

ARTICLE 06

One Network Across Ground, Air and Space

Engineering and monetizing terrestrial–non-terrestrial convergence



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EXECUTIVE PROPOSITION

The strategic prize is not satellite coverage in isolation. It is seamless, governed service continuity across terrestrial, airborne and orbital systems, supported by common standards, spectrum, devices, assurance and commercial settlement.

Executive summary

The strategic prize is not satellite coverage in isolation. It is seamless, governed service continuity across terrestrial, airborne and orbital systems, supported by common standards, spectrum, devices, assurance and commercial settlement.

This evidence-led thought article develops an executive point of view using standards, official data, company disclosures and Moderion Advisory analysis. It separates established facts from emerging direction and reported implementation.

EXECUTIVE QUESTION

How should terrestrial, airborne and satellite systems be governed and commercialized as one service without hiding their different physics and responsibilities?

Key insights at a glance

- GSMA's 2025 NTN paper positions GEO, MEO, LEO, high-altitude platforms and uncrewed aircraft as complements to terrestrial networks, especially for remote coverage, mobility, IoT and emergency response.
- The same GSMA work notes that more than 95% of the population is within mobile-broadband coverage while a large usage gap remains. NTN can reduce a coverage gap; it does not by itself solve affordability, devices, skills or locally relevant services.
- 3GPP Release 17 established foundational NTN specifications, with later releases extending capability. Standards reduce integration risk but do not remove spectrum, terminal, capacity, roaming or commercial constraints.
- Direct-to-device service strengthens resilience and reach, but early services may differ materially in messaging, data rate, latency, device support and emergency functionality. The term should not imply uniform broadband equivalence.
- MNO-SNO partnership design determines customer ownership, spectrum rights, service assurance, lawful access, settlement and failure accountability.

- The executive target is service continuity across layers, not invisible complexity. The network may abstract access selection for the user while retaining explicit responsibility and measurable performance underneath.
- 3GPP Release 17 created NR-NTN and IoT-NTN foundations and addressed latency, Doppler and mobility across terrestrial and non-terrestrial components; implementation still varies by orbit, payload, spectrum, terminal and operator integration.
- D2D in terrestrial IMT spectrum normally requires an agreement with the licensed mobile operator and regulatory protection against interference. MSS-spectrum services follow a different device and authorization path.
- Satellite cost per delivered gigabyte is a poor universal comparator. The relevant denominator changes by use case: covered population, resilient sites, vessel-hours, emergency sessions, remote assets or committed enterprise capacity.
- This article contributes to the Total Connectivity Economy by testing its enabling mechanism against universal reach, open interoperability, governed intelligence, trusted participation and sustainable economics.
- As of September 2026, 3GPP Release 20 remains the principal 6G study release and the architecture report is still draft; Release 21 is the normative phase. Future 6G continuity claims must therefore be presented as target architecture, not completed specification.
- A 2025 IEEE Open Journal survey of hands-on integrated terrestrial/non-terrestrial testbeds finds meaningful progress but also substantial unresolved physical-layer, management and experimental-integration challenges.

Exhibit 1 | Access-layer roles in a total-connectivity service

Layer	Comparative role	Key constraint	Priority use
Terrestrial	Capacity, low latency, indoor reach	Economics of sparse coverage	Mass-market and dense enterprise
LEO / MEO / GEO	Wide-area reach and resilience	Capacity, latency, spectrum, terminals	Remote, mobility, backup and IoT
HAPS / airborne	Regional, relocatable coverage	Endurance, airspace and payload	Events, disaster and targeted corridors

Note: Capabilities vary by system and band; rows are comparative, not performance guarantees.

