In-Depth Desk Research Summary

Surface Phase • Deeper Insights

UKaid from the British people

FRONTIER TECH HUB

Futures Cycle
Mar - Jun 2023

Between now and 2030, what are the most exciting frontier technologies from a development perspective and how might the next seven years of technological change impact the way we do development?

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What are we trying to achieve with this process?

The future is obviously unknowable. But we believe that by imagining and exploring potential futures we will be better placed to develop strategies and take action to encourage the positive and avoid the negative.

We look at signals and drivers of change in the present, then project forward to speculate on where they might lead.

During this exploration, we're asking: what are the emerging technologies that will be most transformational for development over the next 7 years?

Development is the lens we use to look at these frontier technologies. As the focus of development shifts and evolves, we'll need to support and work with different technologies to meet our goals.

Finally, our secondary focus is on challenges that are emerging right now. We're curious about how both the development landscape is changing in a way that may affect the application and demand for tech.

Elements of the research

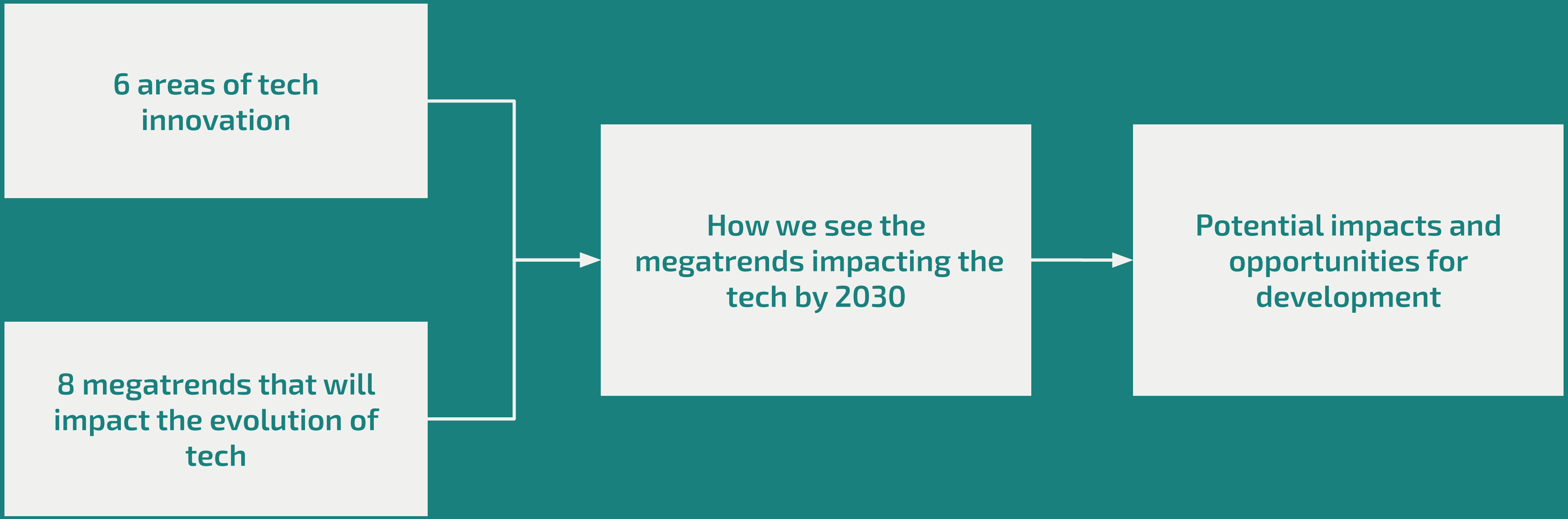
This presentation will take you through what we've discovered so far, in terms of:

- The **6 areas of innovation** we see emerging over the next 7 years
- The **8 megatrends** that are shaping the future of technology right now
- How these megatrends will **impact emerging technologies** by 2030
- Which of these technologies are the most exciting from a **development perspective**

How the 4 elements fit together

We've processed a wide range of trend reports, articles, books, and conducted interviews with experts to arrive at a good understanding of where things are heading.

To make sense of this we've condensed the research into some digestible areas of focus. This is how they flow together.



