Critical Infrastructure communications - Satellite communications vs. dedicated terrestrial networks

substitutes or complements for the communication of critical infrastructures?

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01.
Introduction

Traditionally, critical infrastructures are no early adopters of communication technology. Their increasing critical communication requirements can be technically met by the fast-evolving communication technology. But critical infrastructure operators face important choices of available communication solutions, as many come with relevant restrictions.

Communication requirements

Secure and resilient voice and data communication is must-have for critical infrastructures in these times of energy transition, cyber risks and global turmoil

- Critical infrastructures are essential facilities for the functioning of government, industry, essential services, transport and society and are increasingly under attack.
- This is particularly true for power supplies, as most facilities and functions rely on power. The transition to renewables and flexible loads has already increased the volatility of power networks and the risk of technical induced blackouts
- This risk is further increased by cyberattacks, terrorism or other incidents, as has happened already twice in Berlin, Germany, or even global instability, as can currently be seen in the Ukraine and the Arabian Peninsula.

To enable monitoring and management of critical infrastructures, secure and resilient communication is essential. Communication is even more important in the case of technical failures or attacks, as the availability of secure and resilient communication is the pre-requisite for detection, workforce management & safety, network adaptation and timely repair.

Communication technology

Critical infrastructure operators until recently have been using legacy communication technologies like PLC, PDH/SDH/SONET, narrowband private radio, private microwave, PMR/LMR voice networks using TETRA, TETRAPOL and legacy satellite comms – VSAT, MSS satellite etc.

On the technology side this is undergoing a step change now with new technologies like 4G/5G, LTE-M, NB-IoT, IP/MPLS, DWDM, cloud native OT platforms and new satellite comms (LEO, NGSO). Network architecture is also evolving with modern deployments converging around hybrid architectures using multiple technologies, SD-WAN, zero-trust cyberdesign and cloud native platforms.

These new technologies can technically fulfill the communication requirements of critical infrastructures, but there are important differences in terms of coverage, cost and control to deliver the required overall resilience.

Current situation

Critical infrastructures today are using a mix of communication solutions that fulfill some of their requirements and are therewith well suitable for certain use cases. Fixed use cases can be served by fixed or mobile communication solutions, mobile use case always require terrestrial mobile or satellite communications solutions.

- **Private Fixed networks** on own fibre or copper infrastructure allow for control and – at a cost - full resilience. Coverage is limited to the own infrastructure and extension of this infrastructure to connect distributed assets is not economical.
- **Powerline communication** uses the power copper cables which connect most businesses and households to transmit data and has therefore been a favorite communication solution of many power network operators for smart metering. The scope of PLC is however limited due to dependency on the provision of power, high operating cost and usability for few use cases.
- **Public Fixed networks** are widely available and provide cost effective connectivity but only a best effort or limited SLA service, and offer neither control nor full resilience.
- **Public Mobile networks** are also widely used and cost effective but as public mass market network face issues on availability and exposure to cyber risks and are dependent on external power supply.
- **Residual local or regional PMR networks** are based on legacy technologies and increasingly misaligned with IP-based operational needs.

While none of these solutions alone can fully address the stringent security, resilience and sovereignty requirements of critical infrastructures and address their evolving needs, they define the current connectivity space and its limitations.

Given the evident restrictions and/or shortcomings of these solutions, critical infrastructures have increasingly used Satellite communications for secure and resilient primary of back-up connectivity, particularly for remote sites and crisis scenarios.

Over the last few years critical infrastructures also started to invest in **Dedicated terrestrial 4G mobile networks,** primarily in standardized lower band 410/450MHz spectrum to get access and control for completely secure and resilient communication networks. Such **dedicated mobile network(s) exist** or are being deployed in several countries for utilities, industries, defense and public safety services and in some cases for multi critical communications verticals.

This raises the question whether Satellite Communication and Dedicated terrestrial networks are substitutes or complements in providing resilient communication for critical infrastructures.

