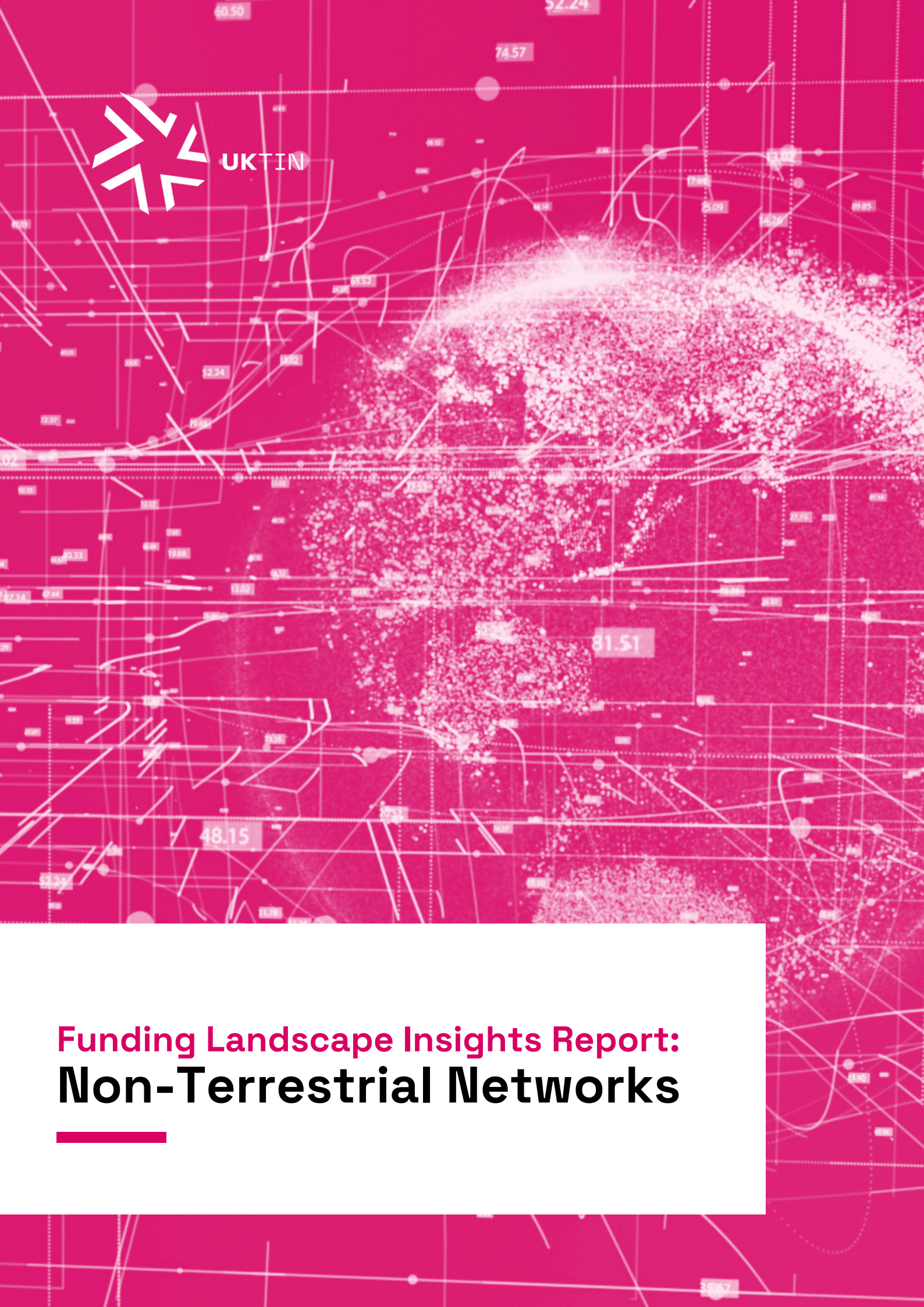

Funding Landscape Insights Report:

Non-Terrestrial Networks

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Authorship, quantitative data & qualitative data processing:

Nathan White, Senior Business Strategy Consultant, Satellite Applications Catapult
Joe Kingswood, Lead Business Strategy Consultant, Satellite Applications Catapult

Introduction

This report presents insights into research, development and innovation (R&D&I) activities taking place in the UK telecoms sector in the area of non-terrestrial networking (NTN) technology. The UK is host to a burgeoning space sector, with around 14% of income delivered by fixed and mobile satellite communications services (SATCOM) according to the Size and Health of the UK Space Industry 2023. NTNs are integral to the development of next generation multi-layer networks, enabling global connectivity and resilience across application areas and for a wide range of purposes, such as enhancing disaster response, supporting remote sensing and navigation, and enabling new scientific discoveries. With rapid technological developments taking place in the areas of both space and telecommunications globally, this report aims to understand the role that NTNs currently play in the UK telecoms market, current public R&D&I activities and their area of focus, and the role NTNs may play in the future, especially as telecoms systems become more diverse and integrated.

Part of the UK Telecom Innovation Network (UKTIN) programme, this report is the third in a series intended to provide a high level, non-technical deep dive into pertinent academic and industrial activities relevant to the UK telecoms ecosystem. The data presented in this report seeks to help identify broad activities in the NTN technology landscape in terms of presenting areas where public funding has been concentrated across a range of funding programmes, and key areas of interest and research among industry and academic experts interviewed for this report. This report may be valuable for a range of stakeholders, including showcasing public R&D&I funding distribution to industry professionals, but also for academics seeking to map current research focus and projects in their fields, as well as for policymakers seeking to understand overall distribution and estimates of funding amounts that have been allocated to R&D&I activities in particular NTN technologies. This report is not intended to be an exhaustive analysis of trends in the NTN technology landscape, but an exploration of where funding has been directed over the period 2017-2023.

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Specific focus is placed on quantitative and qualitative data on topics that are of interest to the UK telecoms community, particularly topics that are currently in discussion by the UKTIN Non-terrestrial Networking Technologies Expert Working Group, as well as reference to other areas of relevance that are likely to emerge over time, including use cases such as self-driving vehicles, smart systems and the Internet of Things. As the convergence of terrestrial networks (TNs) and NTNs is integral to the development of NTNs, terrestrial networking will form a part of the discussion in this report. For a broader discussion on R&D&I funding in wireless networking technology, see the UKTIN Market Research Insights Report on Wireless Networks.

1.1/ Research Methods

Research for this report involved obtaining publicly available data on UKRI's Gateway to Research database and Horizon 2020's CORDIS database, both were retrieved and refined using the UKTIN Discovery Toolkit. Due to the lack of available data on private funding for R&D&I, this report focuses on publicly available data and public funding. More information on methodology and limitations may be found in Annex 1 and 2. Other research methods included desk research and literature reviews carried out by Satellite Applications Catapult, as well as interviews with four industry experts conducted by Satellite Applications Catapult and four university experts conducted by the University of Bristol. This combined quantitative and qualitative approach was conducted with the intention of providing a high level, non-technical insight into pertinent academic and industrial R&D&I activities in NTN technology.