Exhibit 3 | Terrestrial-to-NTN service sequence

Stage	Decision	Evidence	Accountable domain
Eligibility	Device, SIM, market and service allowed	Capability and policy response	MNO / channel
Availability	Beam and terrestrial alternatives	Measurements and ephemeris	RAN / satellite
Selection	Policy, priority and congestion	Route decision	Joint orchestration
Establishment	Authentication and bearer	Session record	Core / gateway
Assurance	End-to-end service outcome	Latency, completion and continuity	Contracted service owner
Settlement	Usage and partner allocation	Reconciled service ledger	MNO / satellite partner

Note: The exact signaling depends on architecture and release support; this is an executive control sequence.

Core analysis

From parallel systems to one service fabric

Satellite communication has long served remote access, broadcast, mobility, emergency and specialized government needs. The current transition is different because non-terrestrial networks are being

incorporated into the broader mobile standards trajectory. Devices, identities and service policies can increasingly operate across terrestrial and satellite domains. That creates the possibility of continuity rather than a separate satellite experience.

The phrase 'zero dead zones' remains an aspiration, not a capacity guarantee. Direct-to-device links face constraints in link budget, spectrum, handset capability, orbital geometry and aggregate capacity. Satellite backhaul and specialized terminals may remain more suitable for many high-throughput or mission-critical cases. The architecture must match the service rather than force every demand into one mode.

The convergence stack

Convergence requires more than a radio link. It includes device support, authentication, mobility management, roaming, policy, quality, lawful access, emergency treatment, cybersecurity and end-to-end assurance. Operators and constellation providers must agree how traffic is selected, prioritized, charged and settled. The user should experience continuity, but the underlying system needs precise responsibility at each handover.

Spectrum strategy is central. Mobile-satellite arrangements, supplemental coverage models and internationally coordinated satellite allocations create different rights and interference conditions. Regulators must balance innovation, competition, national resilience and orbital sustainability while preserving predictable investment conditions.

Where demand is valuable

The strongest opportunities are not identical across markets. Remote population coverage supports inclusion and public policy. Maritime and aviation connectivity can combine communications with operational visibility. Emergency services value diversity when terrestrial infrastructure fails. Utilities, mining, energy and logistics require remote asset connectivity. Governments may treat resilient backhaul and sovereign service continuity as security priorities. Direct-to-device messaging and narrowband services can extend consumer reach, while richer services will depend on capacity and device evolution.

Each use case needs its own economics: reachable devices, traffic, willingness to pay, terminal subsidy, wholesale terms, support, spectrum cost and service obligation. Coverage maps and constellation counts do not substitute for field performance or unit economics.

The operator's strategic choice

An operator can build, partner, wholesale or aggregate. Building space assets offers control but demands enormous capital and specialized capability. Partnership can accelerate service, but the agreement must address customer ownership, branding, data, network selection, priority, assurance and roadmap dependency. Multi-constellation options may improve resilience but add integration complexity.

The preferred posture is often an orchestration strategy: preserve the operator's identity, policy and customer relationship while using the most suitable access layer. That requires a service-control capability able to compare availability, performance, cost, sovereignty and risk in real time.

Moderion Advisory perspective

Design the service before integrating the layers

A single service definition should specify where terrestrial, satellite or airborne access is eligible; supported devices; application priority; expected latency and throughput; handover behavior; emergency treatment; security; and the remedy when a layer fails. Without this definition, technical integration creates an ambiguous promise.

The highest-value early cases are those where the alternative is no service, unsafe operation or expensive dedicated infrastructure: maritime and aviation monitoring, remote asset telemetry, emergency communication, rural public service and sovereign continuity. Mass-market economics require careful capacity and device analysis.

Governance across jurisdictions and orbits

Multi-layer coverage crosses spectrum assignments, landing rights, gateway locations, privacy, emergency obligations and national-security controls. The customer may see a single brand, but regulators and operators need an auditable chain of technical and legal responsibility.

Resilience should also avoid false redundancy. Two access paths that share a gateway, cloud control plane, timing dependency or power system may fail together. Scenario testing must follow the full service chain from device and spectrum through orbit, ground segment, backhaul, core, identity and application.

