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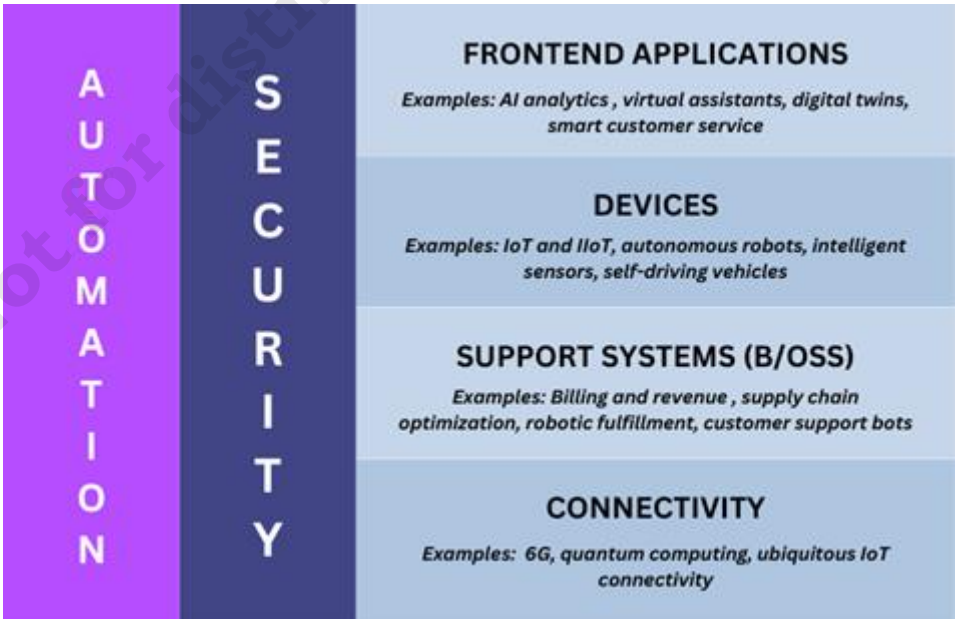
The remainder of the first half of this century will see an array of large-scale technology use cases. Relevant breakthroughs are fast becoming apparent in both the enterprise and consumer spheres, as are their monetization models.

At the core of the advances set to shape the technological future is the *fully autonomous enterprise* — self-operating, surpassing human intelligence, and bound by a stringent web of security and regulation. The opportunity for telecom providers, technical pioneers, and consumer-facing corporations lies in building and implementing innovation stacks capable of powering this autonomy.

The modern innovation stack has six components: front-end applications, devices, support systems (B/OSS), connectivity, security, and automation, as encapsulated in the graphic below.



All are essential for the autonomous enterprise, and demand will precipitate service packages that cater to complex connectivity, security, and automation needs. Basic network and tech commodities are fast becoming things of the past.

Yet the move towards an ubiquitously connected and post-human society poses profound ethical, operational, and social questions. All involved must address these key considerations to

determine how to capitalize on the host of opportunities that fundamental change offers.

The Fully Autonomous Enterprise

The elimination of the need for any human input at both the strategic and operational levels is the hallmark of the fully autonomous enterprise. The most relevant current example of this technology is that of the **AI autonomous agent**, which can match (and often outmatch) humans in domains like trading and customer service.

In *The Coming Wave*, futurist Mustafa Suleyman writes, "In this paradigm, there is no need for a human to laboriously define the manner in which a task should take place. Instead, we just specify a high-level goal and rely on a machine to figure out the optimal way of getting there. Keeping humans "in the loop," as the saying goes, is desirable, but optional.

A picture of what the fully autonomous enterprise will look like is emerging. Imagine a scenario in which self-driving trucks — already in operation in certain European "confined zones," such as mines — deliver materials for storage in a smart warehouse. These materials are then transported by unloading robots — such as the well-known Stretch from Boston Dynamics — to self-governing production lines.

The whole system is overseen by an auto-troubleshooting, self-optimizing AI business process automation (BPA) model. Generative AI advertises the products and handles multivariate testing, marketing, and customer support. On the delivery end, purchases are fulfilled by autonomous warehouses and delivery networks like those offered by Prologis and Amazon. Meanwhile, eXtensible Markup Language (XML) and blockchain provide the basis for compliance and intelligent contracts.