1.2/ Key Areas of Non-Terrestrial Networking Technology & Definitions

This section provides explanations and definitions of key areas of NTN technology that are covered in the report. For more detailed discussion on NTN technology and definitions, please refer to the UKTIN Non-Terrestrial Networks - Future Capability Paper. Terms used later in the report are italicised, relevant industry activity in each area is described, and R&D&I topics from both quantitative and qualitative datasets are highlighted.

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Definition and Scope of NTNs

As defined by the 3rd Generation Partnership Project (3GPP), a NTN refers to a network, or segment of networks using Radio Frequency (RF) resources on board of a satellite or High Altitude Platform (HAP). A satellite (or HAP) may be implemented either as a relay node or a base station, thus distinguishing transparent (former) and regenerative architectures (latter). HAPs are stationed in the stratosphere, providing localised coverage with the capability to dynamically adjust to network demands and offer a more flexible and cost-effective alternative to satellites for regional connectivity. A transparent payload acts as an analogue RF repeater between feeder and service links, simply relaying signals, while a regenerative payload processes and regenerates the signal, effectively placing the 5G base station in the satellite itself. This definition will apply to current 5G and next generation 6G networks but is expected to evolve with future 3GPP standards releases.

For the purposes of this report, NTN in telecoms R&D&I activities are defined as projects and initiatives that aim to expand or develop the capabilities of NTNs in the telecoms sector, such as application areas in Mobile devices, backhaul and network coverage.

Spectral Use and Deconfliction

The spectrum, which refers to the range of electromagnetic radio frequencies used for transmitting data, is a finite resource that must be managed carefully to prevent interference and ensure optimal performance of adjacent wireless networks. Efficient spectrum management is crucial for the effective operation of NTNs and TNs. Spectrum allocation is a key means of management involving the coordination of use of frequency bands to minimise interference between terrestrial and non-terrestrial systems. This requires regulatory frameworks and international agreements to ensure fair and effective use of the spectrum. For example, in the UK the regulator OFCOM is responsible for spectrum management and grants spectrum licences, giving users the right to operate over a set locality within a selected range of frequencies. The ITU-R regulates spectrum allocations through the Radio Regulations. By designating specific frequency bands for different types of communication systems, spectrum allocation helps maintain a clear and interference-free environment. Dynamic Spectrum Sharing (DSS) is a promising method for optimising spectral use, which involves implementing technologies that allow NTNs to dynamically access and utilise spectrum based on real-time demand and availability. This approach optimises spectrum efficiency by enabling NTNs to use underutilised spectrum bands when TNs are not using them.

Space Segment

The space segment of NTNs is composed of HAPs and satellites in different orbits — Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Earth Orbit (GEO)— each playing a distinct role in communication performance. LEO satellites, typically positioned between 500 and 2,000 km above Earth, offer the lowest latency, often below 50 milliseconds, due to their proximity, making them ideal for real-time applications. However, they require large constellations to ensure continuous global coverage. MEO satellites, orbiting between 2,000 and 20,000 Km, provide broader coverage but with slightly higher latency. GEO satellites, located at 36,000 Km, offer extensive coverage and high capacity, particularly for broadcast services, but have much higher latency, around 600 milliseconds. The combination of these orbits allows NTNs to balance between latency and capacity, depending on the service requirements and geographic coverage.

Ground Segment

The ground segment, comprising gateways, the infrastructure that interconnects them and connects them to TN infrastructure, and user terminals, plays a pivotal role in the seamless integration of NTNs with TNs. Gateways serve as the terrestrial interface for NTNs, handling data traffic between satellites/HAPs and TNs. Advanced gateway technologies ensure low-latency and high-throughput connectivity and are already relied upon to provide backhaul services for TNs (i.e. cellular backhaul from Base Transceiver Stations (BTSs)). Globally, NTNs accounts for about 1% to 2% of cellular backhaul sites. Innovative user terminals, capable of switching between TNs and NTNs, are essential for ensuring continuous and reliable service.

1.3/ General outlook for NTN-related R&D&I in Telecoms

A recent report from Euroconsult projects a strong growth trajectory for the NTN market, forecasting that the NTN segment of the global Satellite Communications Market will be worth in excess of $1 billion by 2027. This predicted growth is based upon the ongoing deployment of satellite constellations and increasing demand for global connectivity across various applications such as 5G, IoT, and enterprise communication. According to Euroconsult, the expanding role of LEO (Low Earth Orbit) satellites and their integration into 5G ecosystems will be crucial in shaping the future of NTNs, as more industries adopt satellite-enabled services to enhance connectivity, particularly in remote and underserved areas. Interest in NTN/TN convergence is driven by its potential in supporting three key 5G/6G use cases:

- Enhanced Mobile Broadband (eMBB),
- Massive Machine Type Communications (mMTC),
- Ultra-Reliable Low Latency Communications (URLLC).

eMBB, which enables faster download and upload speeds and greater capacity for mobile and wireless services has the potential to see rapid adoption in NTNs, particularly in regions where terrestrial infrastructure cannot meet the increasing demand for high-speed, high-bandwidth connectivity required for applications such as high-definition video streaming, immersive virtual reality experiences, and cloud computing. This is crucial in ensuring that end users in remote areas are not disadvantaged by poor internet access, and it helps close the digital divide. This goal forms part of the UK Wireless Infrastructure Strategy, 2023. mMTC is becoming an essential enabler for the expansion of IoT, which involves connecting millions of devices across sectors like agriculture, smart cities, and logistics. mMTC focuses on enabling communications for a vast number of low-power, low-data-rate devices that do not require high-speed internet but need reliable and scalable connectivity.

NTNs are increasingly being used in supporting the deployment of IoT devices in areas with limited cellular coverage. Euroconsult reports that the use of NTN=enabled IoT devices is expected to triple over the coming decade. Additionally, NTNs are gaining increased attention for their significant potential in supporting URLLC-dependent use cases, this includes critical use cases such as autonomous vehicles, real-time industrial automation, and even potentially remote surgery. according to IEEE.

NTN-related R&D&I activities are focussed in several key areas:

- Direct-to-device (D2D) connectivity allows user devices such as smartphones, tablets, and IoT gadgets to connect directly to NTNs without the need for intermediary ground stations. This capability opens new service opportunities, including eMBB access in rural and remote areas and improved resilience of communication networks during natural disasters. Current D2D services only allow for short SOS-style messaging, but broadband connectivity services are receiving a lot of development focus.
- Beamforming and MIMO (multiple-input-multiple-output): These technologies enhance signal quality and data rates by dynamically directing signals and using multiple antennas to improve reception and transmission.
- Software-Defined Networking (SDN) and Network Functions Virtualisation (NFV): SDN and NFV enable more flexible network management, NFV virtualises functions like resource management in cloud or MEC environments. SDN can optimise traffic routing and allocate resources within specific network scopes, though efficiency may vary depending on implementation.
- Cognitive Radio Networks (CRNs): Artificial Intelligence (AI) and Machine Learning (ML) techniques are being tested for use in optimising radio network performance by predicting traffic patterns, managing interference, and automating network configuration.