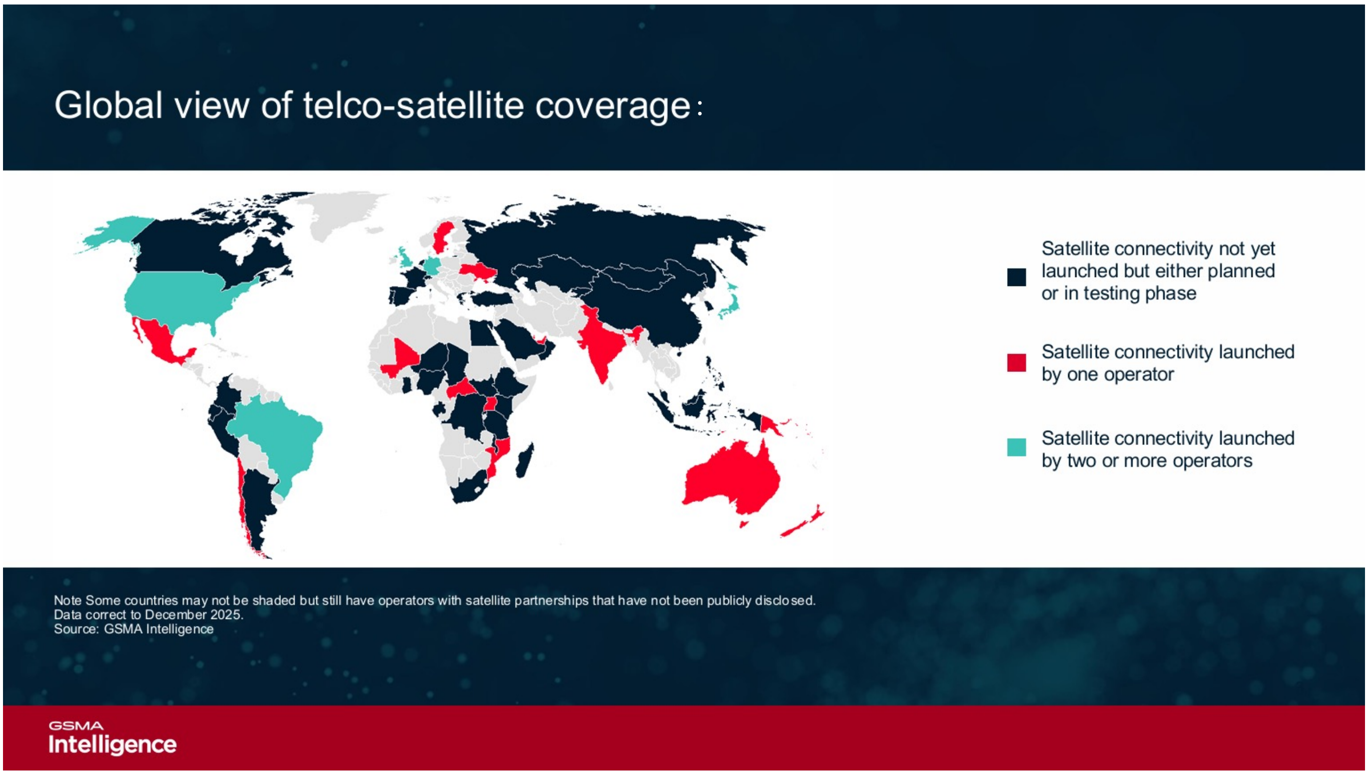
02.
Satellite Communication

As a physically diverse access technology, satellite communication provides a trusted primary backup and secondary backup when alternative communication solutions are degraded or unavailable due to large-scale power outages, extreme weather events, cyber incidents or physical attacks on terrestrial infrastructure.

With the evolution from legacy VSAT and MSS solutions towards new-generation satellite technologies (LEO/NGSO), 5G Non-Terrestrial Networks (NTN) and satellite-enabled NB-IoT, satellite communications are increasingly integrated into IP-based and cellular-centric operational environments. These evolutions allow satellite to interwork with Terrestrial Networks, supporting use cases such as emergency Mission Critical voice fallback, low-bitrate telemetry, remote asset monitoring and temporary backhaul. Satellite also offers rapid time-to-market, enabling immediate connectivity for temporary sites, emergency deployments or newly commissioned assets, and remains the only viable option for coverage extension to remote substations, renewable energy sites, pipelines, offshore platforms or geographically isolated infrastructure where terrestrial networks are unavailable or not economically viable.