The pace of change will likely be fast because enterprises are under pressure to pursue adoption to improve margins and increase operational efficiency. Leaving aside the broader societal discussion for a moment, the C-suite is more than aware that robots don't sue, get sick, or join unions. AI systems don't ask for raises and aren't concerned about work-life balance.

The fully autonomous enterprise is already a reality in some places and is poised to change the face of global commerce. Telecom and tech providers have an incredible opportunity to incorporate the technology and develop new, widespread use cases.

Expanding IoT and IIoT

Internet of Things (IoT) and Industrial IoT (IIoT) devices, integrated through intelligent gateways with built-in security and automation, are forming the backbone of the fully autonomous enterprise and opening doors for innovative use cases, providing continuous feedback loops across organizations and forming an operational foundation for AI decision-making and workflow and resource optimization.

Devices and sensor networks can sync with edge centers for low-latency data transfer and real-time analysis. In addition, AI oversight allows IoT systems to self-optimize, increasing on-the-floor efficiency with digital twins and predictive analytics. This applies as much to individual smart factories as it will to entire energy grids and smart cities.

IoT will also engender a much closer enterprise-consumer relationship. IoT home devices and wearables are already common, but the next decades will see transformative innovations in the human-computer interface and bio enhancement. Consider that the UK government has implicitly recognized Neil Harbisson as the world's first cyborg, and Neuralink — essentially a creator of IoT devices — hopes to complete its first human trial by 2031.

The bio-integrated IoT devices that will underpin future developments in medical IoT constitute a particularly interesting case. As medical IoT advances, implanted devices will require a unique type of connectivity and data center management, with the possibility of specialized networks for

augmented humans. What happens, for example, if somebody's insulin pump or pacemaker gets hacked? Security literally becomes a matter of life and death.

The innovation stack creates the foundation for mass adoption by equipping enterprises with the tools and infrastructure they need to cater to complex IoT requirements. Equally important is the fact that enterprises will ultimately be responsible for the safety and management of sensitive data, which itself represents a significant technical undertaking.

Massive, Instant, and Ubiquitous Connectivity

The emergence of an always-connected, autonomous, and robotic society demands unparalleled bandwidth and instant, ubiquitous connectivity — universal in the sense that it's both global and extraterrestrial. While there are obstacles to a universal network, some of them governmental and some related to financial viability, ubiquity looms as an imminent reality

LEO constellations will supplement terrestrial networks to deliver high-speed broadband to remote areas at ever-increasing speeds, with non-terrestrial networks responsible for mission-critical connectivity. Low-latency lunar and Martian networks will also be key to remote space operations and scientific research.

NASA's Artemis program is perhaps the best-known initiative to establish a base on the moon, but there are others, like the International Lunar Research Station and the European Space Agency Moon Village. Some have heralded China's lunar ambitions as marking the beginning of a new "space cold war" with the US.

There are several notable current examples of the move towards a ubiquitous network. T-Mobile has partnered with Starlink to provide US-wide connectivity by combining SpaceX's low Earth orbit satellites with T-Mobile's 5G wireless network. In addition, AST SpaceMobile is connecting ordinary phones to satellites, and Commstar is building lunar infrastructure to explore IIoT mining and colonization opportunities.

Quantum computing and networking will play a central role in universal connectivity by making it possible to transfer information at superluminal speeds. IonQ already offers accessible quantum cloud computing with enhanced capacity for problem-solving, scale, and speed, and is collaborating with the US Air Force. Similarly, post-quantum cryptography will render current encryption standards obsolete, and quantum key distribution will provide unbreakable encryption for sensitive data transmission.

Teleportation is happening with increasing degrees of accuracy. In 2017, China beamed up a quantum state into orbit. Earlier this year, a team at the University of Science and Technology of China achieved a quantum teleportation fidelity (or accuracy) of around 90 percent using hybrid quantum entanglement. The move from photons to protons is underway.

Quantum computing and networking will inevitably form the basis of future enterprise connectivity, and there are many ongoing research initiatives. EPB, Aliro, and Quibtek pioneered the first commercially available quantum network in the US, and the Quantum Internet Alliance is in the process of building a quantum internet prototype in Europe.

Connectivity providers are uniquely positioned to take advantage of the quantum opportunity, using existing service packages and relationships to gradually open the door to this transformative technology for enterprises.