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- Service orchestration, automation, and intelligence end-to-end (E2E): As networks evolve, end-to-end service orchestration and automation are becoming critical, especially with the migration to optical satellite systems. Service orchestration automates and coordinates complex telecoms services, improving efficiency and network management. Use cases this can support include network slicing, automated service activation and NFV deployment.

Government R&D&I

2.1/ Government Funded R&D&I Programmes

The UK government has committed to several R&D&I initiatives and funds relevant to non-terrestrial networking technology including Rural connectivity and Convergence of Terrestrial and Non-terrestrial networks, emphasising the value of delivering connectivity in all areas of the UK to our society and the economy. The UK government has played a key role in contributing towards non-terrestrial networks ambitions, ranging from 5G Rural Dorset in 2020 to the Rural Connectivity Accelerator in 2023. According to the data obtained for this report (excluding ESA contributions), the UK government has made approximately £151.6m[1] available for R&D&I relevant to NTN technology across seven different projects and funding programmes.

Table 1/ Government Funded R&D&I programmes focused on an aspect of non-terrestrial networking technology.

Fund/Project	Sub-Project	Total Funding Relevant to NTN (£m)
Unleashing rural opportunity	**N/A**	**7**
SBRI Future telecoms challenge	**N/A**	**28**
Rural connectivity accelerator	**N/A**	**7.3**
5G Innovation regions	**N/A**	**40**
5G RuralDorset	**N/A**	**4.3**
Open networks Research and Development Fund	**FRANC**	**30**
	UKTIN	**10**
	FONRC	**25**
Total		**£151.6**

This table represents 6 government-funded policy, programmes and projects which include elements of non-terrestrial networking technology R&D&I in the UK. Data credit: UK Government

[1] This is an estimate based on public data obtained for this report and analysed in the context of this report. This estimate should be understood as indicative rather than definitive

This section illustrates the policies, programmes and projects in the order listed in Table 1.

Unleashing Rural Opportunity (2023-Present)
Driven by the UK government's commitment to rural development, the Unleashing Rural Opportunity programme was introduced to tackle the specific challenges faced by rural communities. Building on previous initiatives, the programme seeks to enhance infrastructure, improve access to services, and boost local economies, ensuring rural areas contribute to and benefit from national progress. It emphasises innovative approaches to housing, transport, and broadband connectivity, showcasing the potential for scalable and sustainable growth across the UK's rural regions. Part of this programme was a fund of £7m for a trial of rural mesh networks (satellite and fixed wireless) in particular for agriculture use cases.

SBRI Future Telecommunications Challenge (2023-2024)
The SBRI Future Telecommunications Challenge, launched in 2023, aims to spur the development of innovative telecom technologies that enhance connectivity, security, and network performance. By encouraging businesses to create next-generation solutions, the initiative seeks to drive significant advancements in the telecom sector, leading to scalable and sustainable improvements in communication networks across the UK.

Rural Connectivity Accelerator (2023-2024)
In June 2023, DSIT was awarded £7.3 million funding for the Rural Connectivity Accelerator, as part of a joint Shared Outcomes Fund bid with DEFRA and DCMS. The Rural Connectivity Accelerator tests new ways to bring together satellite, wireless and fixed line internet connectivity to help support agricultural and tourism businesses to access fast, reliable connectivity in remote areas for the first time.

5G Innovation Regions (2023 - 2025)
Supported by the Wireless Infrastructure Strategy, the 5G Innovation Regions was allocated £40 million to build on the successes of the 5G Testbeds and Trials programme and drive innovative applications powered by 5G and other advanced wireless connectivity from proof of concept to widespread adoption. The programme demonstrates the scalability, replicability, and sustainability of 5G use cases across key sectors of the economy, creating secure connected places across the UK. The regions were encouraged to explore opportunities to integrate 5G with other networks including Satellite.

5G RuralDorset (2020-2022)
5G RuralDorset is a ground-breaking project to understand how next generation connectivity can help people live better, safer and more prosperous lives in rural communities, even in environments as sensitive as Dorset's UNESCO-designated world heritage coastline. The project, funded by the Department for Culture, Media and Sport (DCMS) aimed to show how enhanced connectivity can make Dorset a better place to live, work and visit.

Open Networks Research and Development Fund (2022 - 2025)
In 2022 the Government created and launched the UK Open Networks R&D Fund, driven by the opportunity to build a more diversified telecoms infrastructure, strengthening UK networks' future resilience and security. This £250 million fund aims to build a more diverse and competitive supply market, thereby reducing the UK's reliance on the incumbent dominant industry players for mobile access network equipment.

There are currently multiple projects ongoing under the Open Networks R&D Fund:

1/ Future Open Networks (FONRC) Research Challenge
The Future Open Networks Research Challenge (FONRC) is a £25 million challenge which will enable universities to work with large RAN vendors, and other telecoms organisations, to conduct research and development to drive the openness and interoperability of future network architectures, including NTNs. Satellite initiatives securing funding within this challenge include TUDOR and REASON.

2/ Future RAN Competition (FRANC)
Future RAN, a competition run by DCMS, allocated up to £30 million of R&D funding to projects that support the goals of the Government's 5G Supply Chain Diversification Strategy. The competition was aimed at helping to incentivise industry to create new products and services to unlock the full potential of Open RAN. The only satellite initiative within this competition relating to NTN is the O-RANOS consortium, examining the use of implementing satellite technology into the Open RAN ecosystem.

3/ UK Telecoms Innovation Network (UKTIN)
UKTIN was allocated up to £10 million of funding as the innovation network for the UK telecoms sector, aimed at supporting the telecoms industry to navigate the UK's telecoms R&D ecosystem and drive the development of open networks. It should be noted that UKTIN explores a wide range of technologies of which NTN is one.

2.2/ Multi-network projects

The variety of R&D&I funded programmes and projects outlined above sheds light on the multiple components involved in the development of non-terrestrial and converged non-terrestrial and terrestrial infrastructure. For example, a non-terrestrial network allows mobile network operators to more efficiently and, in a cost-effective way, provide connectivity into very hard to reach terrestrial locations without the need for ground-based infrastructure. The information below outlines the identified project that relates to the multiple components of technology that can be involved in non-terrestrial networks:

Project TUDOR (Towards Ubiquitous 3D Open Resilient Network) (2023-)
Funding amount: £12,000,000

Project TUDOR focuses on the research and development of open network components and their seamless interoperability. The project explores the use of Low Earth Orbit (LEO) satellites and High-Altitude Platform Systems (HAPS) to provide resilient, high-speed broadband services where traditional infrastructure is inadequate. By leveraging these cutting-edge technologies, Project TUDOR aims to solve many societal, environmental and economic grand challenges such as the digital divide and energy efficiency.

