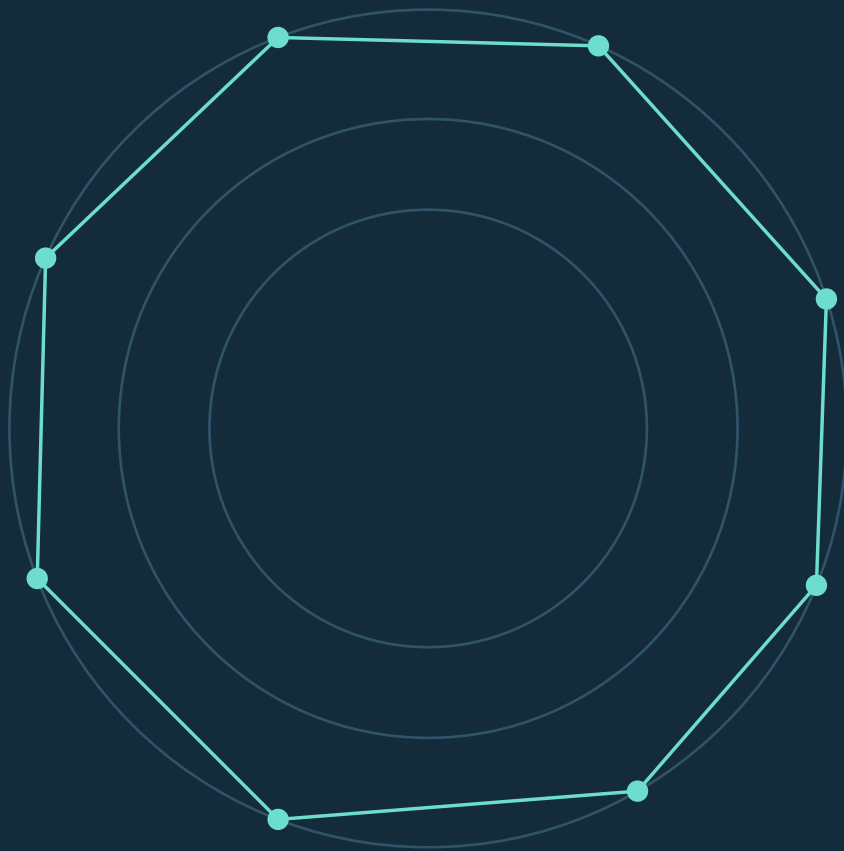


Messages across a moving network.

Optical relays, global coverage and the
engineering of a 1-10 satellite constellation.



Network illustration · not an orbital projection

REVISION 2.0 / 28 SEPTEMBER 2026

Prepared for John Sneisen · Design study and procurement basis

DOCUMENT GUIDE

A practical design basis.

This revision integrates optical relays into the existing worldwide simulation and hardware concept. Read the results together with the hardware, power and pointing limits. The procurement appendix provides links and a price basis for every item.

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01 / DESIGN REFERENCE

What space relays change

Northlink is a proposed delay-tolerant communications network joining community ground stations through a small constellation. This revision adds optical inter-satellite links to the worldwide network simulator, procurement directory and spacecraft model. It preserves the original low-rate ground-radio architecture and makes the enlarged optical variants explicit.

A satellite carrying a complete message can forward it to another satellite that can reach the destination sooner. Light travels at the same vacuum speed whether the carrier is radio or optical; the large improvement comes from avoiding orbital waiting. Laser terminals provide narrow beams and high potential data rates, but acquisition, Earth blockage, pointing and spacecraft resources still matter.

Measured model case	Without space relays	With space relays
100 MB, Sandy Hook → London; 10-satellite global-coverage preset, model time 0	354.77 min	56.23 min
Same route; separately route-optimized 10-satellite fleet, model time 0	171.77 min	3.74 min

Each row compares the same orbital elements with relays switched off and on. The second row changes the constellation design first; its result is specific to that route and start time. Neither case is a measured service guarantee or a statistical global average.

Decisions introduced in revision 2

Two independently pointed optical terminals are allocated per optical spacecraft. The long-range comparison uses TESAT SCOT80; a smaller SCOT30 development option is also shown. Whole-bundle forwarding, a selectable acquisition delay and Earth-clearance checks determine whether a handoff is useful. Hardware is expanded to include terminal electronics, a faster router, larger arrays, power conversion, battery packaging and radiators.

Status: pre-procurement engineering study. No deployed Northlink satellites, flight-qualified integrated bus, verified optical link budget or committed spacecraft price is established by this paper. The simulator moves synthetic payload counters; it does not transmit files over a real satellite network.

02 / DESIGN REFERENCE

Mission baseline and service boundaries

Item	Revision 2 basis
Ground network	18 reference locations; searchable catalog of 34,149 cities across 244 country/territory codes; custom coordinates and saved towns
Space segment	1-10 circular-orbit spacecraft; 97.6° inclination; 550 km default; selectable lower and higher orbit studies
Service	Asynchronous text, pictures and files. Default video/file example: 100 MB decimal (800 megabits)
Ground links	One tracking terminal per endpoint in each transfer; nominal 10 Mbps net cap with optional lower rate profiles
Space links	Whole-bundle handoffs through geometrically available terminal pairs; no file striping or simultaneous fleet-wide throughput multiplication
Horizon and epoch	Up to seven simulated days. Time zero is a design reference, not a live satellite ephemeris

The original ten-node, approximately 40 kg concept remains the non-optical reference. The current map adds test locations and constellation alternatives; those map pins are planning coordinates, not commissioned stations. A custom town inherits the same radio assumptions unless its settings are changed.

A complete end-to-end route needs an upload opportunity, any selected space handoffs and a download opportunity. With one satellite, inter-satellite routing is impossible. With two or three widely separated satellites, useful pair geometry may be absent. Adding links does not enlarge the radio footprint seen by a ground dish.

Public internet access at a ground gateway is optional to the network architecture. A local user could submit a bundle over a terrestrial mesh and receive it at another independent mesh. The current transfer timer starts at the selected satellite ground terminal and ends at the destination terminal; terrestrial access and backhaul delay are outside that timer.

Live calls and uninterrupted streaming are not supported by the modeled service promise. Short modeled deliveries in a favorable geometry do not establish continuous worldwide service.

03 / DESIGN REFERENCE

Architecture and custody

The data path is: local access network → source ground terminal → first spacecraft → zero or more optical relay spacecraft → destination ground terminal → local access network. The renderer shows possible optical pairs in cyan and highlights the selected hop during playback. A potential link is not a continuously active communications session.

Element	Responsibility
Ground station	Queue bundles, authenticate peers, track scheduled spacecraft, upload or receive at a supported net rate, keep receipts
Ku payload	Independent remote/gateway RF paths, modem framing, coding, Doppler handling, receiver isolation and spacecraft interfaces
Optical terminal pair	Acquire and track a partner, exchange frames, report link quality and provide a compatible terminal data interface
Payload router	Verify and store the full bundle, consult a contact plan, choose the next carrier, enforce queue and expiry policies
Flight computer	Safe mode, power and pointing permissions, deployment sequencing, time and orbit distribution, fault response

The simulation counts one logical payload. Upload and download can resume over later ground contacts, but the selected carrier on each ground leg does not change. A space hop starts only when the full payload is present. A receiver becomes the next custodian after serialization and propagation complete. A one-second processing allowance precedes the next hop or the downlink.

A practical implementation should retain the sending copy until a verified acknowledgement arrives and apply expiry, deduplication and replay protection. Acknowledgements, retransmissions, duplicate storage and their capacity cost are not explicitly simulated. This paper uses “custodian” to describe the logical carrier; it does not claim that an optional custody-transfer extension is implemented by the browser.

