A Baseline for Lunar Surface Operations

Surface Operations Breakdown Into Subtasks With Time Estimates

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Disclaimer

While this document acknowledges the contributions of Eagle Engineering's 1988 LBSS studies, all figures, assumptions, and operational frameworks presented herein have been critically reviewed and modernized by SpaceGeotech following contemporary mission architecture (Artemis-class operations), robotics, and the L1–L5 Excavation Zoning Framework.

These updates reflect current engineering best practices and do not represent the views of Eagle Engineering. The operational time estimates presented in this WP 004 have been critically updated from the original Eagle Engineering studies and reflect adjustments based on contemporary Earth-based engineering experiences with autonomous construction, mining cycles, and remote logistics under analog constraints.

These figures are provisional and are intended solely to support initial feasibility assessments and mission planning frameworks. They serve as a practical baseline for early-stage comparisons, resource allocation studies, and the development of conceptual designs.

It is explicitly acknowledged that these durations require in situ validation. A dedicated pilot test area on the lunar surface must be established to refine these values through direct operational feedback, ground-truth data acquisition, and incremental system optimization before deploying any large-scale infrastructure.

Executive Summary

This Brief Tech provides a critical review and modernization of the baseline assumptions for lunar surface operations originally outlined by Eagle Engineering in 1988. While the original framework offered a valuable foundation for early conceptual studies, advancements in lunar mission architectures, robotics, autonomous systems, and in-situ resource utilization (ISRU) strategies now require a fundamental update. The operational speeds, equipment capacities, distances, and construction methodologies presented here reflect current engineering practice, informed by the realities of Artemis-era mission planning, commercial lunar programs, and improved understanding of lunar surface conditions. This update establishes a more realistic and technically defensible baseline for future lunar infrastructure studies while maintaining continuity with the original Eagle Engineering methodology for transparency and traceability.

Note on L1–L5 Zoning

This WP 004 adopts the L1–L5 Excavation Zoning Framework as defined by SpaceGeotech (2025). These excavation classes categorize lunar surface works according to excavation depth, terrain condition, expected geotechnical behavior, and required tooling. This zoning informs risk management, tooling selection, slope design, and mission feasibility. It is explicitly not a perimeter logistics zoning; it is a depth-governed engineering framework aligned with terrestrial excavation standards, adapted to lunar constraints.

1. Baseline Data for Calculations

Mobility Speeds (m/min) — Autonomy and Safety Adjusted

Task	1988	Recommendation	Rationale
Fast Transfer (Unloaded)	100	30–50	Dust control, terrain, and autonomous limits
Grading / Hauling	25	10–20	Cycle time, autonomy, load balance
Trenching (1.5m deep x 0.3m)	1	1 m^3 / 10–15 min	Focus on volumetric rates, not linear
Backfilling	5	5–10	Loader cycles, soil management

Surveying / Layout Tasks (Autonomous Systems)

Task	1988	Recommendation	Rationale
Surveying Time (min/event)	6	Negligible (<1 hr total)	LIDAR, inertial mapping, no manual staking

Site Condition Factors (Adjust to Artemis Regions)

Item	1988	Recommendation	Rationale
Undesirable Boulders per m^2	0.25	Site-specific (LROC, GPR, AVG data)	Polar sites vary from Mare estimates

Equipment Capacities (Autonomous, Modular)

Item	1988	Recommendation	Rationale
Bulldozer Blade Width (m)	3	2–4	Modular autonomous dozers or scraper bots
Prime Mover Width (m)	2	2–3	Teleop/autonomous haulers, light fleet units
Cart Capacity (m^3)	8	4–8	Scalable per haul distance, efficiency cycles
Loader / Shovel Capacity (m^3)	1	1–2	Robotic compact loaders (Lunar Bobcat scale)

Distance Assumptions (Compact Mission Footprints)

Item	1988	Recommendation	Rationale
Landing Pad to Base (m)	1000	300–500	Reduce logistics footprint, minimize paths
Storage Shed to Base (m)	100	100	No change, logical small operations radius
Number of Prepared Pads	4	2–3 phased	Consolidated operations, not spread out
Road Length (total, m)	1400	200–400	Stabilized paths, not heavy roadbuilding

Module Site Plan / Areas (Reflecting Modern Architectures)

Item	1988	Recommendation	Rationale
Module Site Plan (m^2)	2500	1000–1500	Smaller early bases expand as needed
Landing Pad Size (m^2)	1963	1000–2000	Adjust to the lander footprint; Starship ≈ diameter 9m.
Pad Circumference (m)	157	100–160	Reflects pad scaling, not fixed by 1988 logic

Module Dimensions (Reflecting Artemis / Starship / ISRU Trends)

Module	1988 Diameter (m)	1988 Length (m)	Recommendation
HAB / LAB Modules	4.45	13.25	Inflatable 6–8m, ISRU regolith shells
Node	4.45	5.38	Optional, integrated into the lander stages
Airlock	3.66	-	Compact 2-3m dedicated units
Logistics Module	4.45	7.23	ISRU/hardened containers, modular
Radiation Shelter	4.45	7.23	Buried ISRU structures preferred
Crane Trailer Width (m)	5	-	Modular autonomous lifting systems
Bulldozer Blade Height (m)	1	1	No change, low-profile autonomy designs

Additional Operational Distances

Task / Distance Description	1988	Recommendation	Rationale
Storage Shed to Pad (m)	1000	300–500	More compact operational layout
Pads to Lander Storage (m)	400	200–300	Reduced spread, optimized for logistics

Task / Distance Description	1988	Recommendation	Rationale
Dump Soil from Excavations (m)	50	0–50	Reuse for shielding, stockpiled nearby

2. MODULE SITE PREPARATION

Activity	Equipment	2025 Updated Task Description	Time (hr)	Comments
Survey / Layout	Autonomous LIDAR Rover	Digital site scan, topo model generation	1.0	Autonomous replaces the 1988 manual markers
Site Marking / Beacons	Robotic Markers (if needed)	Minimal use, reflective markers only if required	0.5	Artemis relays are likely to reduce the need for markers
Validation / Check	IVA / Data Telemetry	Confirm the site via telemetry	0.5	No EVA; control center verification
Subtotal			**2.0**	IVA / Teleops only

3. BOULDER CLEARING & MINOR OBSTRUCTIONS

Task	Equipment	2025 Updated Task Description	Time (hr)	Comments
Surface Clearing	Small Autodozer / Scraper	Limited to prepared site boundaries	1.0	Site pre-selected to minimize this need
Boulder Handling	Robotic Manipulator Arm	Relocate boulders >0.3m from the module footprint	1.5	Small bots, not large hauling
Subtotal			**2.5**	Teleops only

4. SITE GRADING / FINAL PREPARATION

Task	Equipment	2025 Updated Task Description	Time (hr)	Comments
Grading	Autonomous Small Dozer	Level area ~1000–1500m^2 for habitat	3.0	Compact dozers, teleop-assisted