

# Mars Entry, Descent, Landing, and Ascent Systems Sensitivities to Landing Site and Atmospheric Dust

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## I. Abstract

Plans for human missions to Mars continue to go through several architectural changes, dating all the way back to the 1950s [1]. The continuous study, reformulation, and refinement of Mars architectures and system concepts is necessary in order to incorporate evolving mission objectives, technology advancements, and growth in the body of knowledge regarding human factors and the various environments of human space travel. This evolution has continued into the 21<sup>st</sup> century, with architectures concepts such as NASA's Design Reference Architecture 5.0 in 2009 [2], The Evolvable Mars Campaign in 2016 [3], and as recently as 2020, an architecture focused on a crewed mission as early as the 2030s that aims to minimizing crewed duration and infrastructure investment for the first mission [4]. Within these architectures, numerous studies around the current concept designs for Mars entry, descent, landing, and ascent (EDLA) systems have been performed over the last half a decade [[5], [6], [7], [8], [9], [10]].

Despite the breadth and depth of these studies, landing site, a key design parameter relevant to the design of EDLA systems, has remained nebulous over the years, largely due to the ever evolving mission objectives and architecture concept over the decades. However, the specific landing site has direct impact on the altitude and atmospheric conditions, which subsequently impact the design of EDLA systems. To accommodate the lack of a specific landing site, a baseline reference altitude of 0 km relative to the Mars Orbiter Laser Altimeter (MOLA), which is similar to an Earth sea level reference, has typically been selected and fixed for these past studies. Similarly, a baseline reference atmosphere has typically been utilized in these studies, either the Mars Global Reference Atmospheric Model [11], or a general 1982 standard warm, high pressure atmosphere model derived from Viking lander data [12].

Fig. 1 shows the range of elevations across the surface of Mars. Current architectures are focused on latitudes greater than 30 degrees north in an effort to ensure access to frozen water ice. From the figure, it is quickly evident that elevations over the range of longitudes at or above this latitude are significantly varied between roughly -4 to +4 km MOLA. Based on these observations, initial qualitative assessments of the impacts of landing site elevation on EDLA systems were performed. Fig. 2 depicts the expected trends in EDLA system mass for variations in both land site latitude and elevation. The background coloring is a qualitative evaluation of the current knowledge on ice water availability at the latitudes. Further modeling and simulation was performed to obtain numerical predictions of sensitivities to these parameters. Results indicate up to +2% to -4% mass variation from the current baseline Mars Ascent Vehicle concept, with the potential for greater than 6% mass variation at latitudes greater than 70 degrees north. However, variations in the descent system due to landing site were much more significant with mass variations in the range of -15% to +30% around the current baseline Mars Descent System concept.

Additionally, Fig. 3 provides a depiction of potential Mars atmospheric density variations with both dust and Martian season. Though the Martian atmosphere is relatively thin compared to Earth's atmosphere, it still poses significant impact on the design of EDLA systems. Variations in atmospheric density indicated by this slice of data would have significant impact on the design of EDLA systems. However, due to the highly complex nature of

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atmospheric flight, a qualitative assessment could not be performed. Rather, sensitivity results relied on modeling and simulation to provide numerical results for sensitivities on the current EDLA design concepts under consideration.

Understanding these sensitivities is vital to the overall systems design of a Mars architecture. The resulting mass impacts on EDLA systems, driven by landing site elevation and dust level variations, has rippling impacts throughout the architecture that, ultimately, impact the viability of the architecture. Results showed fairly minor mass impacts to the current Mars Ascent Vehicle baseline configuration, roughly -0.6% to +0.4% mass variations, while the Mars Descent System saw greater variations due to dust, roughly -4% to +6% around the baseline concept.

## II. Optional Supporting Materials

### A. Images, Figures, and Tables

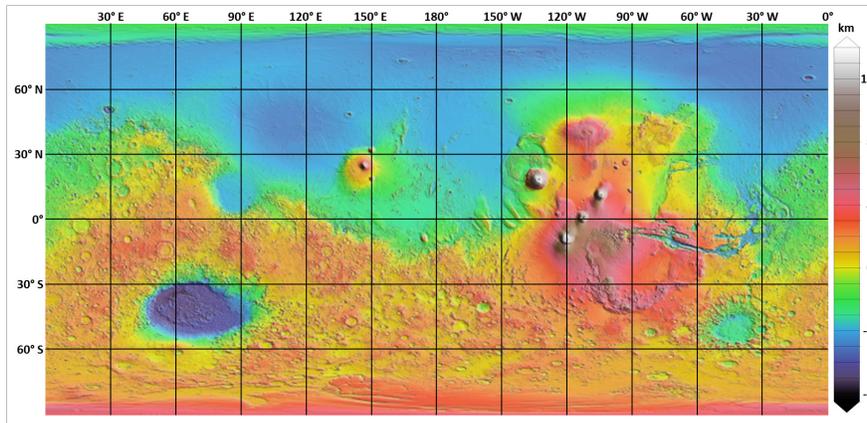


Fig. 1 Mars Elevation Map.

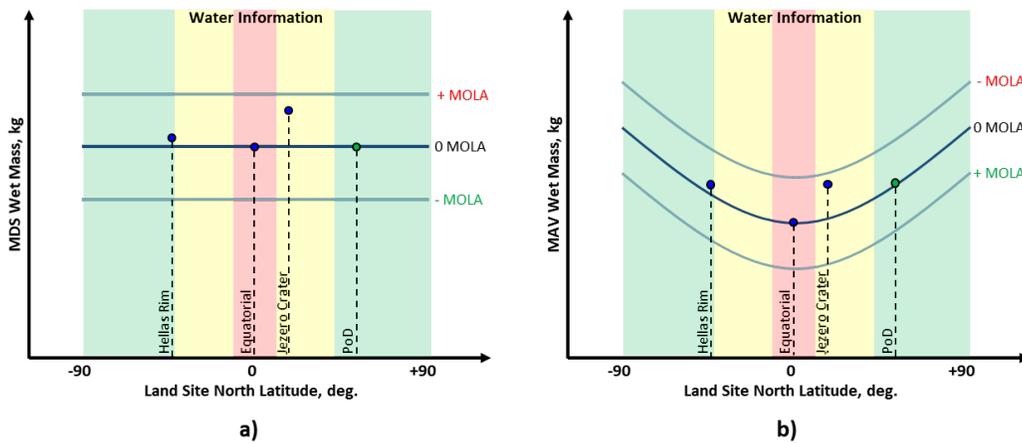
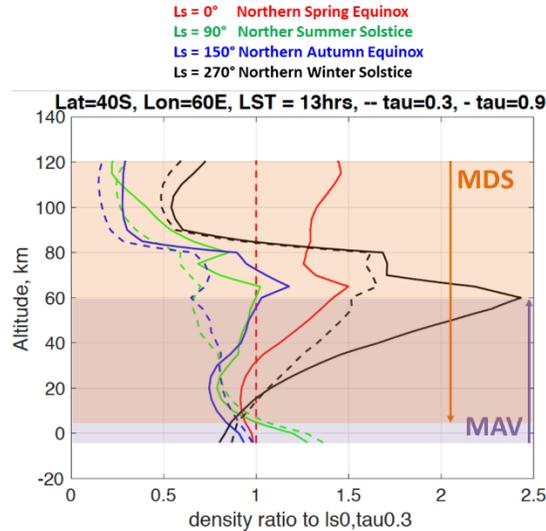


Fig. 2 Qualitative EDLA Systems Sensitivities to Landing Site: a) Descent and b) Ascent.



**Fig. 3 Select Mars Atmosphere Density Variations.**

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