Two optical heads allow a useful relay architecture and later scheduling flexibility. The present simulation only moves one payload through one optical hop at a time, so it does not assume an arbitrary number of simultaneous neighbors. The actual head fields of regard and pair scheduling remain part of the engineering design.

04 / DESIGN REFERENCE

Optical hardware and readiness

Manufacturer specification	SCOT30 development option	SCOT80 long-range option
Range envelope	Up to 3,500 km; configuration dependent	Up to 8,000 km
Published channel rate	Symmetric up to 1.25 Gbps; asymmetric TX 2.5 / RX 1.25 Gbps	2.5 / 10 Gbps bidirectional
Mass per channel	<6 kg; model allocates 6 kg	11.9 kg
Power per channel	Peak <60 W; model allocates 60 W	60–80 W; model allocates 80 W
Published head / unit size	230 × 280 × 200 mm	Head: 31 × 29 × 47 cm; electronics: 26 × 19 × 24 cm
Readiness statement	TRL6 Q2 2027; TRL8 Q1 2028; availability 2028	Manufacturer describes running production
Northlink net rate cap	100 Mbps study assumption	1,000 Mbps study assumption

The manufacturer channel rates are not the simulator net rates. Northlink deliberately uses lower study caps, but a lower rate does not itself prove an adequate received-power, jitter or coding margin. A paired-terminal optical budget and interface review must validate any operational setting.

SCOT80 is the default feasibility comparison because its published range supports more of the sparse constellation geometry. SCOT30 is explicitly a future development comparison. Neither product listing establishes delivery lead time, final configuration, export eligibility, integration compatibility or a public price.

RF crosslinks are another possible technology, particularly at shorter range, but would need their own antennas, frequencies, interference coordination and link budget. This revision implements the sourced optical candidates. It does not assume access to Starlink terminals or compatibility with a third-party satellite network.

Primary sources: TESAT SCOT80 data sheet, 20 August 2025; SCOT30 data sheet, 3 August 2026; TESAT product family. Exact optical wavelength, channel plan and interoperable pairing must come from the final vendor interface document.

05 / DESIGN REFERENCE

Line of sight, range and acquisition

Earth is an obstruction. The distance from the Earth center to the line segment joining two satellites must exceed the Earth radius plus a 100 km study clearance. Each pair must also remain within the selected terminal range throughout acquisition, serialization and the short propagation allowance.

Quantity at 550 km altitude	Model result
Earth radius R / orbital radius a	6,371 km / 6,921 km
Maximum chord above 100 km limb clearance	4,910 km
Neighbor spacing, 10 equally spaced satellites	4,277 km
Complete evenly spaced SCOT80 ring	At least 9 satellites for the specified clearance and altitude
Complete evenly spaced SCOT30 ring	At least 13 satellites; outside the current 1-10 selector

These ring thresholds apply only to a single uniformly populated orbital plane. Multi-plane constellations can create intermittent crossings and useful relay paths with fewer satellites. Conversely, having ten spacecraft does not guarantee a connected space network at every instant.

Continuous contact windows

For the model’s equal-altitude circular orbits, the normalized dot product of two position vectors is $A + B \cos(2nt) + D \sin(2nt)$, where n is mean motion. The code derives the coefficients and solves the allowable intervals analytically. Earth rotation cancels in pair distance. Short crosslink opportunities are therefore not skipped on a coarse sampling grid.

Acquisition can be set to 0, 10, 30, 60 or 120 seconds. Thirty seconds is the default sensitivity assumption, not a manufacturer guarantee. Zero represents an already acquired link. A complete bundle must fit in the remaining uninterrupted window after acquisition. The final transmit-range distance divided by 299,792.458 km/s supplies the modeled propagation delay.

The geometry model assumes unobstructed pointing within each usable pair. It does not yet enforce terminal gimbal limits, body/wing occlusion, Sun exclusion, Earth brightness, ephemeris error, vibration or acquisition failure.

06 / DESIGN REFERENCE

Routing, serialization and timing

For a fixed constellation, the planner first computes the best single-carrier route. It then seeds an earliest-arrival search with the time each spacecraft could finish uploading the complete payload. From the earliest available carrier, it tests the next full-bundle optical contact to each other spacecraft and the next achievable complete downlink. The best end time wins.

Keeping the no-relay route as a candidate means enabling space links cannot intentionally worsen a completed route in this model. A route may contain zero optical hops even with optical hardware selected. Each comparison uses the same payload, ground settings, time and orbital elements on both sides.

100 MB example	Serialization or fixed allowance
Upload at 10 Mbps net	80 seconds
Downlink at 10 Mbps net	80 seconds
One 1,000 Mbps optical hop	0.8 seconds plus acquisition and propagation
One 100 Mbps optical hop	8 seconds plus acquisition and propagation
Default acquisition	30 seconds per optical hop
Router handling	1 second before the next space hop or ground downlink

With a 10 Mbps ground cap, the two ground legs alone take at least 160 seconds for a 100 MB file. A one-gigabit laser hop does not turn the entire end-to-end route into a one-gigabit service. Large files can also miss a ground contact that a tiny text message could use, producing a much larger difference than serialization alone suggests.

Ground transmission is scheduled in five-second intervals and admitted only when start, midpoint and end satisfy elevation and RF headroom checks. The last interval is shortened to the remaining byte count. This is a conservative numerical approximation, not continuous contact integration. Ground-radio acquisition, ground propagation, ACK traffic and contention are outside the current timer.

Payload MB means 1,000,000 bytes. The model conserves uploaded, onboard and delivered logical bytes. A delivered payload is exactly complete; fractional floating-point residue is not displayed as undelivered data.

07 / DESIGN REFERENCE

Measured comparison for 1–10 satellites

The following reproducible run uses the saved global-coverage preset for each satellite count. Source: Sandy Hook, Canada (50.55°, –96.99°). Destination: London (51.507°, –0.128°). Payload: 100 MB. Start: model second 0. Altitude: 550 km; mask: 20°; dish: 0.9 m; weather allowance: 3 dB; adaptive rate cap: 10 Mbps; SCOT80 study: 1,000 Mbps net; acquisition: 30 s.

Satellites	No relay, min	With relay, min	Space hops
1	333.18	333.18	0
2	401.10	401.10	0
3	401.10	401.10	0
4	401.10	166.05	1
5	401.10	75.46	1
6	354.77	95.13	1
7	177.10	121.78	3
8	354.77	82.80	1
9	202.02	32.94	6
10	354.77	56.23	3

The layouts at different counts were optimized for global ground access, not for monotonic performance on this one route. Consequently, five satellites can beat six at this particular start time. The paired on/off comparison within each row is the evidence for the relay benefit. With one, two and three satellites in these specific layouts, the fastest modeled delivery retains a single carrier.

Machine-readable orbital elements, endpoint coordinates and all settings are included in Northlink-Crosslink-Benchmarks.json. Values are rounded only for display. They are deterministic simulation examples, not percentiles or service-level commitments.

08 / DESIGN REFERENCE

Global coverage and route optimization

Coverage and fastest delivery are different objectives. The global optimizer searches plane count, plane spacing, phasing and orientation, evaluates equal-area Earth samples over seven days, and minimizes mean waiting while retaining at least 99% of the original layout’s sampled average availability and payload capacity. Optical relays do not change direct ground visibility, so this coverage metric remains a ground-link calculation.

The route optimizer searches bounded layout candidates for the selected endpoints, payload and current model time using the active relay mode. When increasing satellite count, it retains the previous full fleet as a candidate and adds one spacecraft. This prevents the search from losing a previously achieved route purely because the candidate family changed. It is a repeatable bounded search, not proof of a global mathematical maximum.

