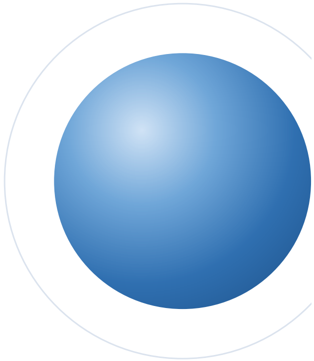
SITE-SELECTION DOSSIER · PHASES 1–4



EXAX

A fixed camera on the Moon that never loses sight of Earth.

Two scientifically defensible surface sites where Earth stays permanently above the local horizon — derived from first-principles positional astronomy, cross-checked against 200 years of JPL DE440 ephemerides, and verified against real LRO LOLA polar terrain.

NORTHERN SITE · THE GEOMETRIC SOLUTION

82°30′00″ N 0°00′00″ E

Earth rests on a near-level skyline near Gioja

SOUTHERN SITE · THE GEOLOGICAL SOLUTION

79°30′00″ S 0°00′00″ E

Earth lifted clear from a +2.2 km massif near Newton

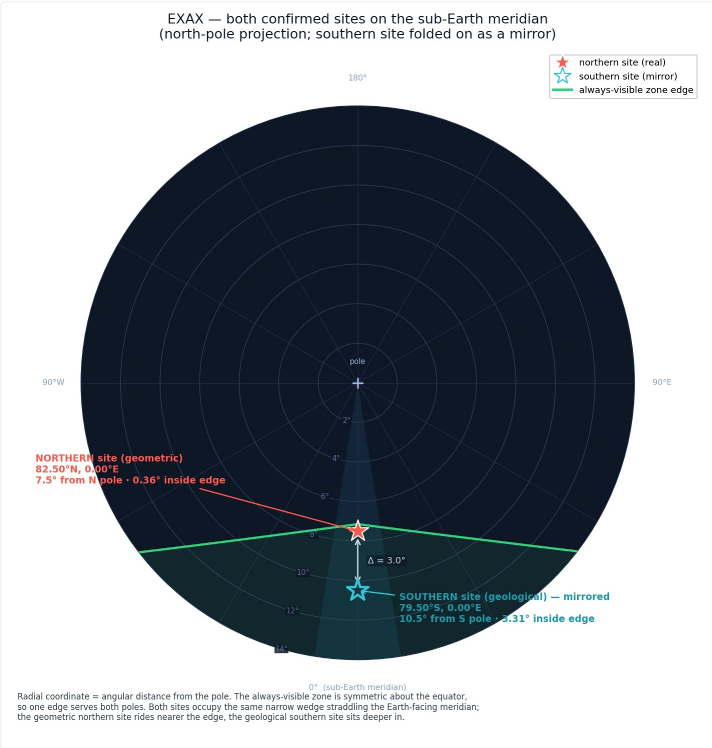
Frame: selenographic Mean-Earth / mean-rotation-axis (ME) · both sites on the sub-Earth meridian λ = 0°
Criterion: Earth's centre strictly above the horizon at every epoch of the full 18.6-year libration cycle
Compiled: May 2026 · figures and candidate table reproducible from the project scripts

MAIN PROJECT PAGE

Holding Earth permanently in frame

EXAX places one camera on the Moon’s near side and keeps it aimed at Earth without pause — a fixed vantage on solid ground that holds the whole planet in view for years, producing a continuous record of Earth seen whole, the way no orbiting satellite can.

Because the Moon keeps almost the same face turned toward us, it is tempting to assume Earth simply hangs still in the lunar sky and nearly any near-side spot would do. It does not work that way: the Moon rocks gently as it orbits — a slow wobble called libration that swings Earth’s apparent position around the sky over a rhythm of about 18.6 years. Toward the edges of the visible face that motion can carry Earth down to the horizon, where even a modest hill or crater rim can cut across the view. A permanent-view site must therefore clear the local landscape at *every* moment of the full cycle. Two such sites emerged, and they form a clean matched pair: both lie on the sub-Earth meridian — the line on the Moon that points most directly at Earth — and they are treated throughout as equal in status.