2.3/ UK Space Agency (UKSA)

The UK Space Agency (UKSA) is an executive agency sponsored by the Department for Science, Innovation and Technology (DSIT). It supports the government to boost UK prosperity, understand the Universe, and protect our planet and outer space. Its value proposition is to:

- Catalyse investment, by deploying our funding and resources to multiply the value of non-Government contracts and private capital secured by UK space organisations to maximise the space sector's long-term growth.
- Deliver missions and capabilities, independently and with others, that use space science, technology and applications to meet national needs and help humanity to understand our universe.
- Champion space, encouraging other sectors to use space to deliver better services, tackle the climate emergency, inspire STEM education and lifelong learning, and advocate for sustainable space activities.

UKSA have provided funding for NTN related programmes and projects primarily through its contributions to the European Space Agency (ESA). UKSA contributions to ESA were £553m (85% of total spend) in the year 2022-23.

The UK is a leading investor in ESA's Advanced Research in Telecommunications Services (ARTES) programme, having committed £190m to the programme. UKSA have also committed £50m to support ESA's moonlight programme (funding companies developing communication and navigation technology for future moon missions).

Highlighted programmes within ARTES include:

Space for 5G:
Space for 5G aims to achieve full integration of satellite with terrestrial 5G networks, demonstrating the added value of space in 5G-enabled services and applications. It focuses on developing satellite communication products compatible with 5G, creating testbeds for trials and pilots, and engaging industry stakeholders, particularly in vertical markets. The programme supports downstream sectors in developing space- and 5G-based applications and showcases multi-technology, multi-provider, and global integration. Additionally, it engages user communities, mobile network operators, and telecom equipment providers in pilots and drives standardisation to ensure satellite inclusion in 5G standards.

Space for 6G:
Space for 6G aims to advance the performance and development of 6G networks, overcoming the primary technical challenges that define next-generation communications. It prioritises the integration of extremely high frequency (EHF) and terahertz (THz) bands, addressing the high penetration losses caused by obstacles, water vapour, and oxygen, which necessitate a complex 6G network architecture. The programme also focuses on integrating satellite communications to extend network reach, mitigating challenges such as high propagation losses, delays, and weather-related impacts. By harnessing advanced technologies like Massive MIMO and Beamforming, the programme supports standardisation efforts and establishes a foundation for multi-technology, multi-provider, and global 6G interoperability.

Within the Space for 5G and 6G strategic programme line The 5G/6G Hub, based at ESA's European Centre for Space Applications and Telecommunications (ECSAT) at Harwell in the UK, was supported by UKSA and supports the UK Government's 5G and 6G strategy.

An example of a specific funding call within the ARTES programme supported by UKSA was the ARTES: Aerial Connectivity call. This call provided £20m of funding in 2023, of which UKSA contributed £7m, inviting applications from UKSA companies "looking to develop future telecommunications technologies and aerial connectivity projects in the fields of HAPS and HALE (High-Altitude Long Endurance) and drones." An example funded project involving UK partners within ARTES is ARTES 5G TINA.

"The ESA ARTES 5G TINA project explores and demonstrates future 3D architectures, between terrestrial and non-terrestrial networks. Transparent payload scenarios, as well as processing payload scenarios where 5G RAN, core and application functions are hosted on a satellite will be analysed to meet the use case requirements of the project. In this paper, we propose as well, a novel architecture for next generation regenerative satellite payloads, by introducing a P4 language-based software switch on the payload in the 5G user plane path, as a traffic steering and offloading function, to support a Push-to-Talk (PTT) emergency use case."

Outside of ESA funded programmes UKSA has committed significant funding to support the development of NTN's. While out of scope for this report, the C-LEO programme (£160m), aims to provide funding 2024-2028 to UK companies and researchers to develop innovative Satcom technology.

UKRI

Composed of Innovate UK, Research England, and seven research councils, the UK Research and Innovation (UKRI) is the UK's national research and innovation body. UKRI funds both academic and industry R&D&I in telecoms.

The funders of the projects identified as relevant for this report are primarily the Engineering and Physical Sciences Research Council (EPSRC), Innovate UK and Horizon Europe Guarantee, with smaller amounts of funding provided by ISCF and STFC.

This section comprises a mixed methods approach in which qualitative insights were obtained from industry experts by Satellite Applications Catapult, academic experts by the University of Bristol, and quantitative insights produced by Satellite Applications Catapult. Quantitative methods for this section involved querying the UKTIN Discovery Toolkit with keywords relevant for non-terrestrial networking technology. These keywords were selected with the input of experts in non-terrestrial networking technology from Satellite Applications Catapult and the UKTIN Non-Terrestrial Networking Technologies Expert Working Group. The following is a presentation of these quantitative and qualitative findings.

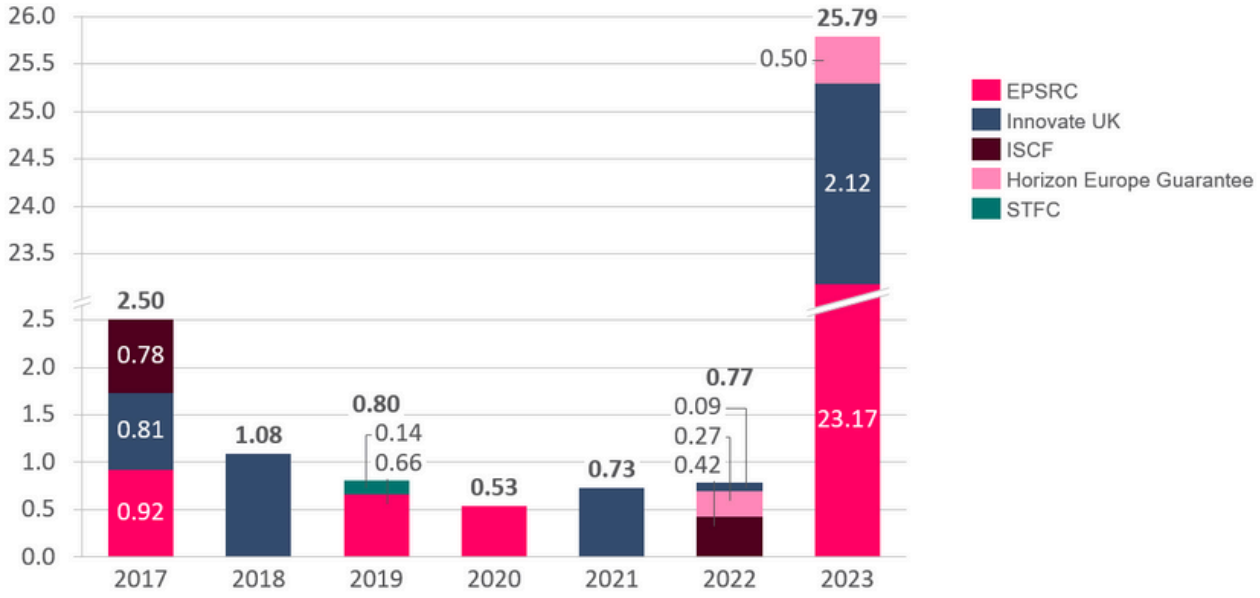
UKRI have also funded three Future Telecoms Hubs and provided resources to bring them together in a federated structure, which will help deliver the six core areas identified in the Wireless Infrastructure Strategy. These are TITAN (Platform Driving the Ultimate Connectivity), HASC (Hub on all-spectrum connectivity) and CHEDDAR (Communications Hub for Empowering Distributed cloud computing Applications and Research).