Satellites	No relay on chosen fleet, min	Relay-optimized delivery, min	Hops
1	171.02	171.02	0
2	170.52	170.52	0
3	170.52	170.52	0
4	316.93	81.13	1
5	402.02	38.18	1
6	403.02	20.69	1
7	174.85	18.43	1
8	172.93	16.16	2
9	171.77	3.74	2
10	171.77	3.74	2

This table uses the same Canada-UK settings as the previous page, but the orbital layouts have been optimized for that route. An early arrival at one time can sacrifice other routes or later opportunities. A deployed constellation cannot instantly change orbital planes; these are pre-launch design alternatives, not a maneuver command or an operational retuning capability.

Before selecting a real constellation, evaluate many cities, both directions, start times, outages and seasonal conditions; include launch deployment, collision avoidance, energy and traffic constraints.

09 / DESIGN REFERENCE

Regional messages, pictures and video

Regional cases use the ten-satellite global-coverage preset at model second 20,070 with the same ground radio, altitude and SCOT80 study settings. “Text” is a 57-byte example, “picture” is 5 MB, and “video/file” is 100 MB. Content type does not change physics; byte count does.

Route / payload	No relay, min	With relay, min	Hops
London → Accra 57 B text	29.93	29.93	0
London → Accra 5 MB picture	29.98	29.98	0
London → Accra 100 MB file	31.27	31.27	0
Accra → São Paulo 57 B text	228.77	54.90	1
Accra → São Paulo 5 MB picture	228.82	54.97	1
Accra → São Paulo 100 MB file	230.10	56.25	1
São Paulo → London 57 B text	619.60	70.31	1
São Paulo → London 5 MB picture	619.65	70.38	1
São Paulo → London 100 MB file	620.93	114.34	1

The London-Accra route shows no benefit in this run because its best carrier already reaches the destination sooner than any useful relay alternative. Accra-São Paulo gains a useful handoff. São Paulo-London shows why a 100 MB transfer can wait much longer than text: the larger payload requires enough usable ground contact, not just the first moment of visibility.

The same search is available for the world city catalog and custom locations. A place name is only a coordinate shortcut. Terrain, nearby obstructions, measured rain statistics, installation height and actual RF equipment must be added before interpreting a town-level result as deployable coverage.

The downloaded benchmark file also includes all of these cases with the SCOT30 development profile. No claim of globally constant latency is made.

10 / DESIGN REFERENCE

Spacecraft accommodation and mass

Allocation	Base	SCOT30 study	SCOT80 study
System mass target	40 kg	65 kg	80 kg
Bus envelope, mm	300 × 300 × 600	450 × 450 × 700	600 × 600 × 800
Two optical channels	—	12 kg allocation	23.8 kg published
Router / interface increment	—	2 kg allowance	2.2 kg allowance
Power / storage increment	—	5 kg allowance	5 kg allowance
Structure / thermal increment	—	3 kg allowance	6 kg allowance
Additional system reserve	—	3 kg allowance	3 kg allowance
Total wing area	1.44 m²	2.16 m²	2.88 m²

The original 40 kg system allocation is carried forward as the base subtotal. The increments sum to the stated optical-variant targets. Only the SCOT80 terminal mass is a specific published channel figure; SCOT30 uses a rounded upper allocation and the other increments are engineering allowances. Supplier bills of mass, harness, mounting, launch adapter and final contingency may require further growth.

The interactive spacecraft contains sixteen inspectable assemblies. The optical version shows two end-mounted terminal heads, terminal electronics, a payload router, additional battery/power packaging and enlarged radiators. Selecting the base profile hides the optical-specific assemblies and restores the smaller bus and arrays.

The GLB download depicts the long-range SCOT80 study in metres, with named assemblies and revision metadata. External envelopes guide the scene, but gimbals, internal optics, boards, cells, connectors and heat paths are illustrative. It is not a vendor CAD assembly, a dimensioned manufacturing drawing or a verified interference-free layout.

The larger bus changes inertia, center of mass, drag area, deployment modes and launcher requirements. The simulator has no structural dynamics, collision-clearance or thermal-accommodation solver. Detailed accommodation must resolve optical sight lines, Ku scan directions, plume zones and solar orientation together.

11 / DESIGN REFERENCE

Power, eclipse energy and thermal design

Power study item	Long-range optical allocation
Solar generation target	600 W useful sunlight power; end-of-life capability to be demonstrated
Battery nameplate	500 Wh optical variants; 400 Wh base
Non-PA bus/payload allowance	90 W
Two 2 W Ku power amplifiers	20 W electrical at an assumed 20% efficiency
Two optical channels	Up to 160 W using the upper SCOT80 channel allocation
Router + conversion/heater allowance	15 W + 15 W
Worked concurrent peak	300 W, excluding electric propulsion

At 550 km, the circular period is approximately 95.5 minutes. A worst-geometry cylindrical-shadow estimate gives about 35.6 minutes of eclipse. A constant 300 W load would consume about 178 Wh in that eclipse. A 500 Wh pack with 80% usable depth of discharge and 90% discharge efficiency yields 360 Wh in this simplified example; aging, cold temperature, contingency and battery current limits still need margins.

With about 59.9 minutes of sunlight, 600 W and an assumed 85% collection/conversion factor yield roughly 509 Wh per orbit, versus about 478 Wh consumed at a continuous 300 W load. That is a narrow illustrative energy margin before propulsion and other losses. A single active optical channel reduces this example load, but two-head duty, pre-acquisition and heaters need a time-resolved schedule.

The linked NanoPower P80 is a 300 W comparison and cannot be treated as a verified 600 W optical EPS. The procurement directory explicitly requires a redesigned system or a qualified parallel architecture. Propulsion may compete with communications for power and must be duty-managed.

At 300 K with emissivity 0.85, an ideal deep-space radiator emits roughly 390 W/m². Rejecting 300 W would need about 0.77 m² before Earth/Sun heating, view factors and margins. The long-range model allocates roughly 1 m² gross radiator area, including the enlarged bus radiator. This is a sizing illustration, not thermal closure.

Current route planning does not inhibit a link for low battery, thermal limit or propulsion priority. The mass, power and thermal budgets remain open engineering gates.

12 / DESIGN REFERENCE

Pointing, navigation and optical operations

A narrow optical beam demands a terminal pointing, acquisition and tracking chain. Bus attitude control supplies coarse orientation and a stable platform; a terminal supplies the fine optical functions appropriate to its design. Existing reaction-wheel and sensor candidates are not evidence that Northlink already meets an optical jitter requirement.

Interface or constraint	Required engineering evidence
Ephemeris / time	Time-tagged position and velocity, covariance, update latency and recovery after lost navigation
Coarse pointing	Bus and terminal steering range, slew time, pointing knowledge, partner search volume
Fine tracking	Acquisition probability, beam jitter, dynamic tracking range and disturbance rejection
Keep-out zones	Sun, Earth limb/brightness, body panels, moving solar wings and propulsion plume
Mechanical / thermal	Boresight calibration, mounting stiffness, thermoelastic drift and launch alignment retention
Failure response	Timeout, safe pointing, reacquisition, alternate carrier and queue expiry behavior

Opposite-end heads in the 3D study provide a starting arrangement, not proof of all-sky access. Their allowed fields of regard must be intersected with the pair geometry. In a sparse constellation, rejecting a single head direction can remove the only useful path, so this is a priority extension before procurement.

The acquisition selector is intended for sensitivity testing. A scheduled, already locked pair can use zero additional acquisition in the model, while a newly selected partner can use a longer allowance. The implementation charges the selected allowance for each new space hop and only accepts a window long enough to complete the bundle.