OVERVIEW · Both sites on a single selenographic chart centred on the north pole, with the always-visible zone edge drawn and the southern site folded onto the same map as a mirror marker. The radial coordinate is angular distance from the pole. The **northern site** sits 7.5° from the north pole and 0.36° inside the zone edge; the **southern site** sits 10.5° from the south pole and 3.31° inside the edge — 3.0° apart in pole-distance.

One chosen by geometry, the other by geology

The northern site is the *geometric* solution — the place where the plain celestial arithmetic of the Moon’s orientation lets Earth hang permanently in view at the lowest point it can reach above the horizon. From here Earth skims a calm, level skyline: the foreground is the smooth, rounded, deeply ancient highland plain just south of Gioja crater, and the land actually slopes gently away toward Earth, so the planet seems to rest just above a faintly sunken horizon. The southern site is the *geological* solution — a place the bare geometry alone would not permit, rescued by terrain. Here the camera stands on the summit of a tall massif in the rugged far-southern highlands near Newton, the deepest crater on the Moon’s near side. The foreground is dramatic and broken — steep slopes, shadowed hollows, sharp relief — and Earth stands well clear above it, lifted into open sky by the mountain underfoot. One site lets Earth graze a quiet horizon by pure orbital chance; the other hoists Earth into view from a peak.

Key numbers

NORTHERN SITE — 82.50°N, 0.00°E

82.50 °N	**+0.35** °	**+1.21** °	**18.6** yr
Latitude — on the sub-Earth meridian near Gioja crater	Earth’s lowest point above the horizon — it never sets	Terrain-clearance margin above the Earthward skyline	One full cycle of Earth’s drift across the sky

SOUTHERN SITE — 79.50°S, 0.00°E

79.50 °S	**+3.28** °	**+2.2** km	**+0.95** °
Latitude — on the sub-Earth meridian near Newton crater	Earth’s lowest point above the horizon — it never sets	Height of the massif summit the camera stands on	Full-disk terrain-clearance margin

