Seize the future:
5 Deep tech areas driving long-term growth

Seize the **growth power** of deep tech

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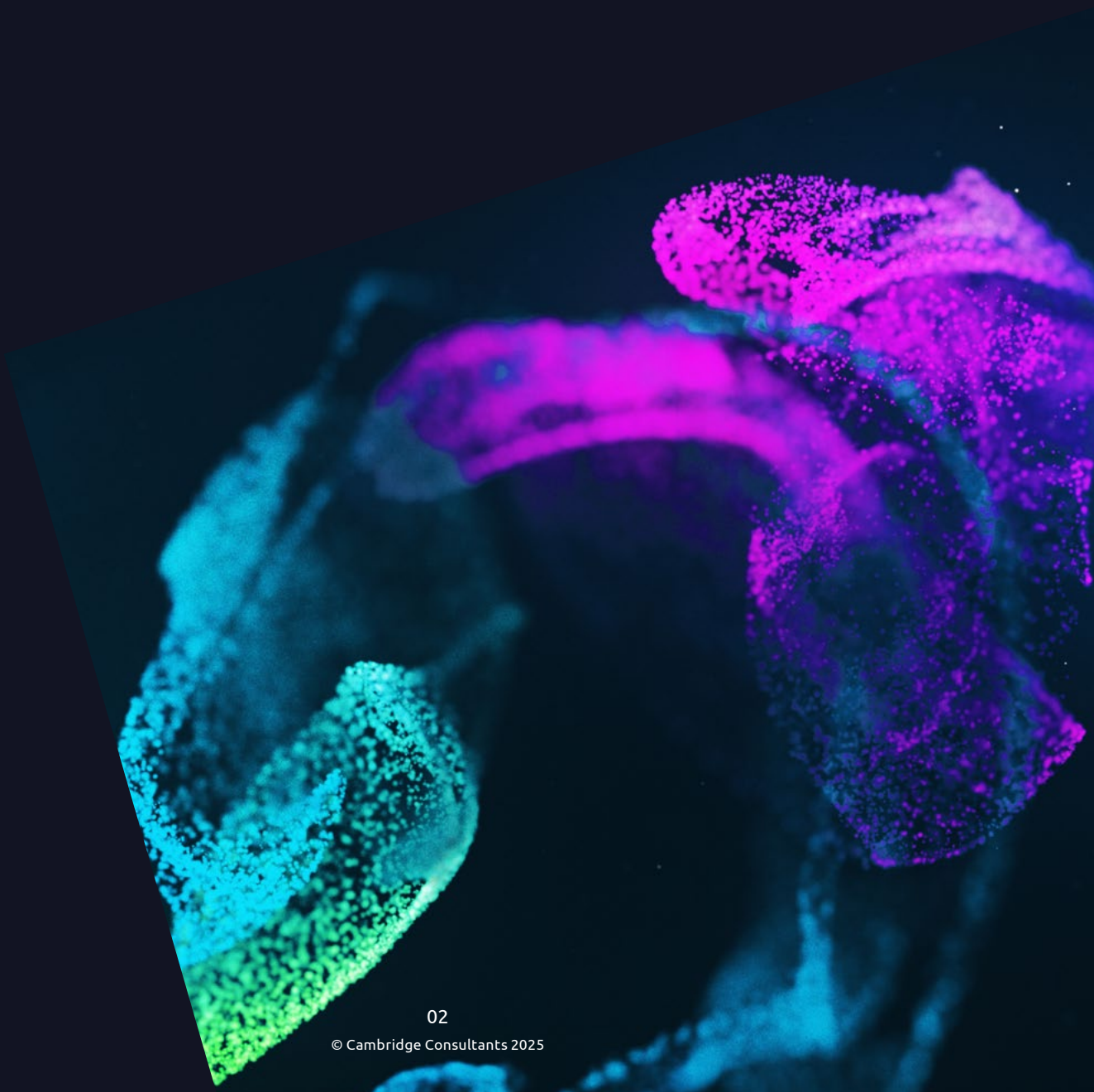
Contents

Overview

Let’s be clear. Telecoms and associated ubiquitous connectivity sit at the heart of profound social and economic change. A new era of AI-driven, energy efficient, sustainable networks is being enabled by extraordinary advances in deep tech. The business leaders who harness these novel technologies and techniques will seize new opportunities, new revenues and transformative growth. This report guides the way.