The 6 areas of tech innovation emerging over the next 7 years

Critical enablers

Foundational technologies on which innovations are built and new opportunities are created.

Governance & transparency

Providing protection, enabling engagement and creating trust at both a personal and governmental level.

Smarter & more connected

Tool and systems that allow the physical world to connect to the digital world.

Faster & more productive

Delivering efficiency and speed through more intelligent and autonomous tools.

Extending into virtual worlds

Methods of creating and exploring digital environments that enhance our physical spaces.

Adapting this world

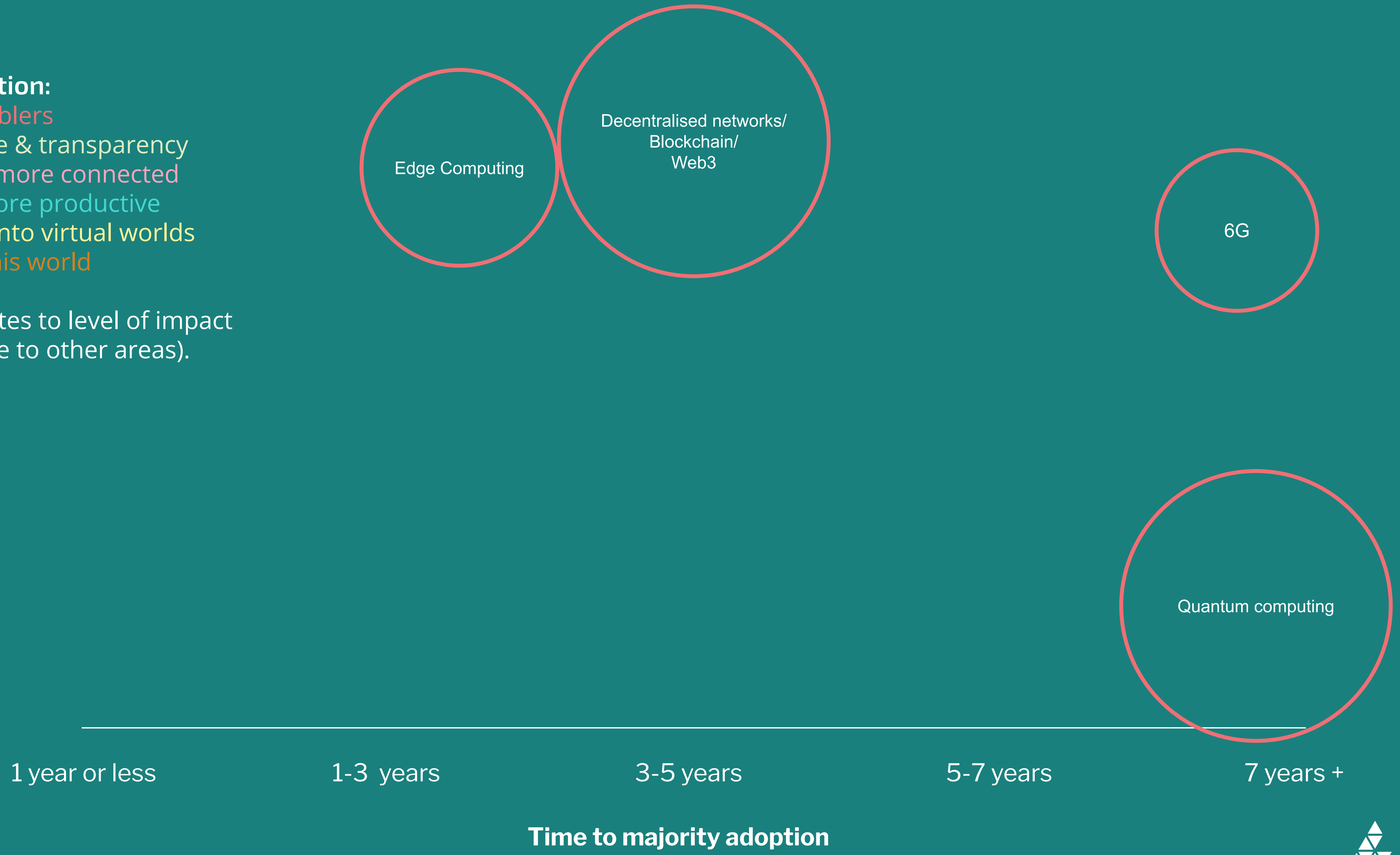
Applying engineering principles to develop new biological devices or redesigning existing systems found in nature.

