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Off Earth Landing and Launch Pad Construction: A Critical Technology for Establishing a Long-Term Presence on Extraterrestrial Surfaces

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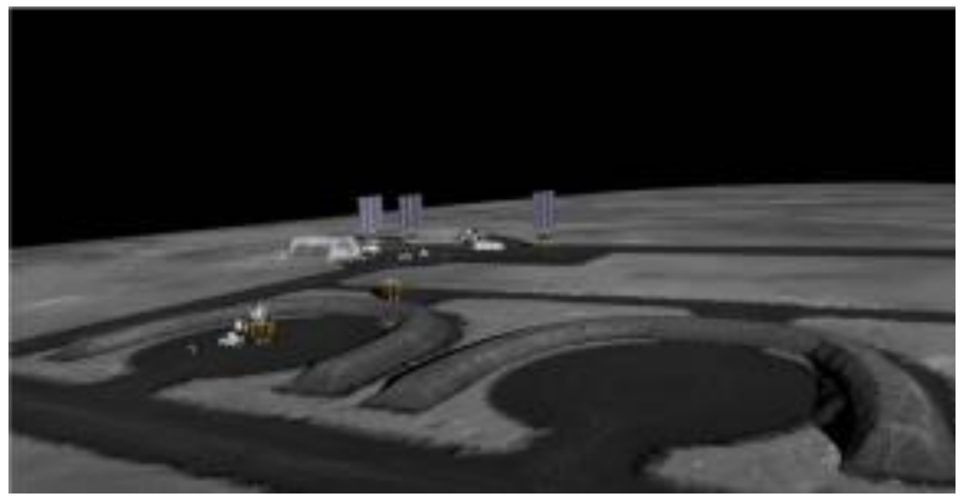
Abstract

In 2017, Space Policy Directive–1 was issued to ensure that “the United States will lead the return of humans to the Moon for long-term exploration and utilization” and engage the National Aeronautics and Space Administration (NASA) in the national effort. A long-term presence on the Moon will require numerous lunar landings and launches to build up surface assets, rotate crew, and deliver logistics supplies to/from the moon. Interactions between landing/launch rocket engine plumes and the unprepared lunar surface will lead to erosion and ejection of regolith particles at high velocities from beneath the vehicle. The associated ejecta elevates mission risks by: obscuring sensors and human vision during landing via lofted dust; cratering/modifying the surface that the vehicle will land upon; and subjecting the vehicle, surrounding assets, and potentially orbital assets to impacts and contamination from high velocity dust particles. The construction of a reusable landing/launch pad infrastructure is a method to mitigate such risks. A landing/launch pad system can provide a known, benign and reliable landing/launch surface, minimize regolith ejecta, and protect surrounding assets from liberated particles. Associated blast barriers can provide protection in case of a landing/launch catastrophic anomaly. This paper summarizes previous work towards construction of off-Earth landing/launch pad infrastructure and begins to identify key technology gaps. Additionally, this paper establishes metrics for comparison of pad construction technologies to guide future trade studies. The overall objective of this paper is to baseline the state of the art of off-Earth landing/launch pad construction technologies and serve as the starting point for further technical development.

Introduction

When a lander vehicle launches or lands on an extraterrestrial body, 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 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, 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 and Martian spaceports will require mitigations to these launch and landing.



Motivation

There are four main objectives of this paper:

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.

Trade Study Criteria

The construction process is divided into 3 phases:

1) Preparation and Staging,

2) Construction,

3) Operations and Maintenance.

Table 1 displays each phase and its list of criteria.

Table 1. Key Trade Study Criteria for LLP Concepts

Preparation and Staging Phase	Construction Phase	Operations and Maintenance Phase
Up-Mass of Construction Materials and Systems	Constructability	Performance as a Landing/Launch Surface
Difficulty of Insitu Materials Collection, Handling, and Processing	Versatility	Expected Life
Effort of Site Preparation/Staging Time	Construction Time	Ease of Repairability
Reliance on other Surface Assets	Reliance on other Surface Assets	Reliance on Lunar, Gateway and Earth Crew Interaction
Reliance on Lunar, Gateway and Earth Crew Interaction	Reliance on Lunar, Gateway and Earth Crew Interaction	Robotics and Autonomy
Robotics and Autonomy	Robotics and Autonomy	Required Power
Robustness of process	Robustness of process	Lifecycle cost
Current Technology Readiness Level	Current Technology Readiness Level	
Required Power	Required Power	
	Ability to Verify As-Built Performance	

Landing/Launch Pad Concepts

This paper attempts to establish a listing of all LLP construction concepts to date surveyed by the authors. Some concepts are simply ideas, others have undergone some development.

Table 2. Launch and Landing Pad Concepts

LLP Structure Concepts
Minimal Preparation
Existing Topography
Compacted Regolith Surface
Bedrock Surface
Ice Surface
Rock Piles
Surface Stabilization Applications
Regolith Bags
Ice Bladders
Pavers
Metallic Plates
Deployable Structures
Direct Emplacement of Sintered Structures
Direct Emplacement of Polymer Concretes
Direct Emplacement of a Concrete Pad

Conclusions

Launch/Landing Pad infrastructure will be necessary to reduce mission risks to acceptable levels and grow human lunar activities beyond “footprints and flags” into a vibrant scientific and economic endeavor. This is true for the same reasons why airplanes use runways and airports, ships use docks and seaports, cars and trucks use roads and service stations, trains use rails and stations, and Earth-based space operations use launching and landing complexes. Off-Earth spaceports will need Launch and Landing Pads (LLP) and eventually Launch and Landing Complexes to reduce mission risks and facilitate the exploration and utilization of off-Earth resources.

Reference

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