Setting the scene

It's time for telco leaders to reclaim their position at the forefront of innovation. The industry has a key role to play in enabling the digital transformation of society and the enterprise. Seen through this lens, it's clear that success will bring transformative, long-term business growth.

To ensure that growth is long-term and sustainable, it will be necessary to leverage emerging and evolving innovation. As the deep tech powerhouse of Capgemini, Cambridge Consultants (CC) is uniquely placed to help. We specialise in creating products, services and processes that have never been seen before.

It means our clients gain unassailable commercial advantage from defendable technology that they own – and which can't be copied. For us, deep tech is a mindset; a strategy that harnesses radical science and engineering to achieve things no-one else can. In this context, telecoms offers opportunities unmatched in any other industry. So, what are you waiting for, let's go!

CC can point to decades of experience in the telecom sector – which has enabled us to identify the five key areas of deep tech that you need to pay attention to in 2025 and beyond. They are:

1. Human augmentation by AI
2. Network autonomy beyond Level 3
3. Non-terrestrial networks
4. Advanced computing
5. Next generation radio networks

In this report we outline each area of technology, explore the value they can deliver, and explain how they can and should be deployed within the telecom ecosystem.

The time is now – and here's why

Industry leaders must come to terms with a fundamental truth – as one of the foundational infrastructures of society, telecoms frequently goes through waves of reinvention. 2025 is a classic case in point. There is a pressing need to respond positively to change, which is being driven by a host of internal and external factors.

They include:

- The global sustainability imperative: mandating more energy-efficient and environmentally friendly operations to meet ambitious sustainability goals
- AI innovation and evolution: unlocking the potential for complex, dynamic networks while focusing on improving usability and optimising human-machine interactions
- Data proliferation: exponential growth in network and third-party data requires robust solutions to extract and monetise value
- Geopolitical volatility: navigating global uncertainty and ensuring resilience in a fragmented, unpredictable world

Cracking the code: today's biggest challenges for Telecom leaders

From challenge comes opportunity. So, let us set out the key challenges and obstacles that stand in the way of long-term sustainable growth. Essentially, telco leaders need to work out:


How to secure strategic differentiation in a hyper competitive market


How to unlock new business models (in 5G and beyond)


How to deliver operational efficiency and cost reduction


How to create enhanced customer experience and personalisation


How to meet sustainability and ESG commitments

1 Human augmentation by AI

For instant decisions to cut costs and boost efficiency

Other industries have shown us that a hybrid human-machine team can outperform a human-only or machine-only team. From fields like cancer diagnosis to warehouse stocking, human strategic guidance – combined with the tactical acuity and tirelessness of a machine – is a winning combination.

We believe this phenomenon will impact telecoms. AI is revolutionising the telecom industry, reshaping its operations and role within business and society. The sector, with its reliance on large and highly complex technology platforms, is primed for transformation. The exciting part of AI implementation is that it will stretch from the most detailed technology level to the most abstracted human machine interface. With such profound change, how can you ensure your future prosperity?

Master the complexity, unlock the intelligence

In today's hyper-connected world, telecoms networks generate immense volumes of data, from call detail records (CDRs) to telemetry, user behaviour and service interaction data. This presents both a challenge and an opportunity: how can you sift through these vast datasets to deliver real-time insights, enhance user experiences, and make smarter decisions that reduce environmental impact and drive growth?

The answer lies in harnessing AI agents for decision-making – a deep tech approach that can revolutionise how telecom networks operate and thrive in the future. Let's explore the potential benefits of human augmentation by AI.