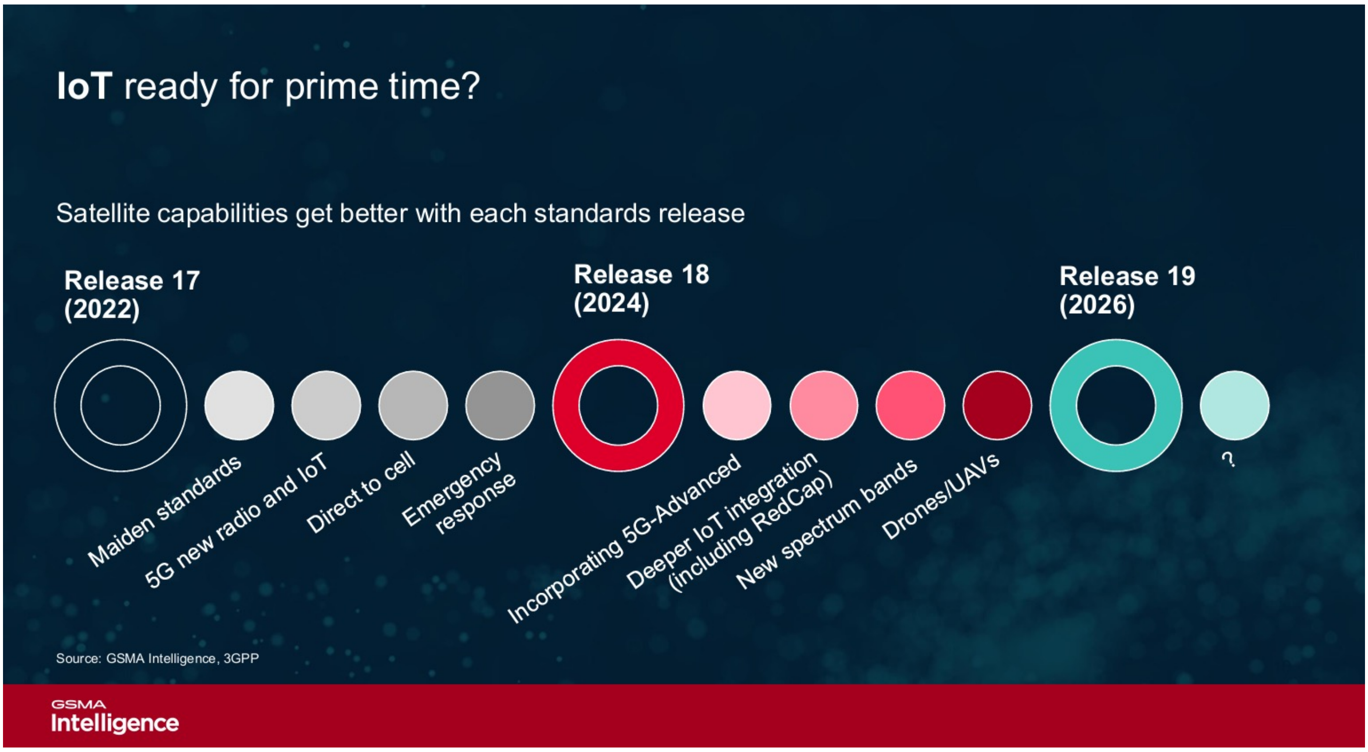
Below is the current state of telco-satellite coverage globally as released by GSMA Intelligence

Figure1:



Due to inherent capacity and indoor penetration limitations, satellite communication is best suited for remote, low-density rural areas rather than dense urban environments or indoor use. These shortcomings are being addressed with new standard releases, improving satellite capabilities and further satellite deployments which will continue to increase the attractiveness for many communication use cases including Industrial IoT and emergency/disaster response.

Figure2:



Despite the ease-of-use, critical infrastructure operators need to consider three shortcomings of Satellite Communication:

- First consideration is **control:** Critical infrastructures require control over their critical communication systems to ensure stability of supply and operating capabilities in emergency situations. This lack of control is the case for any satellite communication solution that critical infrastructures are using, as critical infrastructures do not and will not operate their own satellite communication system. In the best case they can use the satellite communication system of their own government, in which case there may be less of a control issue and more of a guaranteed capacity and resilience issue (see below). But most countries do not have a government-controlled satellite communication system and rely on commercial providers that are under the control / jurisdiction of 3rd parties.
- Second consideration is **guaranteed capacity:** While satellite communication capacity can be contracted with high Service Level Agreements, there is no guarantee that the capacity will be available in a major regional crisis, where all customers of the commercial satellite operators require maximum capacity and capacity may be required by other countries or Defense and PPDR users. Critical infrastructures in certain countries may therefore not cover the tail risk of ending up with no usable capacity but only a legal claim, which may even not be enforceable due to force majeure.
- Third consideration is **resilience:** While it is currently still an unlikely scenario that satellites will be attacked in space, this may change. Once attacked there is no fast track to replace & repair satellites. If capacity is provided by multiple satellites and only few are impacted there is inherent redundancy, but the reduced capacity increases the challenge of access (see above).