The receiver-side propagation addition uses instantaneous range at the end of transmission. Relativistic clock handling, point-ahead angles and receiver motion during light time belong in the terminal/navigation implementation. They are not resolved by this network-level timing model.

13 / DESIGN REFERENCE

Ground radio and antenna design

Parameter	Simulation basis
Ku uplink / downlink centers	14.25 GHz / 11.95 GHz
Transmitted RF power	Ground: 5 W; spacecraft: 2 W per downlink
Ground dish	0.9 m default; 60% aperture efficiency assumption
Spacecraft aperture	Two 160 × 160 mm allocations; 45% efficiency assumption
Receiver noise temperatures	Spacecraft: 600 K; ground: 180 K
Net payload rate profiles	10, 5, 2, 1, 0.5, 0.1 Mbps, constrained by the selected cap
Losses and requirement	1 dB feed; selected weather allowance; 0.5 + 1 + 1 dB fixed losses; 6 dB scan allowance; 9 dB combined Eb/N0 target and reserve
Elevation mask	20° default; user-selectable

Free-space loss is $92.45 + 20 \log_{10}(f \text{ in GHz}) + 20 \log_{10}(\text{range in km})$. The ground gain uses 60% of the ideal dish aperture; the spacecraft gain uses the stated aperture area and 45% efficiency. Received power is compared against kT and the net bit rate, then the assumed requirement is subtracted to obtain headroom.

These are selected design assumptions. There is no measured modem profile, validated coding threshold or antenna scan pattern behind the adaptive rate table. A rate is allowed only when the selected profile has nonnegative headroom and the terminal is above its mask. The ground-network test uses the best available spacecraft at each sample and never multiplies one dish's rate by constellation size.

A practical ground terminal needs a tracking dish or a compatible electronically steered aperture, Ku feed/duplexer, low-noise receiver, uplink amplifier, modem, timing/orbit data, controller, weather protection and protected power. A Starlink consumer terminal is not a drop-in Northlink terminal. Current hardware candidates require a complete interface and pointing design.

These frequencies are calculation inputs, not operating permission or a country-specific allocation decision. Licensing and coordination must be established for the selected service and locations before transmitting.

14 / DESIGN REFERENCE

Ground mesh and independent gateways

The satellite ground terminal and local terrestrial mesh solve different distances. Satellite Ku frequencies are retained for the orbit path. Directional terrestrial backhaul uses a separate 5.8 GHz study profile, while local access uses appropriate independent channels and equipment. “Optimal” depends on local interference, path clearance and the applicable authorized limits.

Mesh calculation	Model basis
Default path / gain	2 km; 23 dBi directional antennas
Default channel width	20 MHz
Receiver noise	Maximum of the user interference floor and −174 dBm/Hz + bandwidth + 7 dB assumed noise figure
Engineering thresholds	12 dB required SNR plus 10 dB reserve; 2 dB other path losses
Clearance test	60% of the first Fresnel radius plus 4/3-Earth curvature bulge
Rate assumption	0.5 × channel width in MHz as Mbps when both margin and clearance pass
Power choice	Smallest modeled power that meets margin, capped by the user EIRP allowance and candidate hardware ceiling

The EIRP input is not a verified legal limit. Terrain, building obstructions, frequency availability, DFS behavior, measured spectrum occupancy and equipment certification are not imported automatically from the map. A planning pass must be followed by a field survey and current local requirements.

One gateway can accept local bundles, store them during an orbital outage, and forward them over a scheduled space route. Multiple independent ground stations reduce reliance on a single operator, but inter-gateway traffic policy, receipts and scheduling still need agreement. No user should have to expose message contents to a gateway to obtain service.

Ground power design should include station controller, modem, amplifier duty, dish motors, heaters or cooling, local radios, network equipment and battery autonomy. Foundation loads, cable runs, lightning protection, earthing, physical security and maintenance dominate some remote deployments and are not captured by a radio-only equipment subtotal.

15 / DESIGN REFERENCE

Orbit tradeoffs, deployment and environment

The default 550 km orbit is a design-study starting point. Lower altitude reduces slant range and can improve RF headroom, but generally narrows the footprint and increases drag sensitivity. Higher altitude widens geometric reach while increasing free-space loss and changing disposal and radiation considerations. Inclination fixes the latitude reached by the subsatellite point; a footprint can extend beyond it when the radio and elevation constraints allow.

All displayed satellites use the same circular altitude and 97.6° inclination. Their plane orientations and phases vary. The equations omit J2 precession, eccentricity, injection dispersions, drag evolution, maneuvers, conjunction avoidance and seasonal Sun geometry. An inclination near a sun-synchronous value does not establish an actual sun-synchronous mission without the corresponding orbit design.

Trade	Engineering consequence
Sparse LEO constellation	Intermittent ground access; useful optical contacts depend strongly on plane and phase choices
Very low orbit study	Greater drag and density uncertainty; propulsion duty and lifetime can drive power and mass
MEO / GEO alternatives	Different coverage and persistence, with larger range losses and a different spacecraft/launch design
Enlarged optical spacecraft	New launch accommodation, inertia, drag, separation dynamics and deployment sequence
End of mission	Reliable passivation and disposal design; assess current launch and licensing obligations for the actual mission

The propulsion model is an ideal sizing tool, not a selected thruster system. The existing ENPULSION Micro comparison sheet lists a 0.5–1 mN class system with 64–120 W and 28 V; suitability depends on thrust duty, total impulse, propellant, lifetime, plume and minimum operating point. Do not assume it can support a larger spacecraft at every chosen altitude.

Before a launch commitment, propagate the selected constellation with higher-fidelity dynamics, verify conjunction and disposal requirements, size injection and phasing maneuvers, obtain the launcher interface and close the power/thermal impact of propulsion. This paper does not issue a compliance or flight-readiness determination.

16 / DESIGN REFERENCE

Software, security and network governance

Delay-tolerant networking suits a service where contacts are scheduled and interruptions are normal. Bundle Protocol version 7 is a relevant protocol basis; BPSec provides bundle security building blocks. A production implementation needs an explicit convergence layer over both Ku and optical interfaces, interoperable addressing, clock handling, expiry and tested forwarding behavior.

Control	Implementation requirement
Confidentiality	End-to-end content encryption; separate device/link credentials from user content keys
Integrity and identity	Authenticated nodes, signed software, verified bundle metadata and replay resistance
Storage	Error-correcting memory, queue limits, verified writes, crash recovery and secure key handling
Fairness	Priority classes, per-user limits, expiry, emergency policy and transparent congestion behavior
Operations	Signed contact plans, key rotation/revocation, command authorization and auditable changes
Ground independence	Documented peering rules, receipt semantics, ownership and exit procedures

Encryption does not hide every metadata feature. Timing, size, routing and gateway presence can still reveal patterns. Node distribution alone does not create anonymity or remove legal obligations. A governance design should state what each operator can observe and which operational logs are retained.

The current browser simulator uses synthetic payload sizes and a single transfer. It does not implement live Bundle Protocol, encryption, wallet transfers, real spacecraft commands, multi-user traffic scheduling or guaranteed delivery. Its playback queue is a visualization of computed events. The website source separates geometry/radio math, optical contact routing, optimization, hardware data and interface rendering so the assumptions remain inspectable.

Future routing should account for energy, limited terminal occupancy, queue priority, failures and uncertainty. Replanning should preserve verified receipts and avoid duplicate delivery. Small messages may reasonably receive a different queue policy from large video files, but that policy must be visible and tested rather than hidden inside the latency claims.

17 / DESIGN REFERENCE

Procurement, prices and programme scope

The directory contains 56 procurement entries. Each links to an official product, data sheet, supplier catalog or engineering enquiry. SCOT80 and SCOT30 are alternative terminal choices. The optical router replaces the base payload-router allocation, and the new optical EPS replaces the base EPS allocation; those alternatives must not be added as complete duplicate systems.

