

Lunar Landing and Launch Pad Construction – Concepts and Criteria

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Introduction: When a lander vehicle launches or lands on the Moon, the rocket engine exhaust plume impinges on the surface and interacts with the regolith to create blast ejecta and associated cratering of the surface. Lunar regolith blast ejecta travels at high velocities ($>2,000$ m/s) for long distances (kilometers) in a vacuum environment [1] creating hazards for surrounding assets and it can also impact the bottom of the lander vehicle, risking damage to the engines, thermal insulation and sensors. Ballistic particles can possibly enter cislunar space and achieve orbit as debris, if the ejecta is sufficiently energetic. The cratering and regolith erosion can endanger the vehicle itself by affecting the soil stability under the landing gear. Landing on unpredictable terrain with varying topography, natural craters and rock hazards is also hazardous risks tipping a lander at dangerous angles in extreme conditions that may also violate maximum slope angles for subsequent launch operations. During launch (Figure 1), an overpressure pulse created by the ignition of the rocket engines can pose significant ejecta risks to the vehicle. Dust clouds raised during landing limit the efficacy of sensors and reduce visibility for the astronaut pilots, creating significant real-time risk during landing site selection by the pilot or computer navigation system. Future lunar spaceports will require mitigations to these launch and landing risks [2].

There are four main objectives of this effort: 1) To establish the state of the art in LLP construction methodologies. 2) To propose criteria for trade studies of LLP concepts. 3) To publicly share the authors' ideas for potential LLP solutions. 4) To serve as the starting point for future development of LLP technologies.

Establishing the state of the art in the area of off-Earth Launch & Landing Pad concepts will baseline the work that has been completed thus far and

highlight the wide span between current Technology Readiness Levels (TRLs) and operational readiness. The authors aim to communicate the need for funding in this area in the near term by illustrating that there is much work to be completed before a truly viable option exists.

Setting forth criteria for trade studies of LLP concepts is important for several reasons. The first and most straightforward is to establish a framework for performing trade studies on LLP concepts. This will enable NASA to select the most promising concepts for continued development, and it will also help technology developers understand how their concepts compare with others and the priorities of development efforts.

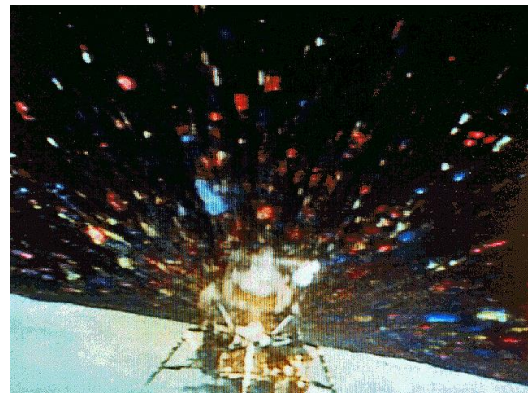


Figure 1. Apollo 16 ascent stage liftoff showing extensive ejecta debris (NASA PHOTO: s72-35613.)

References: [1] Lane, J.E., & Metzger, P.T. (2015). "Estimation of Apollo lunar dust transport using optical extinction measurements." *Acta Geophys.*, 63 (2), 568-599. [2] Benaroya, H., Bernold, L., & Chua, K.M. (2002). "Engineering, design and construction of lunar bases." *J. Aerosp. Eng.*, 15(2), 33-45.