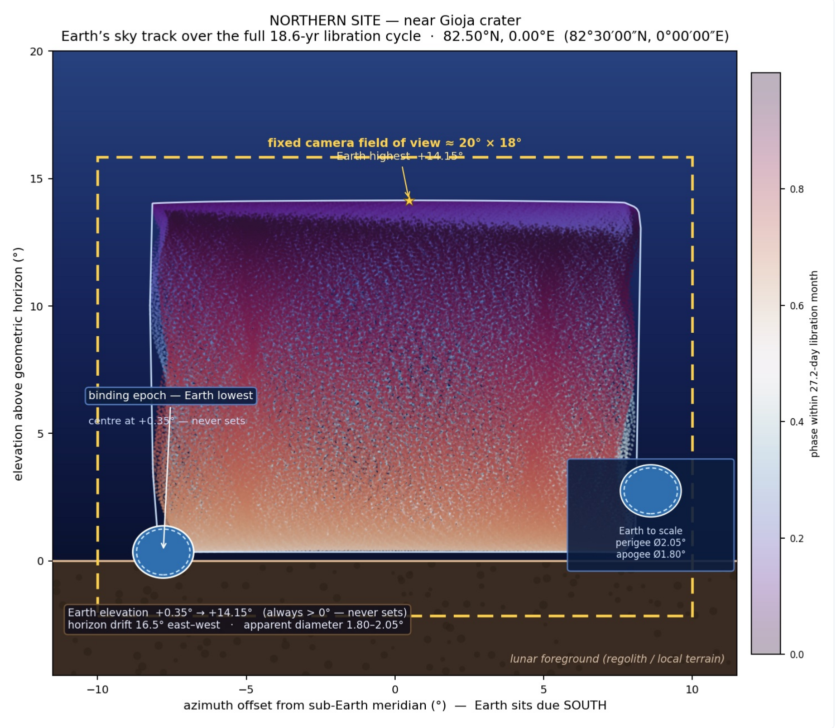
NORTHERN SITE · THE GEOMETRIC SOLUTION

82°30′00″ N · 0°00′00″ E

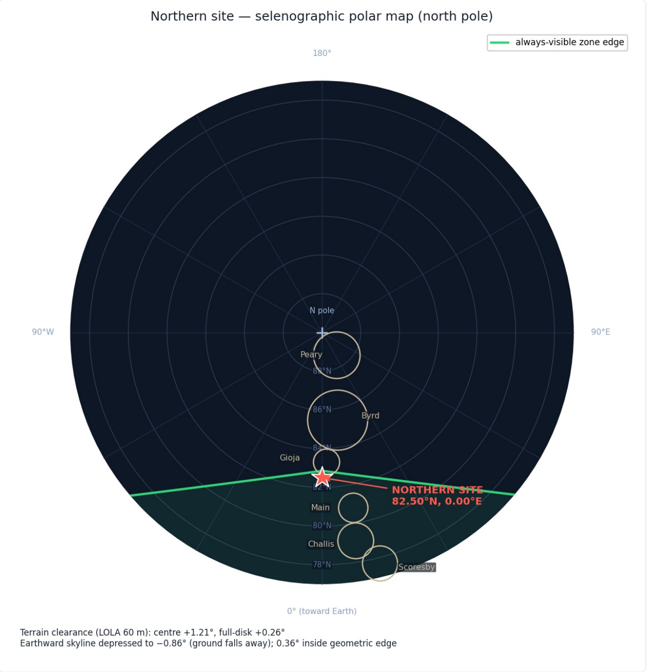
On the prime meridian in the north-polar highlands, just south of Gioja crater. The site sits in worn highland terrain forming the south-west approaches to Byrd; Gioja (about 25 km north-northeast) is the nearest sizeable named feature, with Main and Scoresby to the south-southeast and Byrd and Peary toward the pole.

> *This site sits just inside the geometric always-visible zone — only about a third of a degree from its edge — which is exactly why Earth here sinks lower than at any other confirmed location while still never setting. It works because the ground falls gently away toward Earth, dropping the Earthward skyline below the horizontal so the grazing planet still clears it.*

	DECIMAL DEGREES	DEGREES–MINUTES–SECONDS
Latitude	**82.50° N**	82° 30′ 00″ N
Longitude	**0.00° E**	0° 00′ 00″ E



EARTH SKY-WINDOW · Earth's complete path across this site's sky over the full 18.6-year cycle, shown as compass direction (left–right) against height above the horizon (up–down). Each dot is a moment in the roughly month-long cycle; colour marks where in that cycle it falls. Earth never rises or sets — it drifts within this compact patch low in the sky. Its lowest (binding) and highest points are marked, and Earth's disk is drawn to scale at its nearest and farthest distances.



SELENOGRAPHIC MAP · North-pole polar projection with the site marked (red star), the always-visible zone edge in green, named craters shown to scale, and the terrain-clearance margin called out.

Other northern locations that keep the whole Earth disk visible

Full-disk passers (the stricter test — entire disk permanently up). The margin shown is the full-disk margin. A dagger (†) marks sites whose margin is not yet robust and still needs high-resolution confirmation.