Publicly priced subset checked 25 September 2026	Qty	USD unit	USD extension
Development SDR	2	2,387.00	4,774.00
5 GHz directional radio	6	70.00	420.00
Ethernet routing appliance	3	119.00	357.00
Local Wi-Fi access point	3	193.00	579.00
Outdoor Ethernet surge protector	12	12.50	150.00

The four priced local-mesh item types total US\$1,506 for the listed quantities. The two development SDRs add US\$4,774, producing a US\$6,280 subtotal across the five priced rows. This is neither a complete ground station nor a spacecraft or programme price. The other 51 entries require supplier quotations or configuration work. Published unit prices are dated and exclude taxes, shipping and installation.

No exact current SCOT80 or SCOT30 configuration price was verified publicly. Optical cost must be requested for two terminals per spacecraft, the selected data/range configuration, engineering support, flight acceptance, spares and delivery schedule. Router FPGA and memory design, EPS redesign, array/battery sizing, ADCS, thermal/structural work and qualification are additional scope.

A credible programme estimate should separate non-recurring engineering, recurring flight units, ground pilots, spectrum/coordination work, launch and integration, test facilities, operations, insurance where applicable and contingency. Earlier concept allowances are not treated as supplier-backed prices in this revision. No purchase, launch reservation or fundraising receipt is represented by this document.

The support page only publishes project-owner-supplied receiving addresses. No donation address has been invented. A future public contribution process should specify the receiving network, purpose, custody and reporting policy.

18 / DESIGN REFERENCE

Verification, risks and next decisions

Verification completed for this release	Result or scope
Independent optical geometry	8,370 sampled pair checks across 250, 550 and 1,200 km and both terminal profiles matched analytical contact intervals
Routes and payloads	1,422 ground/space contact checks; byte conservation, carrier continuity, acquisition and light-time calculations
Constellation sizes	All 1-10 sizes; no benefit with a single satellite; Earth-blocked sparse ring cases and invalid inputs
Regional traffic	UK, Africa and South America; 57-byte text, 5 MB picture and 100 MB file
Optimizer reproduction	Applied orbital elements reproduce the evaluated arrival; preceding fleet retained during relay route search
Existing behavior	World-city tests, original constellation tests, RF kernel/coverage constraints and original optimizer tests pass

These are software checks, not hardware qualification. The largest unresolved factors are optical pointing access and jitter, received-power margin, flight router throughput, EPS capacity, thermal closure, mass growth, weather and obstructions at real stations, concurrent traffic and reliable acquisition under navigation uncertainty.

Practical next steps

First, request paired-terminal configuration and interface data from TESAT, including head/electronics allocation, pointing requirements, operational keep-out zones, channel plan and a two-unit quote. In parallel, close a CAD accommodation study and a time-resolved power/thermal model for the 80 kg case. Use the 65 kg case only with its stated development schedule.

Second, build a ground-only bundle-forwarding bench that reproduces scheduled contact outages and the modeled file sizes. Add terminal interface emulators, bandwidth caps, corrupted data, clock error and reboot cases. Test optical acquisition assumptions using supplier-supported equipment and procedures before incorporating their measured distributions into the simulator.

Third, validate the Ku modem/antenna chain and local mesh on authorized test arrangements, with measured pointing, interference and weather allowances. Then evaluate many start times and locations, congestion and failures. Release a revised feasibility decision only after mass, energy, thermal, optical and radio interfaces close.

19 / DESIGN REFERENCE

Equations, reproducibility and sources

Equation or convention	Definition
Orbital mean motion	$n = \sqrt{\mu / a^3}$, $a = R + h$, $\mu = 398,600.4418 \text{ km}^3/\text{s}^2$
Earth rotation	$7.2921159 \times 10^{-5} \text{ rad/s}$; spherical Earth coordinates
Maximum space chord	$\min(\text{terminal range}, 2\sqrt{a^2 - (R + \text{clearance})^2})$
Uniform-ring neighbor distance	$2a \sin(\pi / N)$
Serialization / propagation	$8 \times \text{payload bytes} / \text{net bit rate}$; range / c
Ground dish gain	$10 \log_{10}[\eta (\pi D_f / c)^2]$, $\eta = 0.60$
Thermal illustration	$P = \epsilon \sigma A T^4$, before incoming environmental flux
Benchmark start time	Seconds after the model reference orientation, not UTC flight time

Reproduce with the committed model modules and `verify-crosslinks.cjs`. The benchmark JSON includes complete layout elements and settings. The coverage table uses saved coverage presets; the route table uses the bounded route search and preceding-fleet seed. Five-second ground admission and contact-edge tolerances can move an arrival slightly relative to a higher-fidelity scheduler.

Revision 2 replaces the current white paper and reader while preserving the complete original version as an archive. The revision synchronizes worldwide locations, 18 reference nodes, constellation optimization, three spacecraft profiles, optical routing, 56 procurement entries and the downloadable 16-assembly spacecraft.

Reference links follow on the next page. Manufacturer specifications and availability statements are attributed to the linked dated sheets; all Northlink net rates, budgets, geometry margins and simulation results are explicitly design assumptions or calculations.

20 / DESIGN REFERENCE

Reference register

TESAT SCOT80 data sheet (20 August 2025)

https://tesat.de/images/tesat/products/250820_DataSheet_SCOT80_A4.pdf

TESAT SCOT30 data sheet (3 August 2026)

https://tesat.de/images/tesat/products/260803_DataSheet_SCOT30_A4.pdf

TESAT optical product family

<https://tesat.de/products>

STAR-Dundee SpaceFibre IP cores

<https://www.star-dundee.com/products/spacefibre-ip-cores/>

NASA: what is CLICK?

<https://www.nasa.gov/smallspacecraft/what-is-click/>

NASA: delay/disruption tolerant networking

<https://www.nasa.gov/communicating-with-missions/delay-disruption-tolerant-networking/>

NASA Small Spacecraft Technology: communications

<https://www.nasa.gov/smallsat-institute/sst-soa/soa-communications/>

IETF RFC 9171: Bundle Protocol version 7

<https://www.rfc-editor.org/rfc/rfc9171.html>

IETF RFC 9172: Bundle Protocol Security

<https://www.rfc-editor.org/rfc/rfc9172.html>

GomSpace NanoPower P80

<https://gomspace.com/product/nanopower-p80/>

ENPULSION Micro comparison data sheet (17 March 2026)

https://www.enpulsion.com/wp-content/uploads/DataSheet_Micro_20260317_V2.pdf

ITU-R P.618 propagation recommendation family

<https://www.itu.int/rec/R-REC-P.618/en>

Northlink Network Atlas and current artifact downloads

<https://northlink-network-atlas.icemann84.chatgpt.site>

Optical sources reviewed 28 September 2026. Existing hardware links and the five public price rows retain their 25 September 2026 check date. A source link does not certify compatibility, qualification, current inventory or authorization to operate. The following appendix carries the complete procurement register, including per-entry links and price basis.

APPENDIX / DESIGN REFERENCE

Procurement register · 01–04

NL-001 · Ku frequency converter

Spacecraft / radio · Quantity: 2

One chain per ground terminal. Proposed spacecraft RX 14.0–14.5 GHz; TX 11.7–12.2 GHz.

Candidate; current interface document and qualification evidence needed.

Supplier quote required. Price pending configuration and supplier quotation.

[ReliaSat UDC200](#) · [Product page](#)

NL-002 · Broadband modem

Spacecraft / computer · Quantity: 2 paths

Each path: 10 Mbps net transmit and receive simultaneously, FEC, framing, acquisition and Doppler tracking.