One promising application is in network operations centres. Where high network availability and reliability are critical to business operations, teams are tasked to oversee these complex networking environments, managing and responding to special circumstances to avoid degraded service.

Michelle Lim,
Principal Behavioural Scientist
for Human Machine Understanding

"Our researchers have designed neural networks capable of processing complex, dynamic environments with millions of data points, as well as unpredictable human behaviour."

This real-time dynamic response has strong parallels to military command and control, a field also deeply invested in the application of AI to augment human operators. At CC, we've drawn inspiration from this unexpected yet deeply relevant field to generate insights for telecoms.

Our researchers have designed neural networks capable of processing complex, dynamic environments with millions of data points, as well as unpredictable human behaviour. We've used real-time strategic games as a substitute for command-and-control wargaming. These AI models predict and respond to user actions in real time. Essentially, we showed how AI can sift through chaos and make clear, effective decisions.

By understanding patterns, behaviours and trends in vast datasets, our AI agents can:

- Predict what a customer is likely to do next
- Forecast where network bottlenecks might occur
- Reveal how to deliver superior experience

No more guesswork! It's now possible to uncover real-time insights you may not have thought possible. Whether it's understanding peak usage patterns or identifying customer churn triggers, we can help you make sense of it all with AI models that transform chaotic datasets into actionable intelligence.

Beyond functionality: enhancing user experience

Another key application of AI is in transforming customer experience. As ever, the foundation of superior customer experience is maximising network performance through the technical management of assets. But increasingly, the softer side of customer experience – delivering timely, helpful service – will move the needle on customer loyalty, attraction and retention.

CC has already developed a wealth of experience in building decision support systems. It has shown us that such human augmentation can be truly context specific – and highlighted the increased productivity, the improved quality, and the time-saving benefits that businesses stand to gain.

Our AI models demonstrate that it's crucial not only to predict actions but to enhance engagement by gaining deeper insights into user behaviour, preferences and expectations. We can show you how AI can be used to go beyond functional predictions to address user experience holistically. It can track behaviour patterns, preferences and emotional responses, allowing you to create uniquely tailored and intuitive services.

2 Network autonomy beyond Level 3

Unlocking new business models in 5G and beyond

The growing complexity of networks is leading to increasing costs and tougher management and control. According to a recent report from the Capgemini Research Institute, communication service providers (CSP) that have implemented Level 2 report an 18% reduction in opex and 20% increase in efficiency – highlighting the tangible benefits of even partial autonomy. The answer to the complexity challenge is to use sophisticated analytical AI-based tools – operating in real time – to optimise the network more rapidly and accurately than before.

So – let's look at the importance of accelerating your route towards Level 3 autonomy (and beyond). As our whitepaper, 'Get ahead in the race to autonomous networks' reveals, only 6% of telcos are currently at Level 3. To buck this trend, you need the right mindset and models.

What does full autonomy look like? A network that anticipates bottlenecks, self-configures for optimal performance and heals itself from outages, all without human intervention. Every player in the telco value chain has on its roadmap the need to deliver either the capabilities towards and/or an actual autonomous network.

The concept of autonomous networks isn't new. Indeed, the first SON (self-organising network) was introduced with 4G to limit the impact of teething troubles. And in some cases, SON was even retrofitted to existing 3G networks to help reduce cost and improve service reliability. First deployments occurred more than 15 years ago, aimed at helping mobile operators to decrease network rollout times, reduce dropped calls, improve throughput, lessen congestion and achieve other operational efficiencies such as energy and cost savings.

Stephane Remy,
Commercial Director, Connectivity

"What does full autonomy look like? A network that anticipates bottlenecks, self-configures for optimal performance and heals itself from outages, all without human intervention. Every player in the telco value chain has on its roadmap the need to deliver either the capabilities towards and/or an actual autonomous network."

But despite this early start, and the growing buzz over the last few years, why are most CSPs still at L1 (assisted) or L2 (partial) level of autonomy? And why will only 12% reach L4 (highly automated) and only 3% L5 (fully automated) within the next three years?

