Abstract
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Mars Science Laboratory: Entry, Descent, and Landing System Overview

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The Mars Science Laboratory (MSL) is a NASA mission that is currently under development for launch during the 2009 Mars launch opportunity. MSL is a landed Mars mission whose primary science objective is to investigate Mars Habitability. Habitability is defined here as the potential of a given environment to support life at some time and should be equated to the phrase "capacity to sustain life". In addition to science investigation objectives, MSL has technology advancement objectives that will benefit future Mars surface missions. One of the MSL technology advancement objectives is to improve the Entry, Descent, and Landing (EDL) state of the art. An overview of the MSL EDL system is the subject of this paper.

The MSL EDL system will provide access to previously inaccessible landing sites on the Martian surface. Specifically, MSL will provide improvements in landing site topographic altitude capability and landing site delivery precision. Regarding landing site altitude, previous missions including Viking, Mars Pathfinder (MPF), and Mars Exploration Rover (MER) have landed or intend to land at altitudes up to –1.3 km relative to the Mars Orbiter Laser Altimeter (MOLA) geoid. In general, these previous missions have landed at low altitude equatorial (MPF & MER), and northern latitude (Viking) sites. Due to engineering limitations on previous EDL systems coupled with Martian environmental uncertainties the high altitude Southern Highlands have not been previously accessible. Mars Polar Lander (MPL) is a unique exception to this generalization and the peculiarities of the MPL EDL scenario are discussed within the paper. One fundamental MSL goal is to advance the state of the EDL art such that the Martian surface is accessible on a global scale. Specifically, the working landing site elevation and latitude range requirements are respectively: a) sites up to +2.5 km altitude relative to the MOLA geoid, and b) 60 South to 60 North latitude. Approximately 72 percent of the Martian surface is contained within the MSL landing site altitude and latitude constraints. The MSL EDL architectural approach is discussed in detail here. Conceptually, the MSL EDL architecture is: direct entry; guided lifting entry; supersonic parachute; subsonic parachute; and powered terminal descent. The landing site altitude capability improvement is directly tied to augmenting the EDL architecture with a high kinetic energy guided lifting entry, and the addition of a second parachute, i. e. the subsonic parachute. In fact, it is seen that when a direct entry system utilizes lift in the entry body, performance of the system

is improved as entry speed is increased with the only constraints being associated with maximum allowable heatshield thermal protection system heat flux and heat load.

A second MSL EDL technology advancement objective is to provide scientists with access to previously unachievable landing sites by providing a precision landing capability. Viking and MPF provided successful Mars landings, but were limited to large scale, i. e. 100-200 km, landing sites. Similar to MPF, MER employs a ballistic entry system and will also have landing site accuracy on the order of 100 km. MSL will be the first Mars EDL system to implement precision landing. Elements that contribute to the MSL precision landing capability include: optical navigation during the planetary approach phase to reduce the navigation delivery and knowledge errors; and entry guidance and control to fly out dispersions associated with imperfect atmospheric knowledge and entry system aerodynamic uncertainties. The entry guidance and control design approach is derived from the guidance implemented on Gemini and Apollo.

The third MSL EDL technology advancement objective is to improve the probability of landing safety by avoiding hazardous terrain. The MSL hazard detection and avoidance strategy has three layers. The first layer, employed at the global scale, is to couple orbital site reconnaissance with precision landing to avoid regional size hazardous areas. The second layer applied at the sub-regional scale is to use an imaging radar and associated algorithms to autonomously identify hazards, such as craters and slopes, and then to actively steer away from such hazards during the powered terminal descent phase of EDL. Finally, landing system robustness mitigates local hazards, such as rocks.

This paper presents the status of the MSL EDL system design; elements such as the mechanical configuration, guidance and control approach, throttled powered descent, and hazard detection and avoidance implementation are discussed.

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