Robustness Evaluation of South-Polar Observation and Lunar Visibility Estimates (RESOLVE)

RESOLVE project
Decision-Convergence Auditing for Lunar South-Polar Visibility Models
Technical Research Note — NASA Space Apps Challenge 2026
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***Abstract*—Robustness Evaluation of South-Polar Observation and Lunar Visibility Estimates (RESOLVE) is a decision-convergence auditing framework for lunar landing-window models. Lunar south-polar Sun/Earth visibility depends on terrain horizons, while a precise modeled duration can depend materially on terrain representation and other assumptions. RESOLVE audits whether a modeled landing-window result remains stable across defensible modeling choices. At dGR101, NASA Product 78 SL2 5 m gives 7.397830 days of complete simultaneous geometric Sun/Earth-center visibility; NASA Product 90 native 80 m gives 12.923283 days under the same fixed absolute observer convention, a difference of approximately +5.53 days. Frozen horizon and aligned terrain profiles identify a near-field representation mechanism. A limited negative result at dGR203 preceded this finding and redirected the investigation. These results establish a reproducible representation response, not an accuracy ranking. No terrain representation is validated as physical truth, and no fine-grid convergence plateau has been demonstrated. This note summarizes retained R-01A/B/C evidence; it introduces no new scientific calculation.**

***Index Terms*—Lunar terrain, geometric visibility, model sensitivity, decision auditing, scientific provenance.**

I. Introduction and research question

RESOLVE was built for the NASA Space Apps Lunar Landing Site Navigator challenge. Near the lunar south pole, low solar elevations make local relief important to the terrain horizon. A precise visibility duration can therefore conceal sensitivity to terrain representation, observer position, event sampling or reporting scope. Candidate-site literature and its archive supplied comparison context and site coordinates [1].

The research question is: **Before a lunar landing-window prediction is relied upon, does the modeled answer remain stable under defensible changes in terrain representation and modeling assumptions?** Here, a "window" means a specified geometric-visibility interval, not an assessed landing opportunity with all mission constraints.

II. Data and methods

A. Sources and geometry

The retained experiments use NASA PGDA Product 78 local LOLA terrain and its official clones; Product 90 native 20/40/60/80/240 m terrain; and the separate Product 104 A304 image-enhanced Shape-from-Shading elevation model [2–6]. NASA/JPL NAIF SPICE supplies DE421 translation and the explicit MOON_ME_DE421 cartographic frame, with aberration convention NONE and a 1,737,400 m reference sphere [7]. The primary observable is simultaneous geometric visibility of the Sun and Earth centers above modeled terrain horizons. It does not calculate generated electrical power, a radio link budget, landing safety or mission certification.

B. Matched observer and terrain

At the archived dGR101 point (latitude $-88.5134116385092°$, east longitude $-68.01460926527753°$), the primary observer is fixed at 1535.774658203 m above the reference sphere, defined by nominal P78 ground plus 2 m. Its height above each alternative represented surface therefore varies. A separate convention places the observer exactly 2 m above each surface and updates its absolute position consistently. Terrain replacement uses a common 20×20 km SL2 footprint; the existing native 80 m then 240 m exterior continuation remains fixed. Bilinear terrain interpolation and spherical curvature are retained; missing elevations are not replaced by zero [8].

C. Intervals and refinement

Registered-domain results use [6 November 2026 00:00, 28 November 2026 00:00 UTC). Complete results retain transition-bounded episodes intersecting that domain, with daily extension to discover actual boundaries. Frozen R-01C refinements halve angular/radial sampling and compare 150 s/75 s event discovery. Exact result rows, protocols, kernel/raster hashes and numerical audits remain accessible [8].

III. Research progression

R-01A: a hypothesis not supported. The original hypothesis was that local stochastic terrain uncertainty could reverse the evaluated dGR203 6.5-day simultaneous-center classification. Nominal terrain and the first five official Product-78 clones retained the seasonal classification; the separate fixed-start grid also showed no terrain-driven classification reversal. This limited negative finding was retained, rather than treated as proof of zero terrain uncertainty [8].