It's because:

- Different components of the network are at different levels of automation
- A big ambition for autonomy doesn't necessarily equate to well defined objectives or outcomes
- There's a lack of automation culture within organisations
- A robust AI framework isn't easy to establish

A key factor in all this is the need to understand where AI is best applied – for example it might be at the edge or centrally depending on the use cases and KPIs.

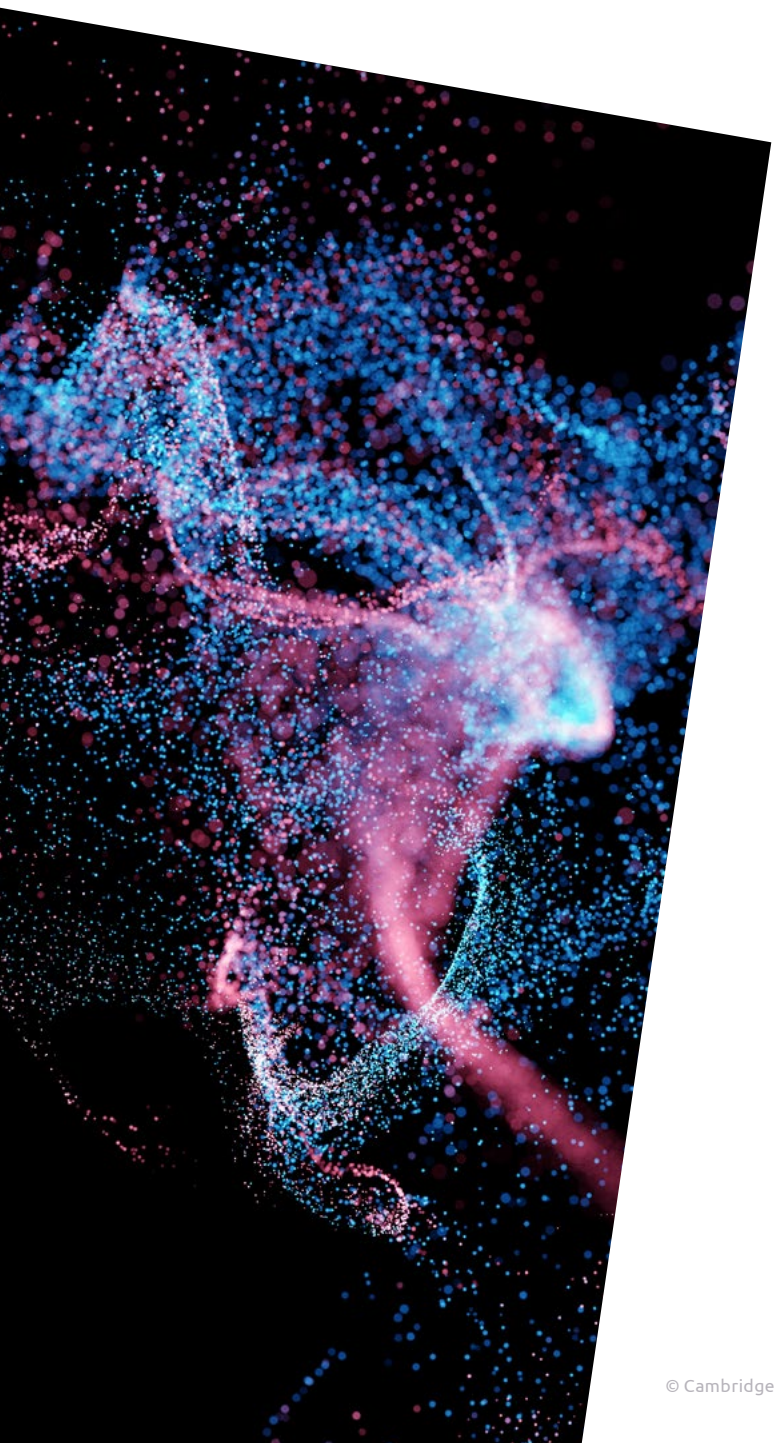
To solve the complex problems inherent to autonomous networks, AI and machine learning models must be trained using real-world and historical data (which is all but impossible to get hold of) or through simulations. The latter is only way to deliver operational and resource efficiency, experience excellence and monetisation.