A hybrid service-integration blueprint

The service begins with a policy that defines when the terrestrial network, satellite layer or both may serve the device. Discovery checks device and SIM capability, spectrum path, satellite visibility, roaming and service eligibility. Mobility management then coordinates measurement, authentication, bearer establishment and service continuity. Transparent payloads depend more heavily on ground processing; regenerative payloads can place selected network functions in orbit. These architectures create different latency, gateway, resilience and lawful-access implications.

The operational chain must include satellite operator, mobile operator, gateway, core network, device ecosystem, emergency authority and service provider. A successful radio attachment is not yet a commercial service: assurance must distinguish coverage probability, session completion, throughput distribution, latency, power consumption, congestion priority and incident responsibility across domains.

Link-budget and unit-economics discipline

A link budget reconciles transmit power and antenna gain with free-space loss, atmospheric and polarization losses, receive gain, noise and implementation margin. It should be evaluated across elevation angle, Doppler, weather, beam loading and terminal orientation. Capacity economics then allocate spacecraft, gateway, spectrum, feeder link, terrestrial transport, customer equipment, operations and replacement cost to the service unit that the buyer values.

Terrestrial fiber, microwave, LEO, MEO and HAPS should therefore be compared by scenario rather than by one global cost per gigabyte. Dense urban capacity usually favors terrestrial systems; remote coverage, mobility, rapid restoration and geographic diversity may justify NTN at higher unit traffic cost because the avoided outage or unserved-area value is material.

The sovereign operating permit

Before launch, the operating model must close national spectrum authority, landing rights, gateway location, lawful interception, emergency calling, data retention, cybersecurity, numbering, consumer disclosure and interference accountability. Cross-border beams do not create cross-border legal permission. The partner contract should allocate regulatory change, service suspension and interference remediation.

The GSMA distinguishes D2D using IMT spectrum from services using MSS spectrum. In the IMT route, the terrestrial license remains a sovereign control point even when a satellite operator supplies the space layer. This preserves an operator role, but only if technical, commercial and incident authority are explicit in the agreement.

Ubiquity is an assured multi-domain service

Terrestrial and non-terrestrial integration can extend participation across rural regions, maritime corridors, air routes and disrupted environments. Ubiquity does not mean identical performance everywhere. It means transparent service classes, continuous identity and policy, explicit accountability and an economically sustainable combination of terrestrial, satellite, airborne, subsea and local infrastructure.

Standards maturity and service maturity are different

Release 17 and Release 18 establish concrete NTN foundations; the wider 6G architecture remains in study. A standards feature can reduce interface uncertainty without proving device availability, cross-operator roaming, satellite capacity, lawful-access integration, customer support or attractive unit economics.

The defensible executive claim is therefore progressive service federation across access layers. Universal seamlessness remains a design objective whose evidence must be assembled service by service and jurisdiction by jurisdiction.

Exhibit 2 | MNO-SNO contract architecture

Decision	Required clarity	Failure if omitted
Customer	Brand, support and remedy	Disputed accountability
Network	Selection, handover and priority	Service discontinuity
Data	Telemetry, consent and jurisdiction	Compliance and learning gaps
Economics	Capacity, usage and settlement	Unscalable unit economics
Resilience	Independent dependencies and recovery	False redundancy

Note: Moderion Advisory partnership framework.

Executive action agenda

- Segment use cases by device, capacity, latency, geography, sovereignty and willingness to pay.
- Conduct independent field tests rather than relying on theoretical or announced coverage.
- Define handover, assurance, emergency, cybersecurity and lawful-access responsibility end to end.
- Model wholesale settlement and customer economics under multiple traffic and capacity scenarios.
- Preserve multi-network resilience and roadmap flexibility in partnership contracts.

Conclusion

Ground, air and space will become one service environment only when technical continuity is matched by commercial and institutional continuity. The winners will not simply own the largest footprint. They will orchestrate heterogeneous networks into a trusted service whose performance, accountability and economics remain clear to the customer. In the wider series, this capability is treated as an enabler of the Total Connectivity Economy rather than as an end state in itself.

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