COORDINATES	EARTH ELEVATION RANGE	MARGIN (FULL-DISK)	BINDING TERRAIN FEATURE
81.00°N, 0.0°E	+1.84° … +15.65°	**+0.41°**	ridge +72 m at 6.8 km (az 187°)
80.50°N, 5.0°W	+2.19° … +16.14°	**+0.83°**	ridge +126 m at 9.2 km (az 181°)
80.50°N, 0.0°E †	+2.33° … +16.15°	**+1.03°**	local pad rise at <1 km (az 187°)
80.50°N, 15.0°E	+1.70° … +16.04°	**+0.43°**	ridge +103 m at 11.3 km (az 203°)
80.00°N, 25.0°W	+1.34° … +16.15°	**+1.92°**	depressed horizon −150 m at 87.5 km (az 147°)
80.00°N, 10.0°W	+2.45° … +16.62°	**+1.63°**	near-level horizon −5 m at 4.2 km (az 162°)
80.00°N, 5.0°W †	+2.67° … +16.64°	**+2.10°**	near-level horizon −2 m at 1.1 km (az 183°)
80.00°N, 0.0°E	+2.83° … +16.65°	**+1.58°**	ridge +14 m at 2.4 km (az 187°)
80.00°N, 5.0°E	+2.68° … +16.65°	**+1.62°**	ridge +367 m at 26.8 km (az 177°)
79.50°N, 30.0°W	+1.24° … +16.30°	**+1.99°**	depressed horizon −751 m at 59.5 km (az 142°)
79.50°N, 25.0°E	+1.79° … +16.63°	**+1.00°**	ridge +41 m at 17.6 km (az 212°)
79.00°N, 15.0°W	+3.07° … +17.53°	**+1.32°**	ridge +213 m at 9.2 km (az 163°)
79.00°N, 5.0°W †	+3.65° … +17.64°	**+1.74°**	near-pad rise at 0.3 km (az 182°)
79.00°N, 0.0°E	+3.82° … +17.65°	**+1.54°**	ridge +74 m at 3.1 km (az 172°)
79.00°N, 5.0°E †	+3.66° … +17.65°	**+2.76°**	near-pad rise at 0.3 km (az 177°)

† Margin not yet robust — sits at or near the camera pad and still needs a high-resolution (LROC NAC) elevation check before it can be trusted.

Closest neighbour: 81.00°N, 0.0°E (1.5° of latitude away), then the three sites at 80.50°N. **Most robust margins** belong to sites roughly three degrees nearer the equator — 79.00°N/5.0°E (+2.76°), 80.00°N/5.0°W (+2.10°), 79.50°N/30.0°W (+1.99°) — but at all of those Earth never drops as low as it does here. The selected site deliberately carries the **thinnest** full-disk margin of the group (+0.26°), because it is the geometric-edge site where Earth reaches its lowest possible point: lowest Earth and slimmest margin are the same trade.

In plain language

From here Earth never rises and never sets. It hangs low in one corner of the sky and stays there — a large, brilliant ball, roughly three to four times as wide as the full Moon looks from a back garden, and far brighter. Day to day and month to month it drifts slowly within a small patch, tracing a slow loop rather than marching across the heavens; over the years the loop shifts, but Earth always keeps to the same low corner. The camera would catch the planet turning once a day, continents and oceans and weather rolling past, the line between day and night sweeping across its face. And Earth runs through phases, just as the Moon does for us — a slim crescent, a half, a full bright disk — completing the cycle about once a month, always opposite to the Moon's phase in our own sky.

The ground here is smooth and rounded rather than jagged, and it slopes very gently away in the direction of Earth. To turn this candidate into a real camera site, the one remaining step is a close-up survey of the ground in the few tens of kilometres toward Earth, mapped finely enough to confirm the exact shape of the horizon down to the last hand's-breadth, so the camera can be set with its view guaranteed clear.