It's also vital for us to make clear that no one can simply start work on L5 tomorrow from scratch. This is because of differences in automation levels across hardware, software and applications in the entire telco value chain.

At CC, we've worked on numerous AI-driven transformation projects:

- From AI root cause analysis on unstructured maintenance and support logs to AI compensating for failed elements in phased array antennas of HAPs
- From mobile network cell load prediction for RAN energy savings to AI inference of user quality of experience using standard network performance parameters
- From investigating neural receiver efficiency optimisation to delivering projects across industries using predictive digital twins with synthetic data. This enables faster AI development, reduced real-world data collection costs, and optimisation across complex systems

The one thing these projects all have in common is that they are approached with an agile mindset. Yes, the initiatives were ambitious, but they all had a clear objective. And that's even more important because AI might not always be the answer to a specific problem. For instance, you might be considering local AI for satellites or remote base stations. But it could be that faster backhaul (promised by new millimetre wave or free space optics) would give you the same advantage with centralised AI compute that is easier to access, update and upgrade.



How autonomy tackles the biggest challenges head-on

Achieving network autonomy beyond Level 3 will directly address the critical challenges faced by telecom leaders today:

- Operational efficiency and cost reduction: By leveraging real-time AI to optimise network performance, automate repetitive tasks, and enable predictive maintenance, operators can significantly lower opex, enhance energy efficiency, and streamline resource usage. These efficiencies will help free up resources for innovation and future growth
- Sustainability and ESG commitments: Autonomous networks driven by AI offer tangible paths to meet ESG goals. Reducing energy consumption, minimising waste, and ensuring smarter resource utilisation all contribute to a greener, more responsible approach to connectivity
- Unlocking new business models in 5G and beyond: Autonomy is a powerful enabler of flexible network slicing, ultra-low-latency applications, and edge innovation – the cornerstones of next-generation revenue streams. Operators can harness these capabilities to adapt to new markets, drive monetisation, and maintain competitive advantage
- Enhanced customer experience and personalisation: An autonomous network self-configures to meet user demands, anticipates bottlenecks before they occur, and delivers seamless, personalised services. This enhances customer satisfaction, drives loyalty, and creates new opportunities for differentiation and growth

For telecom leaders ready to seize these opportunities, embracing network autonomy is not just about tackling today's pain points – it's about building the foundations for long-term resilience, innovation, and success.

Your invitation to make autonomous networks a reality

To deliver closed-loop automation capabilities across multiple services and domains (including partners' domains), an agile mindset approach will allow you to think big, start small – with repetitive tasks for example – iterate fast while gathering data, and ultimately deliver value against clear KPIs.

3 Non-terrestrial networks

Hyper connectivity and new revenues from elevated customer experiences

The rapid evolution of NTNs (non-terrestrial networks) is revolutionising the telco landscape, bridging the gaps in global connectivity that terrestrial networks struggle to address. Acting now to understand and invest in NTNs is critical to harnessing the full potential of 5G and beyond. Now is the time to explore the strategic, long-term investments in NTNs that will drive growth and innovation for decades.

NTNs leverage satellites, HAPs, and UAVs (uncrewed aerial vehicles) to deliver connectivity in regions where traditional terrestrial networks are impractical or unprofitable. This might be providing essential services such as broadband and emergency communications to remote areas, rural landscapes or the ocean.

The global NTN market is expected to reach $32b within five years, which equates to an impressive compound annual growth rate of 35%. By integrating NTNs into a broader telecoms strategy, enterprises can ensure ubiquitous coverage, enabling new business models and innovative solutions. Sectors ranging from agriculture and logistics to defence and disaster recovery will all benefit from enhanced comms-on-the-move.