Not selected; a converter is not a complete modem.

Supplier quote required. Price pending configuration and supplier quotation.

[GomSpace](#) · [NanoCom SDR MK3](#) · [Product page](#)

NL-003 · Downlink power amplifier

Spacecraft / radio · Quantity: 2

2 W usable linear RF per downlink after waveform backoff; thermal and space qualification required.

Not selected; converter output does not establish this power.

Supplier quote required. Price pending configuration and supplier quotation.

[Lucix](#) · [space power amplifiers](#) · [Supplier enquiry](#)

NL-004 · Steerable Ku aperture

Spacecraft / antenna · Quantity: 2

Independent remote/gateway pointing; dual-band RX/TX. 160 × 160 mm allocation per aperture.

Custom development; scan, gain, sidelobes, polarization and isolation unverified.

Supplier quote required. Price pending configuration and supplier quotation.

[MDA Space](#) · [antennas & satellite systems](#) · [Supplier enquiry](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 05–08

NL-005 · RF filters and duplexers

Spacecraft / radio · Quantity: 2 sets

Protect receivers from transmitter leakage; suppress unwanted emissions.

Custom design matched to final frequency plan.

Supplier quote required. Price pending configuration and supplier quotation.

[Lucix](#) · [high-power diplexers](#) · [Supplier enquiry](#)

NL-006 · RF interconnect

Spacecraft / harness · Quantity: 1 set

Low-loss cables, waveguides and connectors joining RF chains and antennas.

Select after layout, connector and loss budgets are fixed.

Supplier quote required. Price pending configuration and supplier quotation.

[Times Microwave](#) · [space-flight coaxial cables](#) · [Supplier catalog](#)

NL-007 · Ground-radio payload router / processor

Spacecraft / computer · Quantity: 1

Base 40 kg configuration only: at least 20 Mbps received plus 20 Mbps transmitted across two ground links. Crosslink configurations replace this allocation with NL-053.

Base comparison; not additive to the optical payload router.

Supplier quote required. Price pending configuration and supplier quotation.

[GomSpace](#) · [NanoMind HP MK3](#) · [Product page](#)

NL-008 · Independent command and telemetry

Spacecraft / radio · Quantity: 1 set

Recovery radio and antenna usable when broadband pointing or payload operation fails.

Radio, safe-mode budget and authorized frequency unselected; not separately depicted.

Supplier quote required. Price pending configuration and supplier quotation.

[GomSpace](#) · [NanoCom AX100](#) · [Product page](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 09–12

NL-009 · Structure and equipment decks

Spacecraft / structure · Quantity: 1

Concept envelopes: base 300 × 300 × 600 mm; SCOT30 study 450 × 450 × 700 mm; SCOT80 study 600 × 600 × 800 mm. Optical heads and wings extend beyond the bus.

Custom enlarged bus required for optical variants; listed supplier catalog is a capability reference, not an exact product.

Supplier quote required. Price pending configuration and supplier quotation.

[EnduroSat structures](#) · [Supplier catalog](#)

NL-010 · Flight computer

Spacecraft / computer · Quantity: 1 baseline

Watchdog, housekeeping, commands, safe mode, deployment sequencing and payload control.

Command computer candidate, not the high-capacity payload store. Interfaces, radiation environment and flight configuration unverified.

Supplier quote required. Price pending configuration and supplier quotation.

[GomSpace NanoMind A3200](#) · [Product page](#)

NL-011 · Base electrical power system

Spacecraft / power · Quantity: 1

Base configuration: P80 comparison supports up to 300 W solar input. Optical variants require the redesigned 600 W system in NL-054.

P80 is not established as a complete 600 W optical-variant EPS. Alternative allocations, not additive complete systems.

Supplier quote required. Price pending configuration and supplier quotation.

[GomSpace NanoPower P80](#) · [Product page](#)

NL-012 · Solar wings

Spacecraft / solar · Quantity: 2 assemblies

Base: two 600 × 1200 mm wings, 1.44 m² and 300 W sunlight target. SCOT30 study: two 900 × 1200 mm wings, 2.16 m². SCOT80: two 1200 × 1200 mm wings, 2.88 m². Both optical variants target 600 W useful sunlight generation.

Concept areas and useful power targets; cell efficiency, temperatures, pointing and end-of-life margin remain unverified. One selected array configuration.

Supplier quote required. Price pending configuration and supplier quotation.

[EnduroSat solar panels](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 13–16

NL-013 · Protected battery

Spacecraft / battery · Quantity: 1 assembly

Base study: 400 Wh nameplate. Optical variants: 500 Wh target with protected charge/discharge paths. One selected battery configuration.

Updated packaging allocation; cell selection, eclipse duty, usable energy, peak current and launch acceptance remain open.

Supplier quote required. Price pending configuration and supplier quotation.

[EnduroSat power systems](#) · [Supplier catalog](#)

NL-014 · Attitude-control electronics

Spacecraft / attitude · Quantity: 1 set

Fuse sensors and control orientation for selected 40 / 65 / 80 kg study. Supply time-tagged attitude and pointing interfaces to each optical terminal.

Optical acquisition and tracking require vendor-specific pointing, jitter and exclusion verification; ordinary bus attitude control alone is insufficient.

Supplier quote required. Price pending configuration and supplier quotation.

[CubeSpace](#) · [Supplier catalog](#)

NL-015 · Reaction wheels

Spacecraft / attitude · Quantity: 3 illustrated; 4 proposed

Three-axis control with redundant wheel arrangement; size momentum capacity and torque.

The original model has three wheels. A redundant fourth wheel is a procurement option requiring a revised layout.

Supplier quote required. Price pending configuration and supplier quotation.

[CubeSpace wheels](#) · [Product page](#)

NL-016 · Magnetorquers

Spacecraft / attitude · Quantity: 3 proposed

Detumble and unload wheel momentum.

Size and magnetic compatibility to be established.

Supplier quote required. Price pending configuration and supplier quotation.

[CubeSpace actuators](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 17–20

NL-017 · Star tracker

Spacecraft / navigation · Quantity: 1 baseline

Precise attitude measurement with suitable Sun/Earth exclusion and mounting.

Candidate; performance and placement need analysis.

Supplier quote required. Price pending configuration and supplier quotation.

[CubeStar Gen 2 datasheet](#) · [Datasheet](#)

NL-018 · Sun sensors, magnetometer and gyros

Spacecraft / navigation · Quantity: 1 configured set

Attitude estimation and safe-mode orientation; control magnetic contamination.

Configuration unselected.

Supplier quote required. Price pending configuration and supplier quotation.

[CubeSpace sensors](#) · [Supplier catalog](#)

NL-019 · Space GNSS receiver

Spacecraft / navigation · Quantity: 1

Orbit position, velocity and time for antenna pointing and frequency compensation.

Candidate; interfaces and mission performance to be confirmed.

Supplier quote required. Price pending configuration and supplier quotation.

[Safran N-SPHERE](#) · [Product page](#)

NL-020 · GNSS antenna

Spacecraft / navigation · Quantity: 1 baseline

Compatible bands, receiver interface, sky view and spacecraft placement.

Select against receiver requirements.

Supplier quote required. Price pending configuration and supplier quotation.

[Anywaves antennas](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 21–24

NL-021 · Electric propulsion system

Spacecraft / propulsion · Quantity: TBD

Dated manufacturer sheet: 0.5–1 mN, 64–120 W, 28 V supply. This is a sizing comparison, not an installed selection.

The original tank/thruster geometry is conceptual, not MICRO R³ CAD. Actual propulsion power is much higher than the earlier ideal estimate; energy and drag budgets remain open.

Supplier quote required. Price pending configuration and supplier quotation.