Immersive and Mixed Reality (XR)

Extended reality (XR) will continue to integrate smoothly with natural reality, driven by enterprise adoption in the initial stages. Mixed reality, in particular, is changing how people and businesses interact with the physical world, allowing for control, modification, and interaction of objects through a virtual interface. "Mixed reality is the next natural evolution of the human-

computer interface," says Tom Cheesewright, a leading futurist and author of *Future-Proof Your Business* who spoke to *Pipeline Magazine*. "We complete that evolution when we allow machines to interact with us in the physical domain through mixed reality. It will enable the richest and most intuitive human-computer experiences we have ever known, until the brain-computer interface matures, at least."

There are many existing applications of XR across customer support, training, collaboration, rapid prototyping, technician support, and research and development. To name just a few specific examples, XR allows for spatial visualization, real-time remote assistance, the simulation of complex scenarios for hands-on training, and the creation of interactive 3D models that speed up design iterations. The metaverse is perhaps the most prominent consumer case.

A variety of enterprise-focused products, such as Google Proto — just one instance of a holographic device — are already commercially available. Gridraster offers immersive AR training environments that use spatial computing for interaction with overlaid digital content in the physical world. Similarly, the NASA JSC Virtual Reality Lab (VRL) provides simulation-based extravehicular activity (EVA) and robotics operation training to astronauts. Gridraster has also pioneered XR and AI combined tech — called immersive intelligence — for manufacturing and engineering error identification and task planning, among other applications.

It's important to see XR devices in a broader IoT context. The sensors, environments, and wearable devices on which XR relies require advanced infrastructure. For technology and network providers, the focus should be on out-of-the-box interoperable solutions for IoT integration and model content distribution, along with necessary high-speed connectivity. For enterprises, the opportunity is to strengthen vast swathes of day-to-day operations through the blending of the virtual and physical.

Social-Ethical Frameworks

Views on robot rights are mixed. Yet this hasn't prevented murmurings from legislative bodies about the possibility of rights-based regulations, with the European Parliament discussing the (admittedly tentative) idea of "electronic personhood." There are also serious ethical discussions about the possibility living brain organoid computers becoming sentient.

More immediately, the European Union's (EU) Artificial Intelligence (AI) Act took effect on August 1, 2024. It either wholly or partially bans certain AI applications like social scoring, predictive policing, and real-time biometric identification in public spaces.

The point here is that regulatory frameworks will set the overarching scope of technological evolution, or at least contribute in a significant way. A web of regulation needs to be contented and complied with. Providers must account for it. The maelstrom of actual and proposed legislation — from an "AI Bill of Rights" to pressure to ban killer robots — will only continue to grow fiercer.

Regulation can and does stifle innovation, and providers and enterprises will be forced to engage in a balancing act between consumer protection and change. In a similar vein, failure to comply is becoming more treacherous, with hefty fines ever-looming, especially where mission-critical infrastructure is involved. It's no longer an option but a necessity. For the consumer and business, data protection is paramount. What's more, security is an all-encompassing vertical layer in the innovation stack.

Companies able to navigate complex regulations and ethical considerations to drive true innovation will benefit most from the opportunities of the next two decades. Legislation is emerging quickly, so enterprises need to be ahead of the curve (making tweaks as more information becomes available). Similarly, ethics will likely become a crucial part of value propositions at both the corporate and consumer levels. Within the constraints of regulation, social evolution is largely in the hands of the enterprise.

Embracing the Innovation Stack

To thrive in the coming decades, providers and enterprises must embrace an intricate and multifaceted innovation stack. They also need to commit to navigating regulatory and ethical constraints in a way that doesn't stifle transformation.

The innovation stack is the lens by which you can see and prepare for the future. It is the basis for making technology decisions that will pay significant dividends. For the service provider, this means bundling integrated connectivity packages that cater to complex enterprise requirements. For the technology developer, it is about building each layer of the stack and determining where they fit within it, all while keeping the broad scope of change in mind. For the consumer-facing enterprise, the task is to manage the shift to full autonomy and create new offerings on top of the stack.

The fully autonomous enterprise will drive mass use cases. It is impossible to say exactly what the world of 2050 will look like, but it will be a vastly different place to the world of today. Change is already noticeable. And it's gaining traction at an exponential rate.

Networks of connected devices are communicating and working together at ever-increasing speeds, and they will soon be components of a ubiquitous network extending beyond the planet. XR will bridge the physical and digital worlds, with governments and regulatory bodies shaping the direction of technological evolution. There is more opportunity for profound innovation than at any other point in human history. Now is the time to prepare.