At CC, here are some of the key development areas we are working on to deliver NTN transformation in telecoms:

1. **The deployment of ISLs (high-speed optical inter-satellite links),** which greatly enhance resilience and bandwidth capacity, as well as negating the need for RF spectrum. They also help mitigate the challenge of maintaining constant connectivity between satellites and ground stations, especially over oceans or sparsely populated areas.

   Developing ISL capabilities will be a key differentiator to reliably provide smarter, more flexible routing and data sharing that is unconstrained by inter-satellite bandwidth. Without ISLs, you risk falling behind your competition. And remember not all ISLs are the same. They have to be incredibly accurate to perform well, simultaneously connecting to other satellites from a satellite travelling at 17,000mph (which is hard), and they have to be reliable over the two-, three- and 10-year lifespan of satellites.

2. **Advanced phased array antennas,** which are enabling better D2D (device to device) communication by improving beamforming capabilities. These antennas are essential for delivering high-speed data to a wide array of user equipment, from smartphones to IoT sensors and connected vehicles.

   However, many find it a complex challenge to navigate the design choices involved. Only companies with a good heritage and experience can help with this. Working alongside experts to incorporate these advances into your solutions will enable scalable, low-cost deployment of novel services.

   Integrating AI with beamforming will further revolutionise the field. Advances in Digital Signal Processing (DSP) are enabling the development of more complex AI algorithms that allow for the real-time adaptation of beam patterns while also accounting for changing channel conditions, user mobility and interference.

3. **Network optimisation / automation using AI.** Through autonomous, AI-driven networks, satellites can make autonomous decisions while in orbit based on real-time data and predefined rules, improving operational efficiency and reducing ground station dependency. Similarly, AI algorithms can autonomously optimise datalinks to gain differentiating performance in terms of throughput, reliability and interoperability.

   Communications service providers (CSPs) that have successfully accelerated their automation journey have already reported a 20% increase in operational efficiency and 18% savings in network operational expenses. Meanwhile, 71% have enjoyed reduced energy use and boast a projected 32% decrease in emissions over the next five years.

4. **Quantum.** Beginning quantum R&D now will position NTN players as industry leaders, allowing them to establish quantum links between satellites ahead of the crowd. CC is already exploring how quantum technologies will feature in the next generation of LEO satellites. Our current focus is investigating quantum networking and cold atom-based inertial sensors to improve satellite communications, positioning and navigation to achieve superior precision and efficiency for defence and scientific applications.

Stewart Marsh,
Head of Satellite Communications

"By integrating NTNs into a broader telecoms strategy, enterprises can ensure ubiquitous coverage, enabling new business models and innovative solutions."

4 Advanced computing

Transformative performance and energy savings

We believe that after many years of concentration – driven by economic and wider political forces – the cellular vendor market is on the verge of a major disruption and realignment. Telecoms networks have been moving to virtualisation for many years. And while initially concepts such as O-RAN (open radio access network) offered the potential for more software-based innovation, this has initially entrenched the Ericsson and Intel (x86) duopoly.

However, these more distributed network architectures enable different network functions to be delivered in different locations and on different compute platforms, while reflecting priorities in cost and performance. Compute intensive and latency critical activities such as forward error correction (FEC) or multiple-in multiple-out (MIMO) antenna control may be best suited to highly optimised silicon – either FPGA or ASIC designed – for optimised power and performance while situated close to the end radio unit.

Other functions can be carried out more centrally or completely in the cloud on dedicated GPUs and CPUs using the appropriate compute as needed, to benefit from scale economies. While these changes can improve performance of today's 5G networks and increase energy efficiency, they will also be critical to the wider introduction of AI capabilities and the ultimate adoption of 6G features.