3.1/ Research Council-funded research: EPSRC, Innovate UK, ISCF, Horizon Europe Guarantee, STFC

3.1.1/ Funding Sources

This report identified 30 UKRI-funded projects that fall into the category of non-terrestrial networks in telecoms R&D&I, with total funding amounting to £32.2m in the period between 2017 to 2023. These sources in order of funding amount allocated, are EPSRC, Innovate UK, ISCF, Horizon Europe Guarantee and STFC.

Graphic 1/ Funding sources for UKRI-funded Non-Terrestrial Networks in telecoms research year on year (£m)



This graphic represents the total amount of funding granted by UKRI to non-terrestrial network projects, split according to scheme. It considers 30 different projects in total. Data credit: UKRI

Over the period 2017-2023, EPSRC funded 8 projects, accounting for £25.3m or 78% of the total £32.2m funded by UKRI. Innovate UK funded 16 projects, accounting for £4.9m or 15% of the overall total. Notably, while innovate UK funds more projects than EPSRC, the overall value of the funding allocated is smaller than EPSRC. ISCF, funded 3 projects, accounting for £1.2m or 4% of the overall total. Horizon Europe Guarantee funded 3 projects, accounting for 2% of the overall total. STFC funded the remaining percentage of the total funding amount.

Funding allocated to projects relating to the development of non-terrestrial network technology increased dramatically in 2023, with £25.8m of funding allocated. EPSRC and Innovate UK represent the bulk of the funding increase from £0 in 2022 to £23.2m in 2023 and from £90k in 2022 to £2.1m in 2023 respectively.

Across seven years, Innovate UK and EPSRC have consistently provided the main proportion of the funding. Overall, in the 2017-2023 period, funding in 2020 was the lowest, however funding across the period of 2018-2022 was low relative to 2017 and 2023. Also consider that funding in 2020 will have been impacted by the COVID-19 pandemic.

When asked about their funding sources and a general outlook on funding for NTN R&D&I one academic interviewee noted the limited amount of funding coming from UKRI and its related research councils noting, “if you have a look at the EPSRC, one of the issues is there is virtually zero funding for NTN. It's because we don't have a large academic community”. While another interviewee noted that in projects that enable or are relevant to NTN, NTN is just one constituent part of a larger project or programme, mentioning “DSIT or EPSRC money is not going into directly non-terrestrial network related projects...from EPSRC funding, most of the funds we have are more focused on telecom and connectivity or digital connectivity, and often not even cellular network related.”

3.1.2/ Projects and R&D&I areas of focus

Table 2/ Top Ten UKRI-funded Non-Terrestrial Networks in Telecoms Research Projects

Project Title	Funding Body	Amount of Funding (£)
Joint Open Infrastructure for Networks Research (JOINER)	EPSRC	£13,000,000
Terahertz frequency devices and systems for ultrahigh capacity wireless communications	EPSRC	7,097,283
Platform Driving the Ultimate Connectivity	EPSRC	2,030,860
Aether-Net	Innovate UK	1,104,511
Satellite Ground Station Research Facility	EPSRC	1,042,525
Phased Array Gateway	Innovate UK	719,531
Methera Preparatory Phase	ISCF	704,207
Ionospheric Measurement, Modelling and Simulation for Future Wideband UHF Satcoms	EPSRC	682,650
Low-Profile Ultra-Wideband Wide-Scanning Multi-Function Beam-Steerable Array Antennas	EPSRC	658,095
Isotropic Systems: A SATCOM terminal utilising unique Optical Beam Forming techniques that will disrupt the COTP Satellite market, specialised for the needs of the emergency services	Innovate UK	571,850

This table represents the ten most highly funded (and multi-partner) projects that fall into the category of research in non-terrestrial networks in telecoms. Data credit: UKRI

The highest-funded UKRI project is Joint Open Infrastructure for Networks Research (JOINER) at £13m. Funded in 2023 “JOINER is the UK's first national accelerator programme towards 6G and beyond. It is a national R&D platform interconnecting academic institutes, research labs and industrial partners to enable innovation within a collaborative experimental environment. Bridging the gap between experimenters, services and equipment, the JOINER fabric is a dedicated transport network interconnecting all JOINER terminals across the UK while a multi-tenancy hybrid cloud platform enables end-to-end service provision.”

The second highest-funded UKRI project is Terahertz frequency devices and systems for ultrahigh capacity wireless communications at £7,097,283. Funded in 2023 this project explores "High data throughput wireless communication systems". The research aims to "develop the first integrated high throughput wireless communication systems operating at terahertz carrier frequencies, between 2-5 THz.... It will support the UK's major space communications industry, and the creation of a resilient global internet, with satellite-to-satellite interconnectivity."

The third-highest at £2,030,860 is TITAN Platform Driving the Ultimate Connectivity which focuses on delivering six interconnected projects reflecting all network elements including "Non-terrestrial networks involving satellites...TITAN will conduct critical research on the integration of non-terrestrial networks which include aerial, satellite and underwater networks all geared towards a seamless end-to-end service provision which is achieved by the holistic approach of TITAN." Additional funding was provided to TITAN in 2024 through the EPSRC's Technology Mission Fund (TMF)