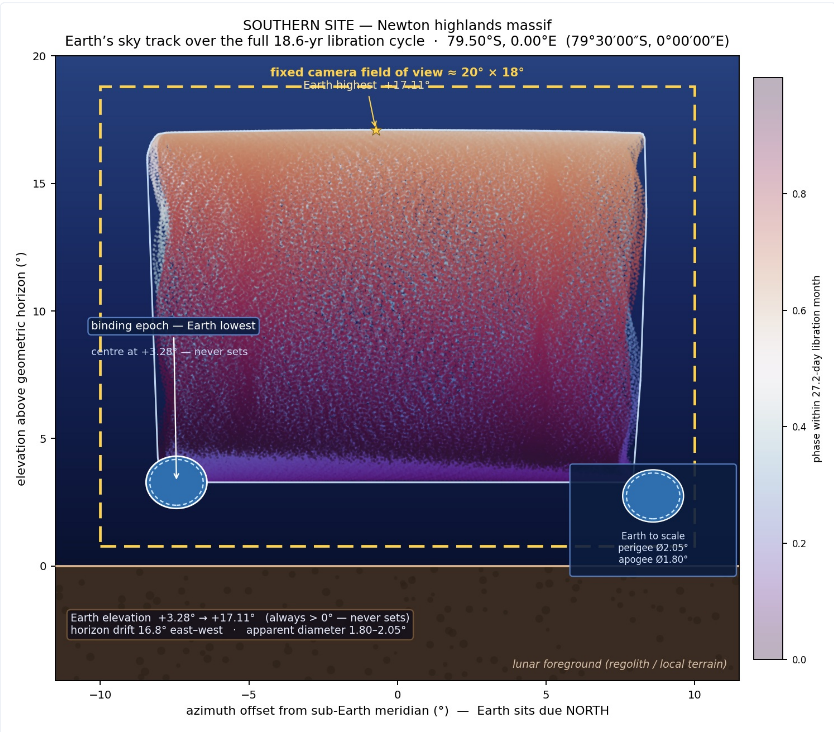
SOUTHERN SITE · THE GEOLOGICAL SOLUTION

79°30′00″ S · 0°00′00″ E

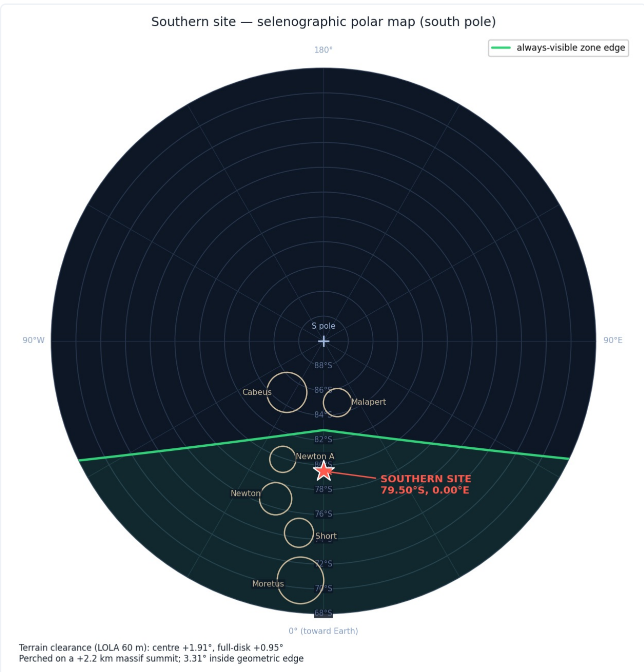
High on a massif summit in the far-southern highlands, near Newton crater. The site sits in rugged, heavily cratered terrain on the sub-Earth meridian; Newton — the deepest crater on the Moon's near side — lies about 135 km to the north-northwest, with Short and Moretus further toward the equator and Cabeus and Malapert toward the pole.

> *This site sits comfortably inside the geometric always-visible zone — more than three degrees from its edge — so Earth rides higher and more securely here than at the northern site. It works because the camera stands on the summit of a high massif that lifts its line of sight clear of the rugged southern terrain.*

	DECIMAL DEGREES	DEGREES–MINUTES–SECONDS
Latitude	**79.50° S**	79° 30′ 00″ S
Longitude	**0.00° E**	0° 00′ 00″ E



EARTH SKY-WINDOW · Earth's complete path across this summit's sky over the Moon's full 18.6-year wobble, as compass direction against height above the horizon. Each dot is a moment in the roughly month-long cycle; colour marks where in that cycle it falls. Earth never rises or sets — it drifts within this compact patch, sitting noticeably higher than at the northern site. Lowest and highest points are marked, and Earth's disk is drawn to scale at its nearest and farthest distances.



SELENOGRAPHIC MAP · South-pole polar projection with the site marked (red star), the always-visible zone edge in green, named craters shown to scale, and the terrain-clearance margin called out.

Other southern locations that keep the whole Earth disk visible

Full-disk passers (entire disk permanently up). All southern passers carry robust margins (combined uncertainty 0.05°).