When that tech is likely to reach wide adoption

Areas of innovation:

- Critical enablers
- Governance & transparency
- Smarter & more connected
- Faster & more productive
- Extending into virtual worlds
- Adapting this world

Size of bubble rates to level of impact expected (relative to other areas).



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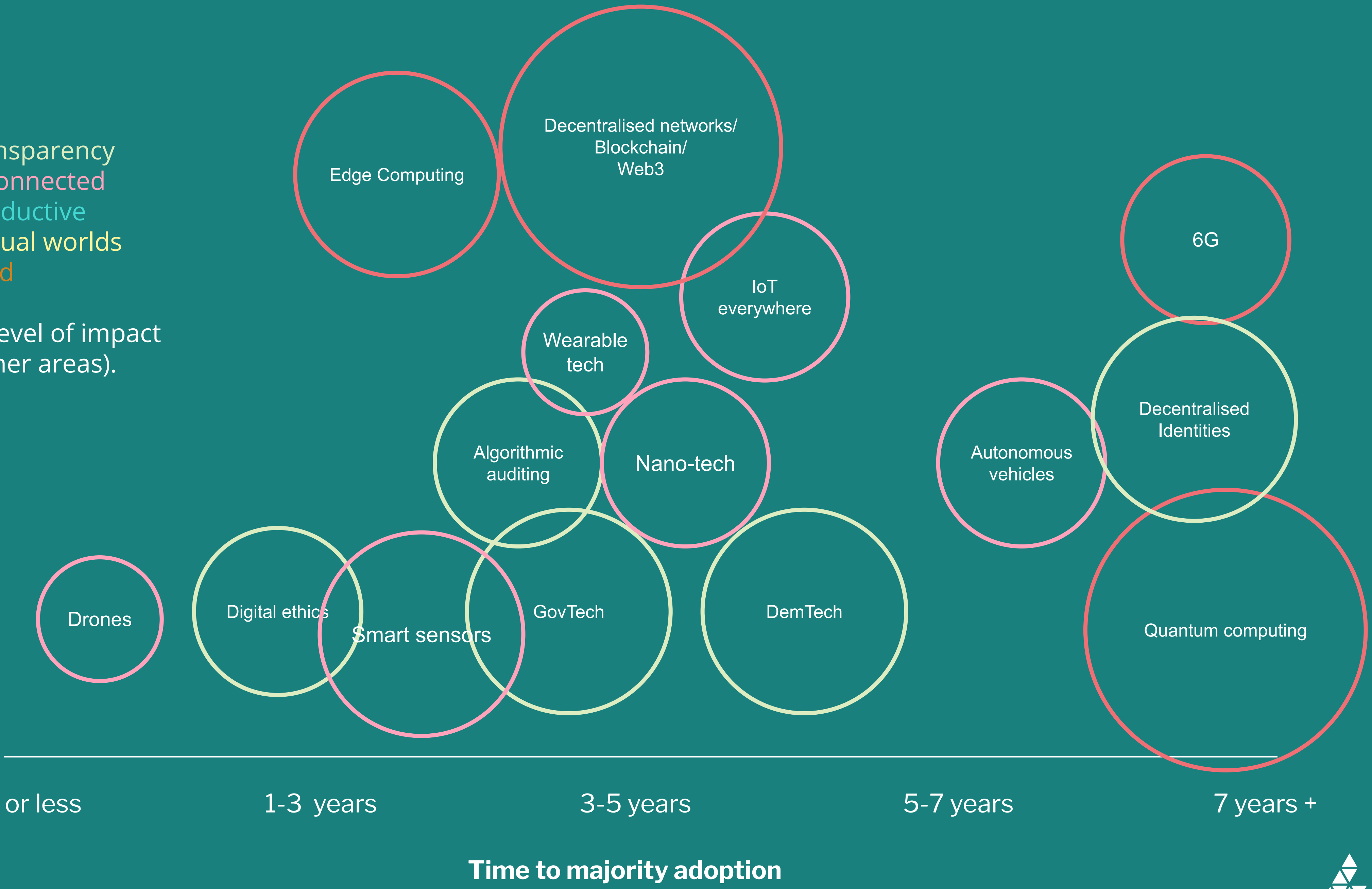

