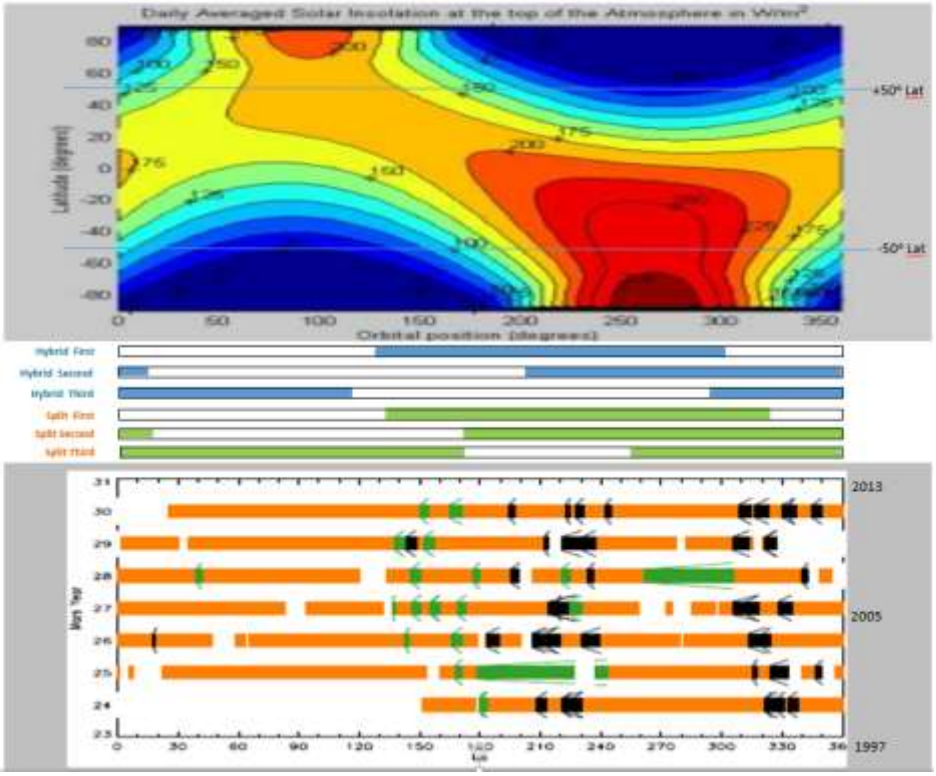

Figure 5. Relative Timing of Mars Surface Missions and Regional Dust Storm History [5,6]

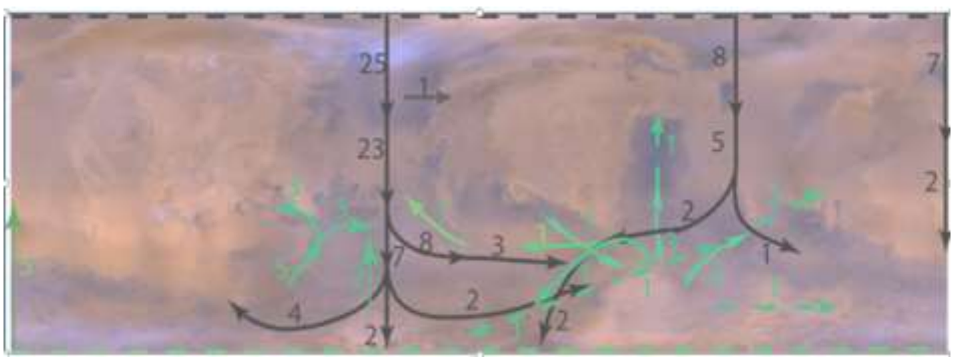

Figure 6. Pathways Followed by Regional Dust Storms [5]

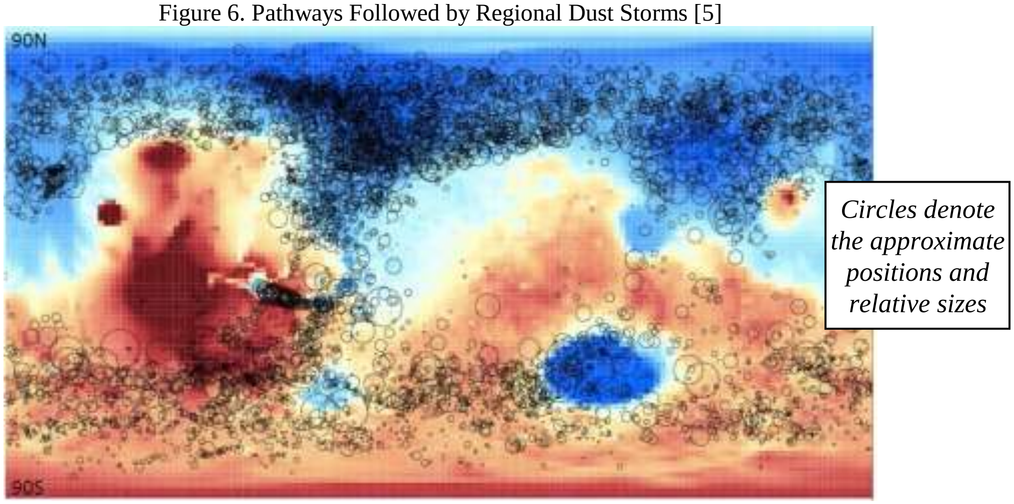

Figure 7. Spatial Distribution of Dust Storms Derived from 4 Mars Years of MARCI MDGMs [5]