COORDINATES	EARTH ELEVATION RANGE	MARGIN (FULL-DISK)	BINDING TERRAIN FEATURE
83.00°S, 25.0°W	−1.23° … +13.25°	**+1.23°**	deeply depressed horizon −3050 m at 87.5 km (az 33°)
82.00°S, 20.0°E	−0.02° … +14.39°	**+0.58°**	depressed horizon −598 m at 46.5 km (az 334°)
80.50°S, 10.0°W	+1.93° … +16.08°	**+0.29°**	ridge +2108 m at 61.2 km (az 11°)
80.50°S, 5.0°W	+2.15° … +16.10°	**+1.11°**	ridge +602 m at 37.2 km (az 357°)
80.00°S, 15.0°E	+2.12° … +16.49°	**+0.88°**	ridge +759 m at 42.5 km (az 338°)
79.00°S, 25.0°W	+2.14° … +17.05°	**+0.21°**	ridge +756 m at 19.3 km (az 22°)
79.00°S, 20.0°W	+2.62° … +17.31°	**+3.42°**	depressed horizon −203 m at 100 km (az 28°)
79.00°S, 15.0°W	+3.02° … +17.48°	**+1.50°**	distant rim +3022 m at 86.2 km (az 23°)
79.00°S, 5.0°W	+3.61° … +17.60°	**+1.51°**	ridge +1196 m at 34.5 km (az 357°)
79.00°S, 5.0°E	+3.61° … +17.60°	**+1.59°**	ridge +709 m at 26.6 km (az 348°)
79.00°S, 25.0°E	+2.17° … +17.07°	**+0.20°**	ridge +766 m at 29.1 km (az 328°)

Closest latitude band: the cluster at 79.00°S (half a degree away), with 80.00°S and 80.50°S close behind. **Most robust margin:** by a clear distance, 79.00°S/20.0°W at **+3.42°**, where a distant depressed horizon leaves Earth a wide berth. Several locations *deeper* toward the south pole also pass — 83.00°S/25.0°W and 82.00°S/20.0°E, both perched about 3 km up on South Pole–Aitken massifs — but along the exact sub-Earth meridian itself the southernmost location that still clears is this one at 79.50°S; further south on the meridian, the terrain wins. That is why a high massif summit, rather than a deeper latitude, is what makes the southern leg work.

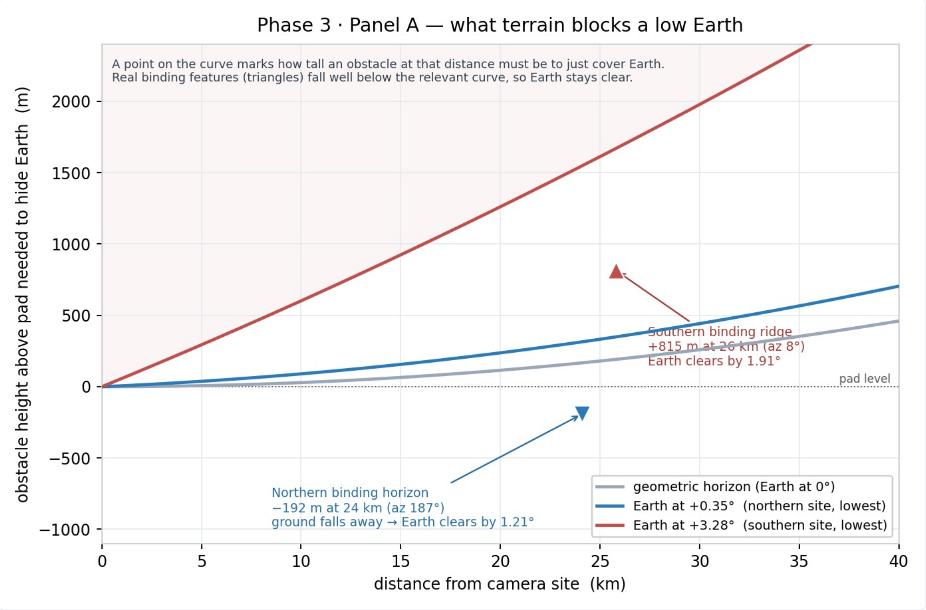
In plain language

This location lies deep in the Moon’s rugged far south, on the line pointing most directly at Earth, in the heavily cratered highlands near Newton. What sets the spot apart is height: the camera would stand on the summit of a tall mountain massif, raised more than two kilometres above the broken country around it.