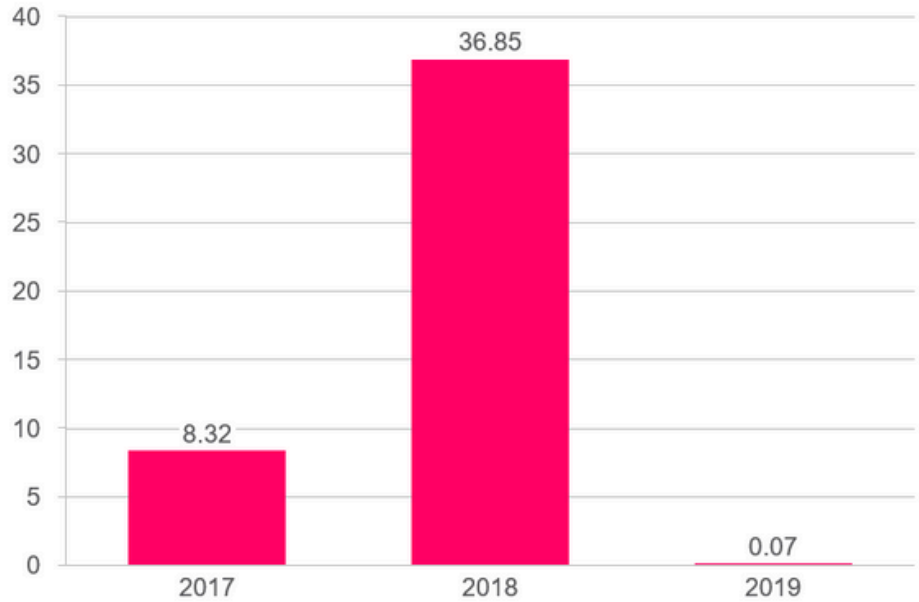
The fourth-highest funded project, with £1,104,511 from Innovate UK is the Aether-Net project. This project "will deliver a multi-role, stratospheric capability supporting cross-sector scenarios including Humanitarian Aid and Disaster Relief (HADR) and Maritime Security use cases." Part of this project relates to internet connectivity delivered via a High-Altitude Platform Station providing "Wideband, long-range, internet connectivity back-haul via stratospheric gateway, connecting remote and inaccessible areas, or regions where infrastructure has been affected by disasters. Internet services are accessible locally using standard, existing Wi-Fi equipment connected to the ground element of the stratospheric gateway."

Of the 30 projects funded by IUK, ten focussed on satellite communications (ranging from Ground infrastructure to Antenna design and development). Four projects focussed on High Altitude Platform Systems (HAPS), concluding optical communication systems and provision of 5G coverage. Three projects focussed on Terahertz and Millimeter Wave research (high-throughput wireless systems and power systems development). Other themes within the 30 projects included AI and machine learning, rural and remote connectivity, 6G technologies, quantum communications and metamaterials for antenna design. While these themes are broad, note that with a sample of 30 projects, some of these themes are aligned to only one or two projects.

Horizon 2020 & Horizon Europe

Horizon 2020 was a European Union research and innovation funding programme which ran from 2014 to 2020 with a budget of close to €80 billion. This programme has been replaced by Horizon Europe since 2021. The projects funded by this mechanism involved multiple partners across various European and non-European countries. This section focuses specifically on projects that involved at least one UK partner, providing insights into the UK R&D&I in non-terrestrial networking technology in the telecoms landscape. It is based on data from CORDIS obtained through the UKTIN Discovery Toolkit and covers six Horizon 2020 projects that commenced between 2017 and 2021. While outside the scope of this report, it should be noted that on 1st January 2024, the UK rejoined the Horizon Europe Programme.

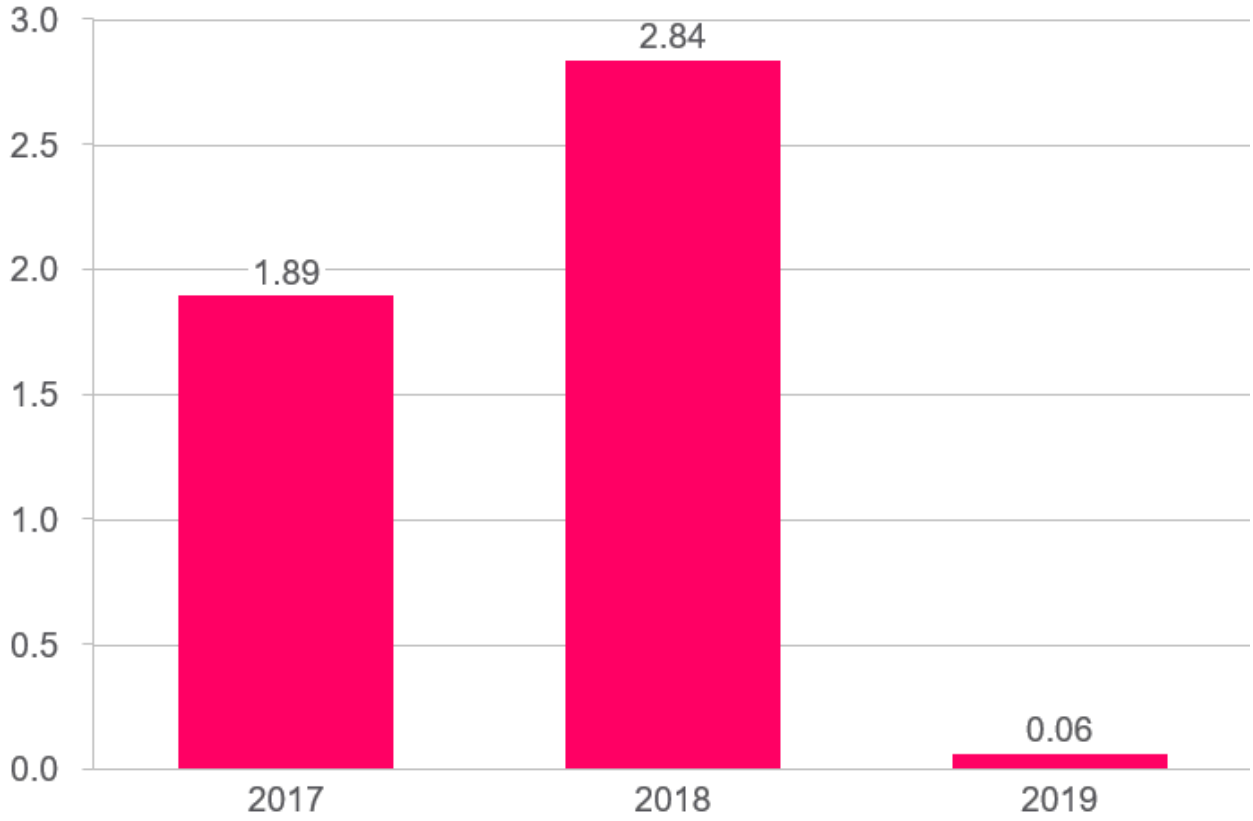
Graphic 2/ Total funding for Horizon 2020 projects with at least one UK partner involved, by Year (€m)



This graphic represents the total amount of funding awarded by Horizon 2020 for non-terrestrial networking technology projects, involving at least one UK partner. It considers 6 different projects in total. Data credit: CORDIS

Between 2017 and 2018 funding increased by 443%, followed by a decrease of 99.8% between 2018 and 2019. With projects funded being one in 2017, four in 2018 and one in 2019. The graphic displays no consistency in the funding provided for NTN related projects.

Graphic 3/ UK Partner's funding for Horizon 2020 projects, by Year (€m)



Total amount of funding (in euros) dedicated to UK partners awarded by Horizon 2020 for non-terrestrial networking technology projects. It considers 6 projects in total. Data credit: CORDIS

Graphic 3 represents the total funding granted to UK partners in the Horizon 2020 projects related to non-terrestrial networking technologies from the previous section. The share of the funding allocated to UK partners over the total project funding varies between years. Across the previous 2017-2023, Horizon 2020 allocation €4.79m to UK partners. In 2017, out of the €8.32m allocated to NTN projects within Horizon 2020, the UK received €1.89m in funding, which accounts for 22.8% of the total funding. However, in 2018, while the amount of funding UK partners increased to €2.84m the share of the total funding received reduced to 7.7%. Within only one project funded relating to NTN in 2019, the UK's share increased to 84.6%.