Recent developments from silicon vendors are starting to deliver on the promise of this new model. Competition is now emerging at the compute level – Layer 1 – in the network. Several Arm-based architectures which offer energy efficient CPU alternatives to Intel x86 are now emerging. These include NVIDIA Grace, Ampere Computing and AWS Graviton.

In addition, NVIDIA's launch of its Aerial suite of services (a focused software defined and cloud-based framework for 5G, and ultimately 6G networks) that exploit the power of NVIDIA GPUs – as well as its partnerships with disruptive operators such as T-Mobile and NTT DoCoMo – have gathered significant industry interest. AMD continues to grow its capabilities in the GPU market across sectors. For the first time in many years, we are facing the possibility of a radical shift in the architecture and balance of commercial power in the telecoms market.

Challenges in implementation remain. The cost of GPUs may be prohibitive if they are to be distributed at the network edge. Therefore, many operators are looking at other AI use cases to justify this investment, ASICs and FPGAs are expensive, can be inflexible, and take time to develop. The AI revolution is coming but use cases are still emerging – as are the questions. How does the underlying compute adapt to include new AI models? How and when should operators and network vendors introduce new computing capabilities? And practically how easy is it to move software to new compute platforms without adding extra cost or complexity?

Nonetheless this change in the market is attracting strong interest from operators, vendors and silicon providers. We're working across the industry to address these opportunities. For many years, we've collaborated with satellite and non-terrestrial operators to select and design the right compute for complex antenna operations, where power, performance, flexibility and cost trade-offs are key. We understand the trade-offs and investment decisions that must be made.

We can help you exploit new approaches such as vector processing and tools like Google Highway to enable the migration of key RAN software across platforms. Already we're working with leading operators to develop their AI use cases across existing high-performance compute platforms.

The compute architecture of radio networks is undergoing a radical change and all players need to understand the impact and opportunities for their business and how they should respond. CC is ready to advise and support you through this complex change.

Dan Kirk,
Consulting Director,
Technology Strategy

"For the first time in many years, we are facing the possibility of a radical shift in the architecture and balance of commercial power in the telecoms market."

5 Next generation radio networks

Adaptive, energy-efficient connectivity for operational performance and reduced costs

Antennas have been, and will always be, fundamental to wireless radio connectivity. They are no longer just devices that simply convert electrical signals to radio waves and vice versa but are fundamental to the efficient exploitation of available spectrum. Furthermore, emerging antenna technologies are essential to overcoming the main challenges in wireless communications and achieve maximum Quality of Experience (QoE) and Net Promoter Scores (NPS).

From digital beamforming to AI for failure compensation, there are a number of key deep tech functionalities that will redefine QoE and – just as importantly – energy management, and hence accelerate long-term growth.

With around 7m 5G base stations in the world – and many more to come as the 5G rollout continues there are a lot of antennas that require monitoring and optimisation.

As we move into the 6G era, not only do familiar challenges remain to be addressed, but new challenges will arise including:

- Indoor penetration
- New and higher frequencies
- Evolving challenging channel conditions, user mobility, and interference as a result of the infrastructure platforms
- Provision of high-performance connectivity in an economic and sustainable manner
- Pencil beam as well as diffraction and free space path loss depending on the environment
- Non terrestrial platforms for the provision of high-quality performance

This is an exciting and potentially transformative area of innovation. So which deep tech innovations should you be exploring and/or developing? Here's our concise run down…

Complex beamforming and ultra-massive MIMO (multiple input, multiple output) layering to maximise capacity of the air interface and enable significant operational efficiency gains. For instance, in the context of a High altitude platforms (HAPs) emulating a tri-sectored site from 20km altitude, think of:

- FR1 frequencies (3 to 6GHz) to get good wide area coverage (with the right design techniques for light weight and cooling)
- Cell splitting to increase capacity by spectrum reuse
- Using handset feedback to further enhance more specific beam selection

MIMO will be a key technology to ISAC (integrated sensing and communication):

- Either for the sensing component itself or to enable trunking vast amounts of sensor data back to the cloud for AI processing
- Possible routes include multiuse antennas for position determination using amplitude and phase mono-pulse methods

New components to enable the use of more efficient protocols over greater distances (for NTNs).