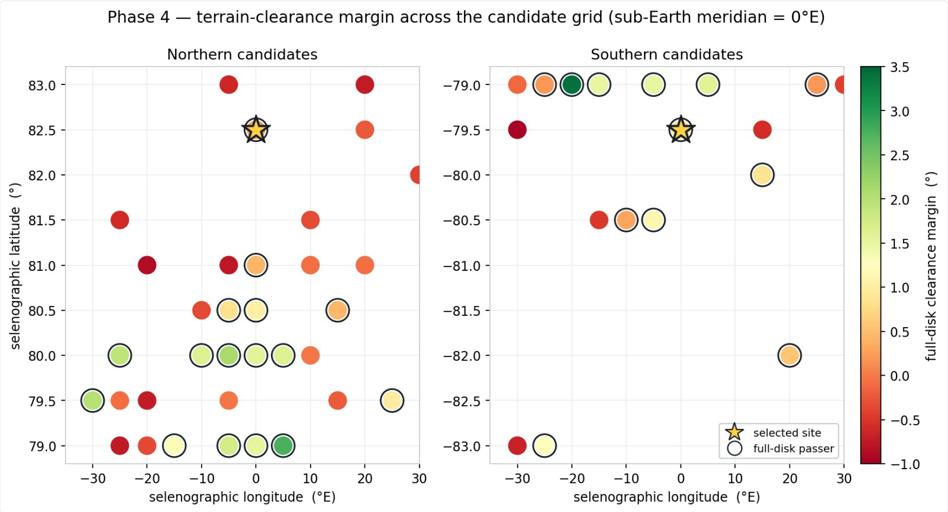
From this summit Earth never rises and never sets. It stands clear in one part of the sky, higher and more securely above the horizon than at the project’s northern site, and simply stays there. Earth appears as a large, dazzling sphere — about three to four times the width of a full Moon and far brighter — and it shifts only slowly, drifting in a small loop over the course of each month while remaining in the same quarter of the sky year after year. The camera would record the planet rotating once a day, its continents, oceans, storms and the moving boundary between daylight and darkness all passing through the frame. Earth also cycles through phases like the Moon does for us, from crescent to full and back, about once a month. The single remaining step before this candidate becomes a real camera site is a detailed close-range survey of the summit and the terrain toward Earth, fine enough to confirm the exact horizon shape and the precise height of the chosen spot.

From sky-track to terrain clearance

Each candidate is judged by one quantity: the smallest gap, over the entire 18.6-year cycle, between Earth's height in the sky and the height of the local skyline in the direction Earth occupies. Earth's position comes from the DE440 ephemeris; the skyline comes from real laser-altimeter terrain. A site passes only if that gap stays positive at the single worst moment — the binding epoch — not merely on average. Two views below make the terrain test concrete: how tall an obstacle must be to matter, and how the whole candidate grid scores.



WHAT BLOCKS A LOW EARTH · How tall a hill or ridge at a given distance must be to just hide a low Earth. The threshold rises with distance because the Moon's surface curves away. The two confirmed sites are marked: the northern binding feature is a stretch of horizon that sits **below** the camera (ground dropping away toward Earth), clearing Earth by 1.21°; the southern binding feature is a +815 m rise about 26 km to the north, well under the curve, clearing Earth by 1.91°.



CLEARANCE-MARGIN MAP · Every candidate tested in the final phase, coloured by how much clear sky stands between the full Earth disk and the local terrain — green is comfortable, red is marginal. Selected sites are starred; ringed points keep the entire Earth disk permanently visible. The northern field clusters along the Earth-facing meridian on smooth highland; the southern field scatters across rugged terrain, with a few passers perched deep toward the pole on South Pole–Aitken massifs.