03.
Dedicated terrestrial mobile networks

When it comes to Terrestrial network communications, dedicated 4G/5G mobile network for critical infrastructures provides a nation with a fully secure and resilient solution.

Only such dedicated terrestrial 4G/5G networks:

- Can be specifically designed to the security and resilience requirements of critical infrastructures
- Can be controlled by the critical infrastructure directly as shareholders or indirectly via public ownership or control of national telecom operators
- Can guarantee that capacity is available for the most critical use cases and users in emergency situations
- Can ensure that ongoing operation is not dependent on any foreign third party
- Can manage risks of cyberattacks by allowing only in-country critical infrastructures onto the network
- Can reduce the risk of any single physical attack by having a redundant network with hundreds to thousands of base stations
- Can provide for timely repair as terrestrial infrastructure is accessible and availability of material and manpower can be pre-organized in-country

The main disadvantage to the use of public fixed or mobile networks or satellite communication is that these networks require additional investment in hundreds to thousands of radio sites and incur the related operating cost.

Figure3: 400 MHz network deployments globally

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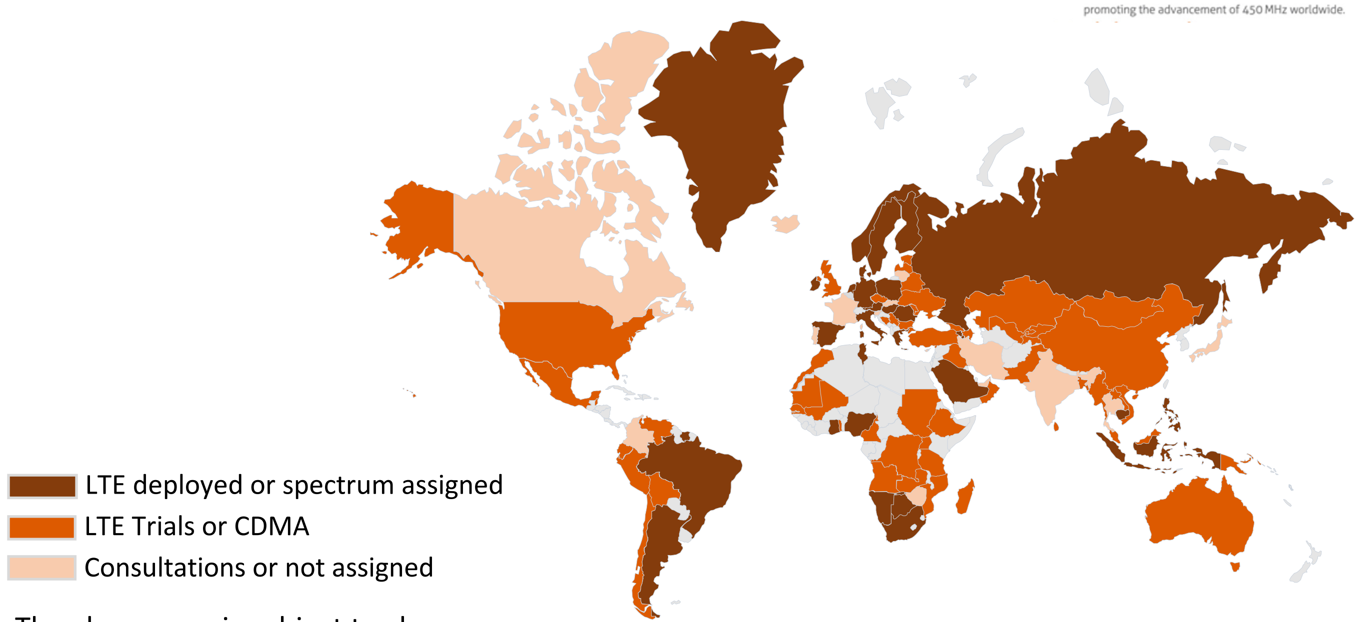
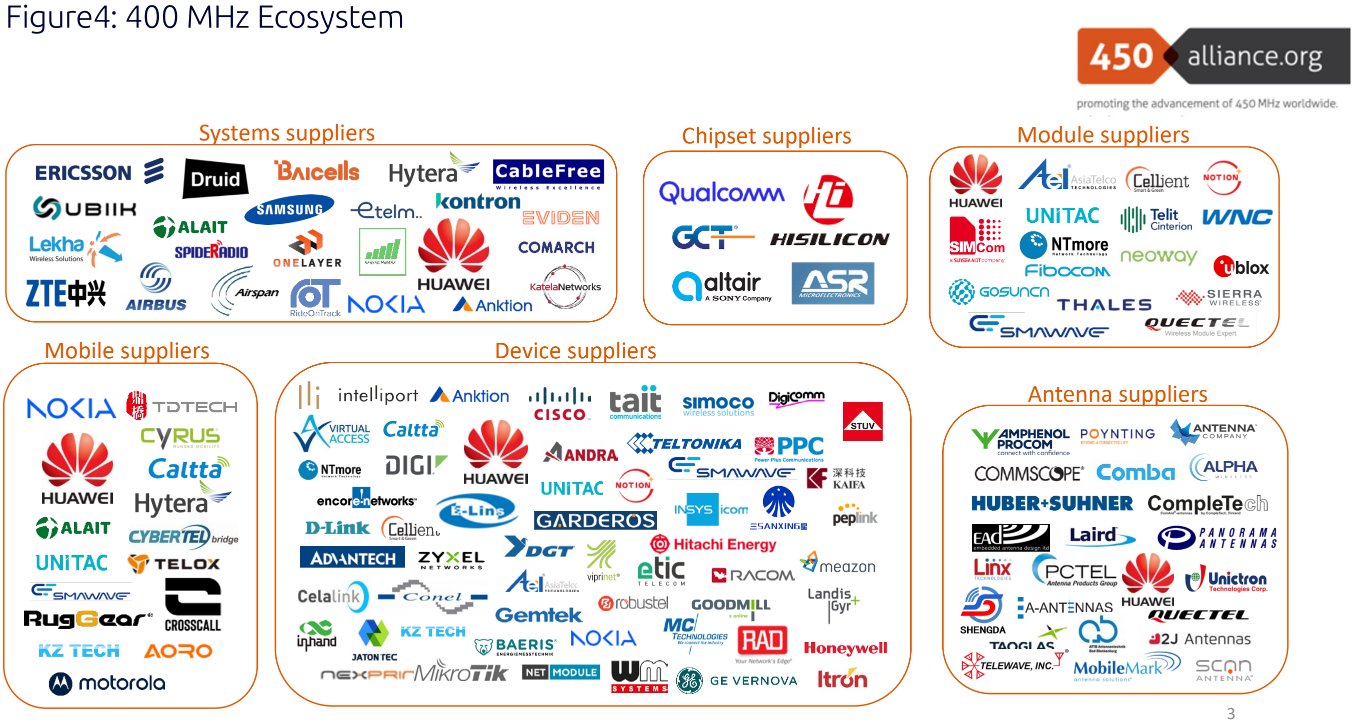


The above map is subject to change

Figure4: 400 MHz Ecosystem



To minimize these costs, dedicated mobile networks for critical infrastructures are typically deployed in low-frequency bands standardized for 4G/5G technologies, providing the following advantages:

- Lower spectrum bands allow for wider area coverage resulting in a much lower site count. And site count is the main driver for the cost of the network capex and opex, not only for the cost of the mobile network equipment, but also for the additional cost of providing resilience (including longer-term power back-up at all radio sites and redundant backhaul). Furthermore the longer wavelength of lower spectrum bands penetrates buildings better improving indoor coverage.