- A world first – CC has developed a flat-panel phased array antenna capable of providing FDD millimetre wave capabilities. This removes the need for two separate panels for FDD operation and also allows for lower latency links. In the 3GPP space, this enables system design to work higher up the O-RAN stack. This has been enabled by novel antenna design and improvements in fabrication methods
- Metamaterials that are artificially engineered with unique EM (electromagnetic) properties to accelerate miniaturisation, higher gain, and wider bandwidth

RIS (Reflective Intelligent Surfaces)

- Dynamically modify their characteristics based on operating conditions for increased efficiency will form a critical part of 6G and NTNs.

Derek Long, Commercial Director, Telecommunications

"From digital beamforming to AI for failure compensation, there are a number of key deep tech functionalities that will redefine QoE and – just as importantly – energy management, and hence accelerate long-term growth."

Development of integrated antennas with other components leading to smaller and more efficient devices.

- Transparent antennas – V2X – transparent panel antennas can be embedded into cars, increasing possibilities of V2X

RAN digital twins

- Digital twins are virtual models of a physical system that have a high degree of accuracy. These systems can be used to perform live predictions and analyses of system performance and can be leveraged for RAN optimisation – for coverage, signal quality, operational efficiency, base-station positioning
- The fast information provided by digital twins allow for rapid diagnosis of the potential causes of degraded performance. For instance, the local physical geography, and other interferers
- Advanced techniques allow more complex interactions with other access networks, whether that is a seamless hand-over between NTN and terrestrial networks, or geofencing protected regions such as airports or military sites

AI enhanced digital beamforming

- The trend is for beamforming systems to be larger and support more complicated beam patterns, including nulls and pencil beams. This implies standards will de-emphasise codebook-based pre-coding methods and move toward dynamic beamforming. The linear algebra involved is incredibly computationally expensive. To support this, AI may be a tool that can be utilised to help the calculations, without breaking a compute budget, and maintaining good adherence to the classical beamforming performance
- A specific example realised at CC, is element failure mitigation. When phased array elements fail, for various reasons including (e.g. power supply path failure), this can generate undesirable beam patterns. This could be a degradation in the signal to noise quality at the target, or inconvenient side lobes. Inefficiencies like these are a suboptimal use of power and may also violate governmental regulations. Down-time to fix these situations are costly in repair and service disruption
- CC has developed AI models that solve these element failure scenarios. AI precoding can correct against these element failures, which perform well against classical algorithms, but scale much better with panel size

Collaborating with us at CC will enable you to tap into unique and relevant experience. We're working to help beam 5G from the stratosphere (for Stratospheric Platforms Ltd) and we've used AI to tackle some of the key challenges – including compensating for failed elements in phased array antenna applications.

The fact is that the time has come to join and contribute to the antenna revolution. Whether it's adapting channels to maximise reception quality or bringing large arrays, many radios, and multiple beams together, antenna technology is evolving exponentially. New rewards and revenues will come from delivering higher bandwidths to meet the demands of the future. Our advice? Don't be late to board that train.

Ready to seize the future? **Let's talk.**

Please reach out to our deep tech experts. We're well placed to help activate and accelerate your response to the challenges and opportunities ahead.

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About Cambridge Consultants

As the deep tech powerhouse of Capgemini, Cambridge Consultants (CC), is a global team of 800 bright, talented people. We are united by the ambition to turn brilliant ideas into technologies, products and services that have never been seen before. And which will transform business, society and the planet. Deep tech is a mindset; a bold strategy that harnesses radical science and engineering to achieve things no-one else can. It enables our clients to gain unassailable commercial advantage from defendable technology that they own. We are trusted by some of the world's biggest brands and most ambitious start-ups to realise their critical technology-based aspirations – and we've been doing it for 60 years. Cambridge Consultants is part of Capgemini Invent.

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