[ENPULSION](#) · [Datasheet](#)

NL-022 · Thermal-control hardware

Spacecraft / thermal · Quantity: 1 engineered set

Radiators, straps, insulation, heaters and temperature sensors; include up to 160 W from two SCOT80 channels plus bus and power-conversion loads.

Optical variants add NL-055 mounting and heat paths. Radiator geometry is an allocation, not a closed thermal design.

Supplier quote required. Price pending configuration and supplier quotation.

[ACT](#) · [space thermal hardware](#) · [Supplier enquiry](#)

NL-023 · Deployment mechanisms

Spacecraft / solar · Quantity: As required

Hinges, hold-downs, releases, harness routing and deployment sensing.

Specify with array and bus suppliers.

Supplier quote required. Price pending configuration and supplier quotation.

[Glenair](#) · [space connectors, cables & release mechanisms](#) · [Supplier enquiry](#)

NL-024 · Launch separation interface

Spacecraft / structure · Quantity: 1

Attachment and controlled release; must match launch-provider interface and loads.

Candidate family; launch-provider acceptance required.

Supplier quote required. Price pending configuration and supplier quotation.

[ISISPACE M3S](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 25–28

NL-025 · Electrical harness and launch inhibits

Spacecraft / harness · Quantity: 1 set

Locking connectors, pinouts, grounding, protected wiring and release/transmit inhibits.

Custom harness tied to final interface documents.

Supplier quote required. Price pending configuration and supplier quotation.

Glenair · space connectors, cables & release mechanisms · Supplier enquiry

NL-026 · Service covers

Spacecraft / covers · Quantity: 1 set

Removable panels, vents, electrical bonding, surface finishes and access clearances.

Custom structure/thermal design; 3D surfaces are concept geometry.

Supplier quote required. Price pending configuration and supplier quotation.

ACT · thermal & structural engineering · Engineering enquiry

NL-027 · Ku transmit/receive dishes

Ground stations / antenna · Quantity: 2 total

Two LEO tracking terminals for one end-to-end route; diameter selected by the link planner (0.6–1.8 m), dual-band Ku feed.

Request LEO-capable configuration; automatic GEO alignment is insufficient.

Supplier quote required. Price pending configuration and supplier quotation.

CPI · satellite communications systems · Supplier enquiry

NL-028 · Tracking mounts and controllers

Ground stations / antenna · Quantity: 2 total

Rapid pass tracking, near-overhead geometry, calibration and orbit prediction.

Exact tracking rates, pointing accuracy and mount unselected.

Supplier quote required. Price pending configuration and supplier quotation.

CPI · satellite communications systems · Supplier enquiry

APPENDIX / DESIGN REFERENCE

Procurement register · 29–32

NL-029 · Ground upconverter / amplifier

Ground stations / radio · Quantity: 2 total

Proposed 14.0–14.5 GHz band; current simulation uses 5 W linear RF. Original 10 W BUC candidate needs waveform backoff and reference/IF verification.

Verify exact option, linear output and corrected LO/IF values.

Supplier quote required. Price pending configuration and supplier quotation.

[Norsat ELEMENT 10 W Ku BUC · Product page](#)

NL-030 · PLL low-noise downconverter

Ground stations / radio · Quantity: 2 total

Receive 11.7–12.2 GHz and supply compatible intermediate frequency to modem.

Confirm exact band, reference, noise and output-level option.

Supplier quote required. Price pending configuration and supplier quotation.

[Norsat 1000 PLL LNB · Product page](#)

NL-031 · Feed, orthomode transducer and filtering

Ground stations / antenna · Quantity: 2 sets

Connect transmit and receive paths to each dish with adequate isolation.

Specify as matched antenna package.

Supplier quote required. Price pending configuration and supplier quotation.

[Norsat · Ku feed, OMT & transmit-reject filter · Product page](#)

NL-032 · Ground modem

Ground stations / computer · Quantity: 2 total

Matching spacecraft waveform; simultaneous 10 Mbps net each way, Doppler compensation and Ethernet.

Not selected; begin with development SDR.

Supplier quote required. Price pending configuration and supplier quotation.

[Ettus · USRP B210 development SDR · Product page](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 33–36

NL-033 · Frequency reference and distribution

Ground stations / navigation · Quantity: 2 sets

Compatible reference stability, signal level and connectors for BUC, receiver and modem.

Select after hardware interfaces are known.

Supplier quote required. Price pending configuration and supplier quotation.

[Ettus](#) · [OctoClock-G reference distribution](#) · [Product page](#)

NL-034 · Control computer and router

Ground stations / computer · Quantity: 2 sets

Tracking, modem control, routing, logging and remote management.

Industrial PC/router specifications follow software testing.

Supplier quote required. Price pending configuration and supplier quotation.

[OnLogic](#) · [Helix 500 industrial computers](#) · [Supplier catalog](#)

[MikroTik](#) · [L009UiGS-RM router](#) · [Product page](#)

NL-035 · Power supply and backup battery

Ground stations / power · Quantity: 2 sets

Support RF, tracking motors, modem and computer through peak loads.

Size from measured terminal consumption.

Supplier quote required. Price pending configuration and supplier quotation.

[Victron](#) · [inverter / charger systems](#) · [Supplier catalog](#)

NL-036 · Outdoor mounting and cabling

Ground stations / harness · Quantity: 2 sets

Foundation, weatherproof enclosure, grounding, surge protection and RF cabling.

Site-specific design.

Supplier quote required. Price pending configuration and supplier quotation.

[ROHN](#) · [antenna mounts](#) · [Supplier catalog](#)

[Times Microwave](#) · [cables & assemblies](#) · [Supplier catalog](#)

[Panduit](#) · [outdoor & harsh-environment copper cable](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 37–40

NL-037 · Off-grid solar and battery

Ground stations / solar · Quantity: Remote site

Sustain terminal through local weather and seasonal solar conditions.

Separate energy calculation required; not the spacecraft battery allocation.

Supplier quote required. Price pending configuration and supplier quotation.

[Victron · solar chargers & panels · Supplier catalog](#)

[Victron · inverter / charger systems · Supplier catalog](#)

NL-038 · Internet backhaul

Ground stations / computer · Quantity: 1 gateway

Wired/fibre or another suitable internet connection at the gateway.

External service; satellite does not supply internet by itself.

Supplier quote required. Price pending configuration and supplier quotation.

[Starlink · business connectivity · Example backhaul service](#)

NL-039 · Development SDR

Laboratory / computer · Quantity: 2 initially

Prototype one simultaneous bidirectional link at intermediate frequency. B210 covers 70 MHz–6 GHz, full duplex, up to 56 MHz real-time bandwidth.

Ground development only; external converters needed for Ku. Not selected flight hardware.

US\$2,387.00 per unit; checked 2026-09-25. Manufacturer US list price; 2 boards = US\$4,774. Ground laboratory use; converters, clocks and computers extra.

[Ettus · USRP B210 development SDR · Product page](#)

[Ettus · published USRP price list · Price reference](#)

NL-040 · Host computers

Laboratory / computer · Quantity: 2 initially

Run waveform processing and measure simultaneous useful IP throughput.

Size CPU, USB throughput and software after prototype tests.

Supplier quote required. Price pending configuration and supplier quotation.

[OnLogic · Helix 500 industrial computers · Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 41–44

NL-041 · Attenuators, cables and dummy loads

Laboratory / radio · Quantity: Matched set

Conducted RF testing; calculate attenuation and power ratings to protect receivers.

Select from equipment output powers and maximum receiver inputs.

Supplier quote required. Price pending configuration and supplier quotation.