Figure5: Standard 400 MHz 4G and 5G bands

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380	382.5	385	387.5	390	392.5	395	397.5
Band TBD	⇧			Band TBD	⇩		

410	412.5	415	417.5	420	422.5	425	427.5
	Band 88	⇧			Band 88	⇩	
Band 87	⇧			Band 87	⇩		

450	452.5	455	457.5	460	462.5	465	467.5
	Band 31	⇧			Band 31	⇩	
Band 72		⇧		Band 72		⇩	

- At the same time spectrum bands need to be standardized for 4G and 5G to enable the use of modern telecom solutions and ensure the availability of network and user equipment

The favorite spectrum bands to date are therefore 450MHz and 410MHz which have long-been used for mobile terrestrial communication in most countries, are fully standardized by 3GPP, are not being used by the public mobile operators and for which a good ecosystem of network and user equipment exists. Countries where 410/450MHz is not available are currently considering making spectrum available for these urgently required networks in 600MHz or 700MHz.

Not least due to these arguments have utilities in many European countries decided to deploy secure and resilient LTE 450, LTE 410 networks under their full control. The same is the case for Aramco Digital in the Kingdom of Saudi Arabia.

Below is the list of 450 MHz network operations in Europe as published by 450 MHz Alliance

While only dedicated terrestrial mobile networks can address these requirements of critical infrastructures, there are also certain restrictions that have to be considered:

- Given limited spectrum availability these networks are also capacity constrainted, so that public communication solutions should be used for non-critical best effort communication to keep the limited capacity for critical use cases
- These networks have to be rolled out, and even once deployed, geographic coverage may not reach 100%, as there is no business case for full coverage in remote areas—this gap can be effectively addressed by satellite communication.

Figure6: 450MHz network operations in Europe (as of Mar 2026)

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Company	Country	Use Case – MCX, smart meters, smart grid etc
Cibicom	Denmark	Broadband and Mobile, Utilities and Public safety
Utility Connect	Netherlands	Smart meters
Teracom	Sweden	Smart meters, Smart grid, Broadband, Air to Ground
450Connect	Germany	Smart meters, Smart grid, Broadband, Handhelds
BGE (Telent)	Germany	Nuclear waste underground facility
ice	Norway	Broadband, IoT and Mobile, Utilities, Military and Public safety
Elisa	Finland	Water control, Handhelds
ESB	Ireland	Smart grid, Broadband
ArgoNet	Austria	Smart grid, Broadband
HMEI	Hungary	Critical comms Mobile (Smart grid, Broadband, Smart city)
Polkomtel/Puls	Poland	Handhelds PTT, Public safety and Critical comms
PGE	Poland	Smart meters, Smart grid, Broadband, Handhelds
SIRDEE/MoI	Spain	Test (Handhelds)
MoD	Italy	Tactical system

04. Conclusion: *Complements not Substitutes*

Today Satellite communications play a distinct and complementary role within modern Energy & Utilities critical communications architectures, acting as an independent resilience layer alongside fixed infrastructure and mobile networks. Satellite connectivity can be particularly valuable in black start scenarios, grid restoration phases and crisis management, where maintaining minimum voice, data and situational awareness capabilities is essential to coordinate field teams, secure assets and adapt network operations.

However, a closer look shows that Satellite Communication does not cover the tail risk of a country and its critical infrastructures in terms of control, guaranteed capacity and resilience. And ensuring the reliability of critical infrastructures in the times of energy transition, cyberrisks and global turmoil including manging the tail must be the focus for critical infrastructures.

Nevertheless, Satellite Communication will continue to grow and provides a great solution for general back-up communications including remote areas. Critical Infrastructure operators will continue to use public and satellite communication in various use cases in their communication mix but should not rely on public mobile networks or satellite communication for managing their critical networks.

To overcome these limitations of public networks, some countries and critical infrastructure operators are moving towards a more structured and sovereign approach based on dedicated nationwide 4G/5G mobile networks for critical infrastructures, designed as the terrestrial backbone of mission-critical communications. Secure and resilient national 4G/5G networks dedicated for critical infrastructure provide another layer of resilience to national governments, states and societies. Satellite communications are not designed to replace such terrestrial critical networks, but to reinforce them where resilience, independence and coverage continuity are required, within a deliberately hybrid and layered architecture.

Satellite communication and Dedicated terrestrial mobile networks are therefore complements not substitutes. Dedicated nationwide 4G/5G mobile networks with the option of satellite backhaul connectivity for critical infrastructures provide the foundational communication layer and address the structural limitations of purely satellite-based or public-network solutions, while enabling effective integration of satellite connectivity where additional resilience or coverage is required.

Satellite communication and Dedicated terrestrial mobile networks are Complements not Substitutes.