4.1/ Non-terrestrial networking technology projects funded with UK partners under Horizon 2020

Table 3/ Projects Funded under Horizon 2020 and including at least one UK partner

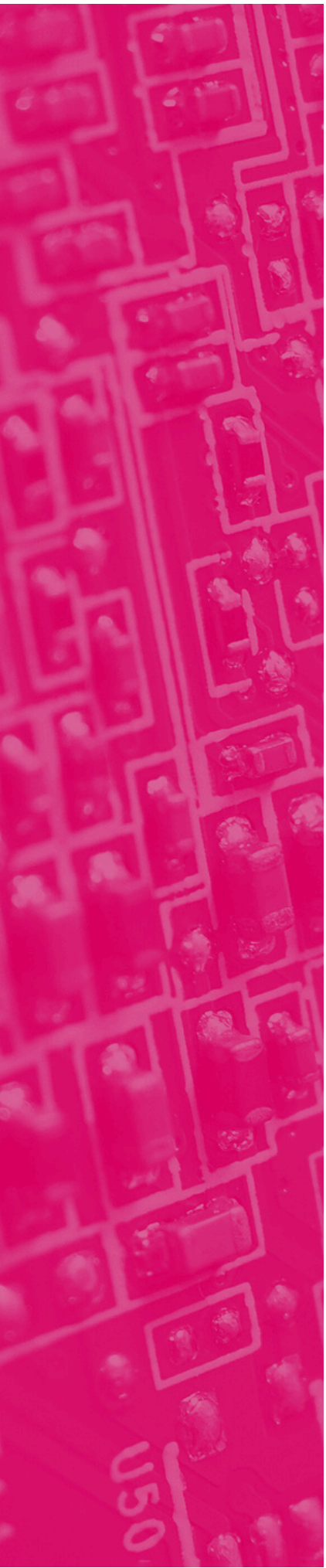
Project Title	Total Funding (€)
5G-MOBIX - 5G for cooperative & connected automated Mobility on X-border corridors	26,795,156
SaT5G - Satellite and Terrestrial Network for 5G	8,316,502
Hi-SIDE - High-Speed Integrated Satellite Data Systems for Leading EU Industry	6,997,016
ORIONAS - Lasercom-on-chip for next generation, high-speed satellite constellation interconnectivity	2,985,290
Pearls Constellation - A next generation telecommunication platform based on a nano-satellites constellation	71,429
RF Beamformer - Ultra-low-cost terminals that meet the special requirements of all satellite operators allowing them to access markets currently inaccessible due to terminal economics.	71,429

This table details the 6 projects funded under Horizon 2020 relating to non-terrestrial networking technology involving UK partners. Data credit: CORDIS

This table highlights the 6 projects funded under Horizon 2020 programme involving at least one UK partner. The projects primarily focus on advancing satellite and non-terrestrial network technologies to improve global connectivity and address the challenges of underserved and remote areas. Key themes include integrating satellite capabilities with 5G networks for enhanced backhaul and traffic management, developing innovative space-based data handling systems, and creating high-speed, low-latency satellite communication links through optical inter-satellite connections. These initiatives also explore scalable and affordable satellite solutions, such as nano-satellites and ultra-low-cost terminals, to bring reliable broadband services to hard-to-reach regions and bridge the global digital divide.

Among these 6 projects, the first three projects with the highest funding allocations were as follows:

- Starting in 2018 and lasting for 36 months, the 5G MOBIX project focused on enhancing automated vehicle functionalities using 5G. Involving 60 partners, this €26.8m project aimed to test 5G core technologies across two cross-border corridors and six urban trial sites, leveraging 5G for connected and automated mobility (CAM) applications. Within this, the Satellite applications Catapult provided technical inputs on the exploitation of Satellite Communication technology within the 5G ecosystem.
- Start in 2017 and lasting for 30 months, the Sat5g project vision was to develop a cost effective "plug and play" satcom solution for 5G to enable telcos and network vendors to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for satcom industry stakeholders. Principal UK partners in this project were the University of Surrey, BT Plc. And Quortus Ltd.
- The Hi-SIDE project, starting in 2018 with a consortium of industrial and academic partners, aimed to develop innovative technologies to significantly improve on-board data handling and transfer capabilities. Hi-SIDE targeted an aggregate instrument data-rate of 50 Gbps, encompassing advancements in inter-satellite networks, payload processing, and data transmission.



Commentary

Funding trends in non-terrestrial networking technology in the UK

This report has identified that, in the data retrieved across the period 2017-2023, a total of approximately £378m has been allocated to R&D&I projects relevant to non-terrestrial networking technology. Of this amount, UK government-funded programmes, excluding ESA contributions accounted for £151.64m (40.1%), UKRI accounted for £32.24m (8.5%), UKSA contributions to ESA programmes accounted for £190m (50.3%), while EPSRC and Innovate UK as the main funders within UKRI and Horizon Europe Guarantee accounted for £4.05m (1.1%)[2].

Exploring government-funded R&D&I programs, including contributions from UKRI and Horizon 2020 projects highlights and emphasises innovations that push the boundaries of connectivity, particularly in challenging environments like rural and remote areas. Noteworthy focus has been observed in leveraging cutting-edge wireless technologies, such as 5G and beyond, to enhance communication infrastructures. A particular emphasis has been placed on ensuring resilient and high-throughput communication systems that can support a variety of critical applications.

A significant trend in recent years has been the growth of funding initiatives aimed at diversifying the telecoms supply chain within the UK. These initiatives are designed to bring new vendors into the market, promoting innovation and competition, with a focus on expanding the use of Open RAN and fostering the development of a robust telecom ecosystem.

[2] These figures are based on the data retrieved for this report and a different methodology, in particular the inclusion or exclusion of certain projects and programmes, may yield different results. It should be noted that these figures are to be understood as indicative rather than definitive and are meant to provide an indication of R&D&I spending in non-terrestrial networking technology, rather than definitive figures.

Key Areas of Research and Applications of Interest

The R&D&I initiatives identified covered a broad spectrum of research and applications:

- High-Frequency and Terahertz Communication: There is significant research into the development of high-frequency communication systems, including terahertz technologies. These efforts aim to achieve ultra-high data throughput and extend the capabilities of NTN in supporting advanced applications.
- Convergent Networking Systems: Researchers are exploring the integration of satellite and terrestrial networks, creating hybrid systems that combine the strengths of both to provide seamless and efficient communication across various terrains, including underserved regions.
- Satellite Ground Infrastructure and Phased Arrays: Investment in experimental satellite ground stations and phased array technology is crucial for improving the infrastructure that supports NTN. These innovations are geared towards enhancing signal reliability and coverage, particularly for global communication networks.
- AI and Machine Learning for Network Optimisation: Research is increasingly focused on integrating AI and machine learning into NTN systems to optimise network performance. This includes predictive maintenance, automated resource management, and enhancing the overall efficiency and reliability of NTN operations in dynamic environments.
- Cybersecurity in Non-Terrestrial Networks: As NTN systems become more widespread and critical, ensuring their security is paramount. Efforts are being directed towards developing robust cybersecurity frameworks tailored specifically for satellite and hybrid networks, protecting them from emerging threats and vulnerabilities.