R-01B: a revised question. A retained pre-outcome protocol specified a metadata-based multi-site screen after the dGR203 audit. That screen identified a large dGR101 response to a synthetic area-averaged 59.88 m local representation. A subsequent fixed-absolute-observer diagnostic was explicitly registered after detecting the contrast. The synthetic control

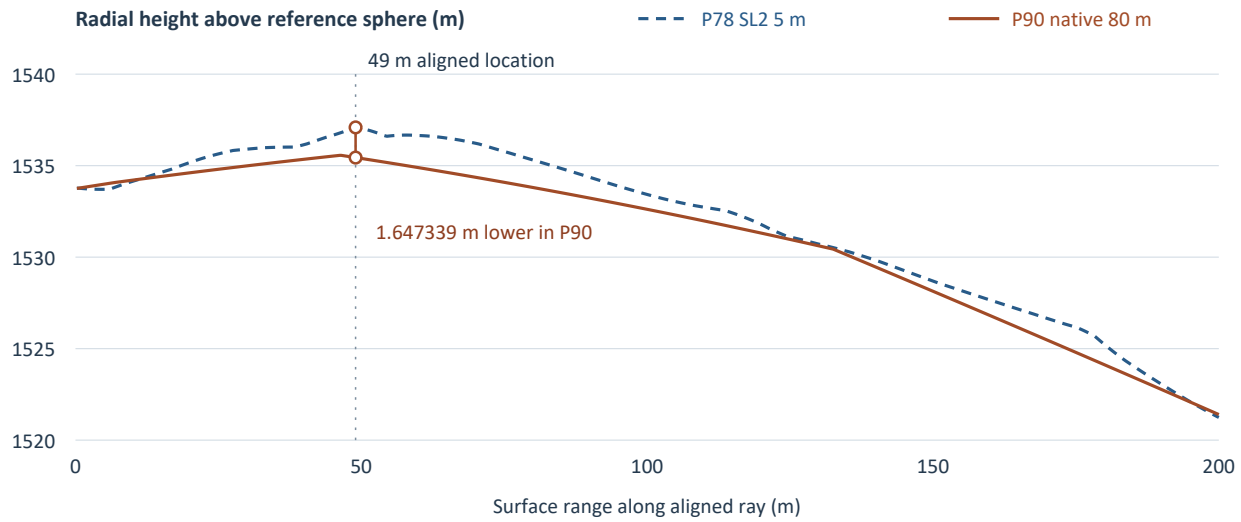


Fig. 1. Aligned near-field profiles at the nominal P78 onset azimuth, 89.8356°. Vector redraw of the frozen P78/P90 section samples over their retained 0–200 m range; no terrain or visibility calculation was rerun. Heights are radial elevations above the 1,737,400 m reference sphere. Axes have different scales. The marked 49 m location differs from the 49.125 m own-event lower-bracketing witness below. Full original multi-product figures remain in the public evidence [8].

TABLE I
LONGEST COMPLETE SIMULTANEOUS GEOMETRIC SUN/EARTH-CENTER VISIBILITY EPISODE INTERSECTING THE REGISTERED DOMAIN, AT DGR101 UNDER THE PRIMARY FIXED-ABSOLUTE-OBSERVER CONVENTION. VALUES ARE REPORTED TO SIX DECIMAL PLACES FROM THE FROZEN R-01C RESPONSE TABLE [8].

Terrain representation	*Complete window (d)*
P78 SL2 5 m	7.397830
P90 native 20 m	8.358389
P90 native 40 m	9.676205
P90 native 60 m	11.461184
P90 native 80 m	12.923283
P90 native 240 m	13.293702
P104 SDEM 5 m	2.987840

is distinct from native NASA 60 m terrain. This sequence is falsification-driven research, not a result selected in advance [8].

R-01C: native-product testing. A further retained protocol tested the response using authoritative native Product-90 grids, a common absolute observer, complete intervals and numerical refinement. The several-day response persisted, showing that synthetic averaging alone did not account for the R-01B observation. Shared observations, geodetic ancestry and product processing preclude treating this as independent physical-truth validation [8].

IV. RESULTS

The stored 80 m-minus-5 m contrast is 5.525453 days, approximately **+5.53 days**. The response is not a monotonic-convergence claim: native products differ in processing lineage and grid alignment as well as spacing. No fine-grid limiting window W* has been demonstrated; the retained 5 m-to-20 m complete-window difference is 0.960559 days. Product 104 is a separate product family, not another point on a single-resolution convergence sequence.

Observer and reporting definitions materially change interpretation. Product 104 gives 2.987840 days at the fixed absolute observer but 7.273578 days at 2 m above its own surface. Nominal P78 gives 5.379206 days when reporting-clipped, versus 7.397830 days for the complete episode. The clipped value cannot establish a physical failure of the 6.5-day benchmark.