[Mini-Circuits · attenuators & terminations](#) · [Technical reference](#)

[Times Microwave · cables & assemblies](#) · [Supplier catalog](#)

NL-042 · Reference-clock equipment

Laboratory / navigation · Quantity: As required

Test synchronized operation and realistic oscillator offsets.

Select against modem reference inputs.

Supplier quote required. Price pending configuration and supplier quotation.

[Ettus · OctoClock-G reference distribution](#) · [Product page](#)

NL-043 · RF measurement equipment

Laboratory / radio · Quantity: Rent / laboratory access

Measure spectrum, signal quality, receiver sensitivity and interference.

Final instruments must cover selected RF/IF and test dynamic range.

Supplier quote required. Price pending configuration and supplier quotation.

[Keysight · signal & spectrum analyzers](#) · [Supplier catalog](#)

NL-044 · 5 GHz directional radio

Ground mesh / mesh · Quantity: 6

23 dBi integrated antenna; six radios make three dedicated point-to-point edges. Includes a 24 V passive PoE adapter.

Candidate ground hardware; outdoor link survey and country-approved configuration required.

US\$70.00 per unit; checked 2026-09-25. US\$65 base; US\$70 with displayed surcharge. Canadian store separately lists CAD96 with surcharge; no currency conversion used.

[LBE-5AC-Gen2](#) · [Product page](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 45–48

NL-045 · Ethernet routing appliance

Ground mesh / mesh · Quantity: 3

One router per site joins dedicated backhaul radios and local clients; routing and failure recovery must be configured.

Candidate ground hardware; outdoor link survey and country-approved configuration required.

US\$119.00 per unit; checked 2026-09-25. Manufacturer suggested USD price (MSRP), not a reseller quotation. Use included radio injectors; do not assume PoE compatibility.

[MikroTik L009UiGS-RM](#) · [Product page](#)

NL-046 · Local Wi-Fi access point

Ground mesh / mesh · Quantity: 3

One client access point per site. Local Wi-Fi is separate from the airMAX point-to-point backhaul.

Candidate ground hardware; outdoor link survey and country-approved configuration required.

US\$193.00 per unit; checked 2026-09-25. US\$179 base; US\$193 with displayed surcharge. Model name does not make the backhaul radios a self-forming mesh.

[U6-Mesh](#) · [Product page](#)

NL-047 · Outdoor Ethernet surge protector

Ground mesh / mesh · Quantity: 12

Planning allowance: two protectors per outdoor backhaul cable run; bonding and local installation design required.

Candidate ground hardware; outdoor link survey and country-approved configuration required.

US\$12.50 per unit; checked 2026-09-25. Manufacturer US price. Quantity is an installation allowance, not a completed electrical design.

[ETH-SP-G2](#) · [Product page](#)

NL-048 · Towers, mounts and outdoor cabling

Ground mesh / mesh · Quantity: Site-specific

Three sites: mast/foundation, shielded Ethernet, earthing and professional installation.

Design and quotation required.

Supplier quote required. Not included in the priced subtotal.

[ROHN](#) · [communication towers](#) · [Supplier catalog](#)

[ROHN](#) · [antenna mounts](#) · [Supplier catalog](#)

[Panduit](#) · [outdoor & harsh-environment copper cable](#) · [Supplier catalog](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 49–52

NL-049 · Site power and UPS

Ground mesh / mesh · Quantity: Site-specific

Three sites: mains or off-grid generation, correct PoE injectors, backup and enclosures.

Design and quotation required.

Supplier quote required. Not included in the priced subtotal.

[Victron](#) · [inverter / charger systems](#) · [Supplier catalog](#)

NL-050 · Tracking Ku gateway integration

Ground mesh / mesh · Quantity: Site-specific

LEO mount, dual-band dish/feed, BUC/LNB, modem, reference and integration. Mesh radio prices do not include a satellite terminal.

Design and quotation required.

Supplier quote required. Not included in the priced subtotal.

[CPI](#) · [satellite communications systems](#) · [Supplier enquiry](#)

NL-051 · Long-range optical terminal

Spacecraft / crosslink · Quantity: 2 per spacecraft; SCOT80 variant

Published: 2.5 / 10 Gbps bidirectional, up to 8,000 km; 11.9 kg per optical channel, 60–80 W, 28 V, Ethernet; 31 × 29 × 47 cm head plus 26 × 19 × 24 cm electronics. Simulation uses a conservative 1,000 Mbps net study cap.

Manufacturer describes running production. Final paired-terminal configuration, pointing envelope, optical link budget, integration and delivery date require confirmation. Alternative to NL-052.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[TESAT SCOT80](#) · [Official datasheet](#)

NL-052 · Compact optical terminal — development option

Spacecraft / crosslink · Quantity: 2 per spacecraft; SCOT30 variant

Published: symmetric up to 1.25 Gbps; up to 3,500 km depending on configuration; mass <6 kg, peak <60 W, 230 × 280 × 200 mm. Simulation allocates 6 kg per unit and uses 100 Mbps net.

Development roadmap: TRL6 Q2 2027, TRL8 Q1 2028, availability 2028. Future comparison, not currently flight-ready inventory. Alternative to NL-051.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[TESAT SCOT30](#) · [Official datasheet](#)

APPENDIX / DESIGN REFERENCE

Procurement register · 53–56

NL-053 · Optical payload router, buffer and FPGA interfaces

Spacecraft / relaycomputer · Quantity: 1 custom assembly; replaces NL-007

Target at least 1 Gbps net bundle forwarding and 100 MB payload buffering with error correction, watchdog recovery, time-tagged contact plans and terminal Ethernet interfaces. Size storage for the mission queue, not just one test file.

SpaceFibre IP is a building block, not a complete flight router or drop-in terminal Ethernet bridge. FPGA, memory, transceivers, protocol conversion, software, qualification and sustained throughput remain custom work.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[STAR-Dundee SpaceFibre IP · integration reference](#) · [Official IP product page](#)

NL-054 · Optical-variant power distribution and conversion

Spacecraft / relaypower · Quantity: 1 redesigned system; replaces base NL-011 allocation

600 W sunlight input target, 500 Wh battery interface, two protected terminal feeds, controlled inrush and bus-specific voltage conversion. Support up to 160 W optical terminal load, router, Ku radio, heaters and duty-managed propulsion.

The linked P80 is a 300 W comparison, not a verified 600 W selection. A new EPS or qualified parallel architecture must be engineered and quoted. No complete compatible unit selected.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[GomSpace power systems · engineering enquiry](#) · [Supplier capability reference](#)

NL-055 · Optical mounting, radiator and heat-transport upgrade

Spacecraft / relaypower · Quantity: 1 integrated set

Terminal mounting load paths, isolation from wheel jitter, optical alignment stability, heat straps and added radiator panels. SCOT80 model depicts about 1 m² gross radiator allocation including the enlarged bus radiator.

Custom thermal/structural design; supplier capability reference. Usable radiating area, view factors, Earth/Sun heat, flexure and coupled loads need analysis. Mounting mass is inside the variant structure allowance.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[Advanced Cooling Technologies · space thermal engineering](#) · [Supplier enquiry](#)

NL-056 · Optical acquisition and tracking integration

Spacecraft / crosslink · Quantity: 1 spacecraft integration package

Two terminal fields of regard, ephemeris exchange, terminal pairing, acquisition timing, boresight calibration, contamination control, keep-out zones and time synchronization. Confirm wavelength and channel pairing from the vendor interface document.

Integration work, not a separately identified off-the-shelf head. Simulation tests 0–120 s acquisition but does not resolve pointing jitter, Sun exclusion or body/wing occultation. Do not double-count terminal internals.

Supplier quote required. Supplier quotation required; no public configuration price verified.

[TESAT optical communication systems · Official product family](#)