NTN use in telecommunications is undergoing significant evolution, driven by the advancements in Satellite Communication services from traditional Geostationary Earth Orbit (GEO) platforms to High Throughput Systems (HTS), software-defined satellites and Low Earth Orbit (LEO) constellations. These technologies, together with those discussed in a previous section (1.2), are enabling NTN usage to be expanded beyond traditional applications in cellular backhaul, towards the inclusion of IoT and device-to-device (D2D) communications.

Challenges and opportunities

- Long term funding from industry is critical. While lower Technology Readiness Level (TRL) research is often supported by public funding, higher TRL projects typically rely on private capital, accrued revenues, and a mix of bonds or loans secured against future revenue projections. This financial model underscores the importance of developing a sustainable and scalable funding strategy to support the long-term growth of NTNs. Private funding is increasingly recognised as a critical enabler for the UK to scale its LEO satellite manufacturing sector, which is essential to remain competitive globally. The need for substantial financial investments is underscored by the complexity and high costs associated with satellite technology development and deployment, particularly in scaling up manufacturing capabilities to meet the growing demand for NTNs. One industry expert noted that "It is going up and particularly from the VC side, also a lot of investment from corporate partners who have an interest in using constellations". With another noting that "There will be a role for public funding to incentivise the private sector, but the capital investment involved are very high and difficult to justify to the taxpayer".
- Antenna technology is also evolving, with manufacturers developing larger antennas to enhance data rates and maintain competitiveness with TNs. The continuous use of innovative approaches, such as origami techniques for antenna design, reflects the ongoing efforts to optimise performance within the physical constraints of satellite technology.
- Terrestrial network deployment costs in hard-to-reach areas can be prohibitive compared to satellites. The high costs associated with last-mile coverage in terrestrial networks worldwide have made satellite communications a pragmatic alternative. The deployment of NTNs, particularly in LEO, offers a viable solution for extending coverage to remote and underserved areas, where traditional terrestrial infrastructure is either too expensive or impractical. The proximity of LEO satellites to Earth makes them particularly attractive for NTNs, providing lower latency and improved communication quality compared to GEO satellites.
- The business case for D2D is improving. Notable developments in D2D communications include Apple's introduction of a D2D-capable antenna in the iPhone 14, which, although limited to low-bandwidth emergency services via Globalstar, represents a significant step forward in mainstream consumer access to satellite connectivity. This development highlights the growing interest in integrating NTNs with consumer devices, paving the way for broader applications in the future.

Commentary

- Despite the UK's strong track record in innovation, there are challenges in scaling these innovations into large, successful businesses. This issue is particularly pertinent in the context of NTNs, where the business model and business case remains unclear. However, the business case for the UK only appears limited, one expert interviewee called out that "The business case has to be global, If you launch a constellation of satellites, it's providing global coverage and the UK is a very small part of that land area." The lack of a well-defined revenue model for NTNs, as evidenced by Qualcomm's failed attempt to exclude Mobile Network Operators (MNOs) and attract Original Equipment Manufacturer (OEM) interest, suggests that successful commercialisation will likely depend on the involvement of the MNOs.
- Data sovereignty was noted by an expert interviewee as a significant barrier and consideration in NTN-related R&D&I, particularly concerning the routing of traffic through other nations. As NTNs become increasingly integrated into global communication networks, ensuring that data sovereignty is maintained will be crucial for national security and privacy.

Annex

Annex 1/ Methodology

For this report, a combined approach was taken to provide detailed insight into some of the key UK R&D&I non-terrestrial networks in telecoms topics, relevant to the UK ecosystem. The approach incorporated quantitative and qualitative information gathering from different elements of the R&D&I ecosystem, including desk research, database collation and web scraping from key datasets and the UKTIN AI discovery toolkit, industry expert interviews by the Satellite Applications Catapult and academic expert interviews by the University of Bristol, and discussions between programme partners and relevant stakeholders. All data incorporated in the report is from publicly available information and is complemented with primary and secondary research.

In terms of qualitative information gathering, the Satellite Applications Catapult conducted four interviews with industry experts from four organisations. The University of Bristol conducted four interviews with non-terrestrial networking in telecoms academic experts from four leading research Universities working in cluster V on the UKRI KEF2 database.

In terms of quantitative information gathering, three approaches were used for the different sections in this report. All methods retrieved projects beginning on or after 1/1/2017. The year 2017 was established as the starting point for data collection to ensure that the data is relevant and recent.

Annex

For Section 2: Government R&D&I, data on the different funding schemes and projects was collected and collated manually from government webpages. This was conducted in July and August 2024 and the data is accurate to this point.

For Section 3: UKRI, in order to identify the relevant projects, a list of keywords was compiled in order to capture the breadth of R&D&I in non-terrestrial networking technology, complemented by a list of keywords to exclude to ensure projects were relevant to the telecoms industry. These were submitted as a query using the UKTIN Discovery Toolkit, with the data coming from the GTR-UKRI database. Specific search terms were used to remove irrelevant subject areas, and the data was then manually curated over several iterations to generate a reliable data set with technology experts at the Satellite Applications Catapult. Results retrieved using this process were obtained in June 2024 and are accurate to this point.

Finally, Data for section 4: Horizon 2020, was obtained from the CORDIS database also using the UKTIN Discovery Toolkit. The same set of keywords from UKRI was used to include and exclude projects for this section of the report to ensure consistency. The data was subsequently manually curated, cleaned and analysed.

Annex 2/ Limitations

This report relies on publicly available data and therefore focuses on public funding for R&D&I. Private company's R&D&I investments are typically commercially sensitive and access is restricted, meaning that web scraping methods are not applicable. The data retrieved for this report is determined by the methods described above and is presented as an indicative snapshot of information on non-terrestrial networking in telecoms R&D&I, rather than as a definitive and exhaustive list of projects and funding. Different methodologies, specifically different keywords, may yield different results. There may also be inconsistencies in the raw data and the data may change over time.

Annex 3/ Data sources list

Dataset	Source
Government-funded programmes	Open Networks Research and Development Fund
	FONRC
	FRANC
	Unleashing Rural Opportunity
	SBRI Future Telecommunications Challenge
	5G RuralDorset
	Project Gigabit
	5G Innovation Regions
	Rural Connectivity Accelerator
	UK Telecoms Innovation Network (UKTIN)
UKRI	UKRI Gateway to Research
CORDIS Horizon 2020	data.europa.eu