Why near-field terrain dominates. A feature's blocking angle scales roughly as its height divided by its distance, so modest rises close to the pad matter most: at the binding low Earth, a hill of only a few tens of metres at 1 km can already cut the view, while at 100 km it would need to rise several kilometres — essentially nonexistent on the Moon. The mandatory search radius is therefore the first ~30 km at high resolution, a regional sweep to ~200 km, and a single coarse check beyond.

SOURCES & REPRODUCIBILITY

Data provenance and uncertainty

Every figure and the candidate table are reproducible from the project scripts. The four primary sources below, and what each specifically contributed, apply to both sites; site-specific numbers appear on each site's page.

JPL DE440 planetary and lunar ephemeris. SPICE SPK kernel `de440s.bsp` (NAIF *generic_kernels*); formally Park, Folkner, Williams & Boggs (2021), *The JPL Planetary and Lunar Ephemerides DE440 and DE441*, Astronomical Journal 161:105. **Contribution:** every position of Earth in each site's sky is computed from DE440 — the measured elevation ranges (+0.35° to +14.15° north; +3.28° to +17.11° south), the east–west swing of about 16.5°, and the libration extremes that fix the binding low point.

LRO LOLA polar elevation models. Products **LDEM_75N_60M** and **LDEM_75S_60M** (LOLA GDR, polar, 60 m/pixel), heights above the 1737.4 km reference sphere, retrieved from the LOLA PDS node (imbrium.mit.edu). **Contribution:** the entire terrain side of the result — the clearance margins (north +1.21°; south +1.91° centre, +0.95° full-disk), the −347 m grade and −0.86° depressed skyline at the northern site, and the +2212 m summit grade with +815 m binding ridge at the southern site.

Meeus, *Astronomical Algorithms*, 2nd ed. (1998), Chapter 53. "Ephemeris for Physical Observations of the Moon." **Contribution:** the reduction from raw orbital geometry to the Moon's apparent orientation — the optical libration that sets where Earth sits and how far it swings each month — follows this chapter's physical-libration method (validated to 0.001° against the book's worked example).

Gorkavyi, Krotkov & Marshak (2023). *Earth observations from the Moon's surface: dependence on lunar libration*, Atmospheric Measurement Techniques 16, 1527–1537. **Contribution:** this independently published paper corroborates the Earth-disk scale (about 1.8–2.0° across) and the multi-year reshaping of Earth's track — without drawing on any of the project's own calculations.

COMBINED UNCERTAINTY

Technical: each site's angular budget closes at a combined one-sigma uncertainty of **0.05°**, set not by the ephemeris (sub-arcsecond) or the libration reduction (milliarcsecond-level) but by the registration and effective resolution of the LOLA polar model — the decimetre-scale pad/summit elevation and the exact profile of the Earthward horizon. **Plain:** where Earth sits in the sky is known essentially perfectly; the only thing left to pin down is the precise shape of the ground toward Earth, to the last few tens of centimetres — the single most important remaining measurement before a camera is placed (a high-resolution LROC NAC survey).

GITHUB REPOSITORY — RECOMMENDED CONTENTS

Include: the Python scripts from all four phases, the phase PDF reports, and the candidate CSV — together small, and fully documenting both method and result. **Exclude and link instead:** the intermediate NPZ data files (reproducible — ship the scripts plus a one-line regenerate command); the LOLA DEM files (large — link the LOLA PDS product pages for LDEM_75N_60M / LDEM_75S_60M at imbrium.mit.edu); and the DE440 kernel (large — link the NAIF *generic_kernels* SPK, `de440s.bsp`).

EXAX Site-Selection Team (2026). *EXAX Lunar Earth-Camera Site Selection (Phases 1–4): positional-astronomy and terrain-clearance analysis.*

Code, candidate table and phase reports: https://github.com/[owner]/exax-site-selection

Built on JPL DE440 (Park et al. 2021, AJ 161:105), LRO LOLA polar DEMs (LDEM_75N_60M / LDEM_75S_60M), and the libration reduction of Meeus (1998, ch. 53).