Numerical evidence. The retained R-01C report records 29 software tests passing, a maximum accepted spatial transition/duration change of 327.157 s, and a maximum 150 s/75 s temporal change of 0.011926 s. Relevant event counts and scoped threshold states were stable. The preferred 60 s spatial target was not met in every check; the 600 s hard ceiling was met. These are deterministic consistency checks, not physical-accuracy bounds or confidence intervals [8].

V. PHYSICAL MECHANISM

At the nominal P78 solar-onset sector, the fixed-observer horizon is approximately **+1.537878**° in P78 and **−0.185233**° in native P90 80 m. Along the aligned ray at 49.000 m surface distance, P90 represents the terrain **1.647339 m lower** than P78. The retained near-field profiles therefore explain a lower represented skyline in this sector; they do not show that a physical lunar ridge disappears [8].

These own-event witnesses occur at different event times and azimuths. They are not two points on the same ray. A horizon interpolates bracketing rays, and a witness is a sampled/interpolated terrain point rather than an independent

TABLE II
FROZEN OWN-EVENT LOWER-BRACKETING WITNESSES, WITH A COMMON ABSOLUTE OBSERVER [8].

Representation	*Range*	*Azimuth*	*Own event (UTC, 2026)*
P78 SL2 5 m	49.125 m	89.8356°	22 Nov 14:53:56.611
P90 native 80 m	2.017 km	151.0098°	17 Nov 14:00:06.219

laser return. The shared-azimuth profile and separate own-event witnesses are complementary diagnostics.

The duration contrast also includes a changed end boundary. For the late simultaneous episode, the frozen 80 m-minus-5 m onset shift is −5.037389 days and the end shift is +0.488064 days. The entire complete-window difference must not be assigned to one solar-onset ridge. All mechanism statements remain conditional on the matched geometry and represented terrain [8].

VI. LIMITATIONS

No evaluated terrain representation is validated as physical truth, and no fine-grid convergence plateau is established. Product lineages differ in more than pixel spacing; pixel spacing is not effective independent terrain knowledge. The local high-resolution replacement retains a fixed coarser far-field continuation, so this is not a uniform-resolution lunar south-pole analysis. Numerical convergence tests address model consistency, not physical accuracy.

The exact DE441 effect remains unknown: a matched DE441 orientation/cartographic chain was not validated. The separate historical dGR203 approximately-seven-day literature discrepancy remains unresolved; unknown historical settings and an archived Sun-only/combined-product inconsistency prevent unique attribution. Product 104 shows strong observer-convention sensitivity. The dGR203 clone pilot contains only five local clones and is not a calibrated probability distribution. Limited sites and configurations do not support universal south-polar claims. No mission safety, certification, success probability or NASA endorsement is claimed [8].

VII. IMPLICATIONS

A precise lunar visibility duration can remain model-sensitive across defensible terrain representations. Planning interfaces can benefit from exposing the stability of a result together with its assumptions, rather than presenting a duration alone. RESOLVE provides that audit for its evaluated cases, connects result changes to terrain-horizon evidence, and retains negative findings and unresolved limits. Broader applicability requires separately specified evidence.

VIII. REPRODUCIBILITY AND DATA AVAILABILITY

Live interface: resolve-lunar-audit.vercel.app. Source and released product records: GitHub repository. Protocols, findings, numerical audits, exact CSVs, source hashes and reproduction instructions: Science & Evidence. This note summarizes the frozen evidence retained in release 324d5b6a8d8b6cdd99a3d5ed314e5874268cb4de; it adds no new research run.

The public repository reproduces the interface from included frozen product records; it does not contain the full raw DEM/SPICE research environment. Full scientific reproduction needs the specified retained raw inputs, kernels and research code. Acquired native-window and byte-range checksums are scoped to those bytes, not unknown whole-remote-raster digests. The note's editable source, builder and file hashes accompany the release. AI assisted drafting and software development; numerical claims here are attributed to retained computational evidence.

REFERENCES

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[7] NASA/JPL NAIF. Lunar frame definitions; archived planetary ephemerides including DE421.

[8] Robustness Evaluation of South-Polar Observation and Lunar Visibility Estimates (RESOLVE). Frozen R-01A/B/C evidence: findings, protocols, R-01C response/witness tables, numerical audit, source/frame/literature audits and reproduction instructions. Public evidence index. Specific input paths and SHA-256 values are listed in the accompanying note provenance record.