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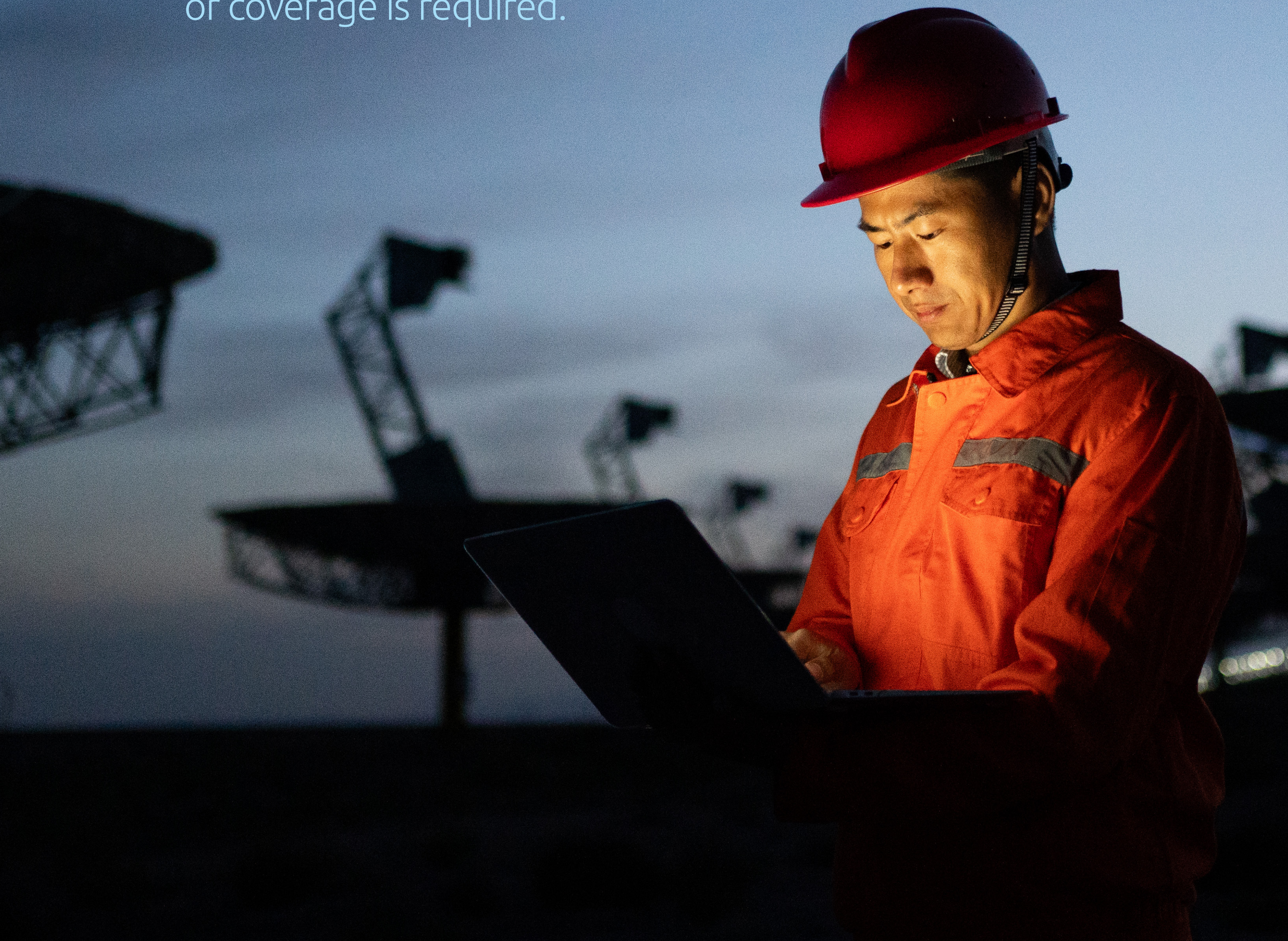

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The Group reported 2025 global revenues of €22.5 billion.

About 450MHz Alliance

The 450 MHz Alliance is an industry association representing stakeholders involved in the deployment of dedicated networks. Its members include wireless carriers, equipment manufacturers, and companies spanning a wide range of vertical markets in private mobile network communications. The Alliance is committed to championing the potential of dedicated networks and empowering its members to achieve their goals with efficiency and effectiveness.

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