NASA Lunar Grounding Challenge: Appendix A (supplemental)

The Lunar Mobility Augmentation Layer

The outer layer GroundSkin rides on. Adapted from DragonWorx's idea submission to NASA's Moon Base solicitation (hq-moonbase@mail.nasa.gov, 30 July 2026). Evan Norman, DragonWorx Biomimetic Technologies.

> **Why this appendix exists.** Different teams may review this entry, and some will meet DragonWorx here for the first time. GroundSkin meets every challenge threshold on its own, and a 0.45 kg vest-and-sleeve carrier provides its panels when no LMAL is worn. Its full value shows, though, when it rides on the LMAL: one passive outer layer that helps the crew member move, and then gets them back to the lander electrically safe.
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> **What changed since July.** The July submission estimated 35 to 45 m per bound and 15 to 20 km/h. Those figures assumed launch speeds a suited crew member cannot reach, so we have replaced them with the bounded estimates in A.2. The engineering approach is unchanged; the numbers are now conservative.

A.1 Two platforms, one wear-over layer

DragonWorx develops two wearable platforms around biomechanical principles that lunar physics amplifies rather than cancels. The **JumpSuit** contributes resilin-mimetic leafspring joints at the ankle and knee. The **DragonSuit** contributes articulated panels on the arms, chest and legs. For the Moon, both combine into the LMAL, a single layer donned over the pressure garment at the airlock. It needs no pressure-system integration, no power connection and no change to the life-support interface.

A.2 Energy-return joints and lunar bounding

Resilin, the elastic protein in insect jump and flight mechanisms, returns about 97% of stored energy, more than high-resilience synthetic rubbers [A1]. The JumpSuit leafsprings take resilin as their benchmark: they catch landing energy at the ankle and knee and release it into the next push-off. That does not raise how fast a crew member can launch; muscles still set that. What it does is cut the metabolic cost of each bound, and loping, the gait Apollo crews adopted on their own, already costs less than running in lunar gravity [A2, A3].

Ballistic range on the Moon follows $R = v^2 \sin 2\theta / g$ with $g = 1.62$ m/s². For the launch speeds a suited crew member can plausibly sustain, at a 30° take-off and an assumed 0.3 s ground contact per bound:

Launch speed	Flight time	Bound length	Peak height	Sustained speed	600 m return
2.5 m/s	1.5 s	3.3 m	0.48 m	6.5 km/h	5.5 min
3.0 m/s	1.9 s	4.8 m	0.69 m	8.0 km/h	4.5 min
Apollo walk-back planning [A2]	–	–	–	2.7–3.6 km/h	10–13 min

Apollo J-mission crews already sustained running speeds above 5 km/h without assistance [A2]. The LMAL target is to make a 6.5 to 8 km/h lope sustainable over kilometres at lower metabolic cost, a target that Phase II treadmill and partial-gravity testing would confirm or revise.

A.3 Panels in vacuum: attitude, not lift

In vacuum the DragonSuit panels generate no aerodynamic lift; we did that math before anyone asked. During a 1.5 to 1.9 s ballistic arc they act as a controllable moment arm. Moving them shifts angular momentum between limbs and torso, which helps a crew member arrive feet-first instead of pitched forward onto uneven regolith. For lunar use, nickel-titanium shape-memory ribs replace the Earth version's polymer ribs, because the polymer would lock in the −170 °C cold of a shadowed crater. On the Moon the panels also do a second job: they carry the GroundSkin coating.

A.4 Integration with lunar EVA suits

The joint sleeves interface at the boot-to-lower-leg and knee junctions common to current and proposed lunar EVA suits, including the AxEMU architecture. The panels attach at arm-torso and leg channels through magnetic quick-release points. A crew member dons or doffs the layer at the airlock, as with a safety harness. GroundSkin adds one strap from its hip bus hub to the suit's bonding attachment point; nothing touches the pressure garment's material.

A.5 Mass

Configuration	Mass	Note
LMAL (joints and panels, lunar materials)	4.5–6.0 kg	UHMWPE laminate, NiTi ribs, aerogel-composite thermal panels
GroundSkin system, including wand and lander target	1.34 kg	1.67 kg with 25% margin (Physical Properties Estimate)
LMAL with GroundSkin	**5.8–7.3 kg**	**Well under the 20 kg limit even with the LMAL counted**

At lunar gravity the combined layer weighs what 1.0 to 1.2 kg weighs on Earth, though its inertia is unchanged, which the joint and panel design must still respect. The challenge's 20 kg limit applies to the grounding device; we show the LMAL here only to make clear the whole layer still fits.

A.6 Why the combination is stronger than either part

- **One layer, one donning step.** Mobility and charge management arrive together, with no extra hardware to remember at the airlock beyond the wand in its holster.
- **Fewer footfalls per kilometre.** A 3.3 to 4.8 m bound means roughly 200 to 300 regolith contacts per kilometre, several times fewer than a walking stride. Jackson et al. model suit charging as a build-up per step [A4], so bounding should reduce charge accumulated per kilometre. We flag this as a hypothesis for Phase II, not a credited benefit.

- **The return leg ends safely.** The scenario the LMAL was built for, a crew member walking back from a shadowed crater rim after a rover failure, ends at the lander. GroundSkin makes that last metre safe, so the layer covers the full trip.



Figure A1. Return from a shadowed crater rim. One crew member seats the Discharge Wand in the lander target while the other approaches.

A.7 The scenario this solves

A crew member on a science traverse to a permanently shadowed crater rim, 600 m from the lander, loses the rover to a mechanical failure or terrain-blocked communications. Walking back at Apollo planning rates takes 10 to 13 minutes. With the LMAL, a sustained lope covers the distance in roughly 4.5 to 5.5 minutes, at lower metabolic cost per metre: a meaningful margin for a suit approaching its consumable limits. At the lander, the crew member draws the wand, seats it in the target and counts to ten before touching the ladder. In shadow, with almost no plasma current to drain the suit, that is precisely the moment GroundSkin exists for.

References

1. Elvin, C. M., et al. (2005). Synthesis and properties of crosslinked recombinant pro-resilin. *Nature* 437, 999–1002.
2. Jones, E. M. (ed.). Apollo 11 Lunar Surface Journal: Gaits and walking speeds. NASA History Office.
3. Rader, A., Newman, D., and Carr, C. (2007). Loping: a strategy for reduced gravity human locomotion? SAE Technical Paper 2007-01-3134.
4. Jackson, T. L., et al. (2011). Discharging of roving objects in the lunar polar regions. *Journal of Spacecraft and Rockets* 48(4), 700–704.