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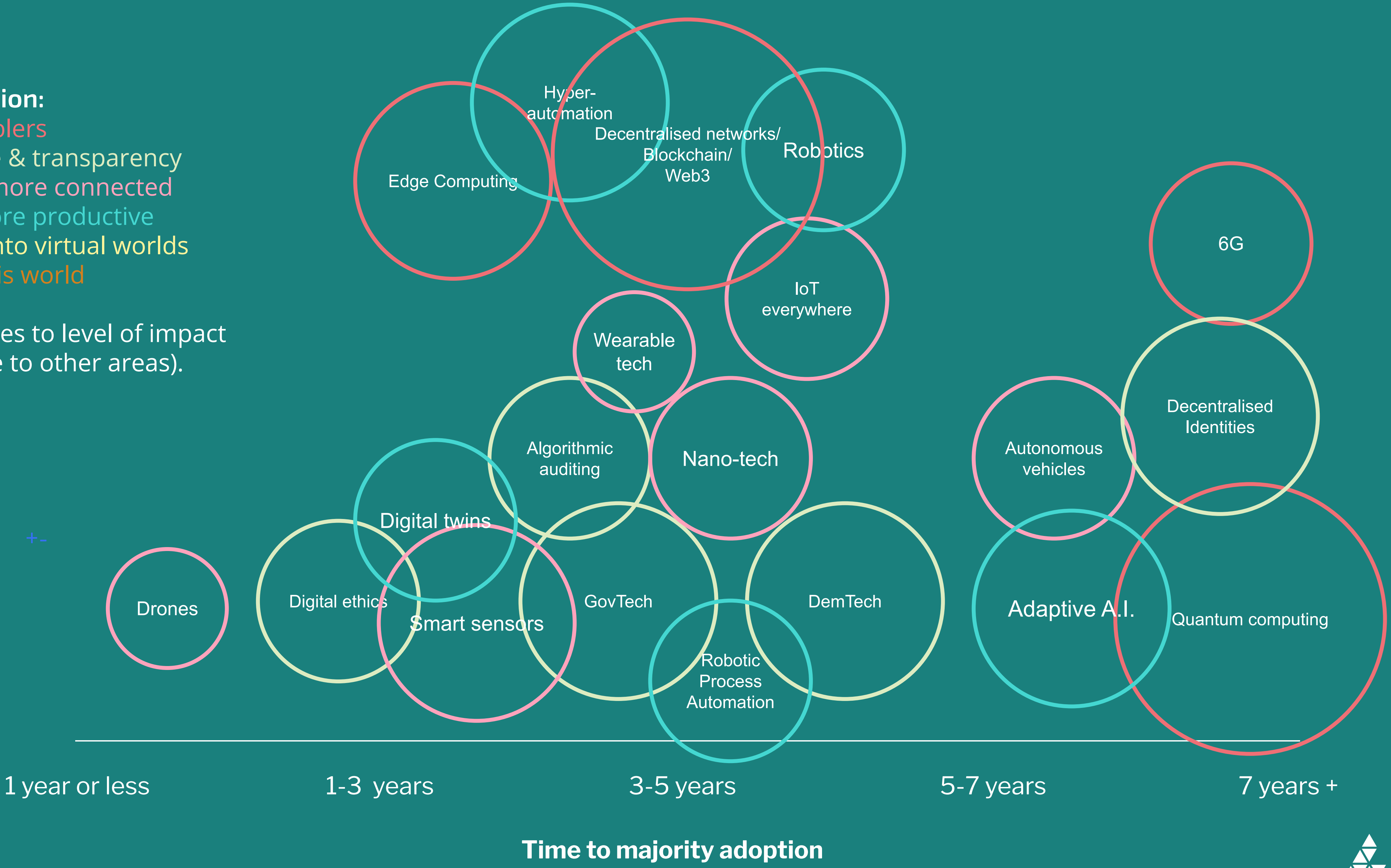

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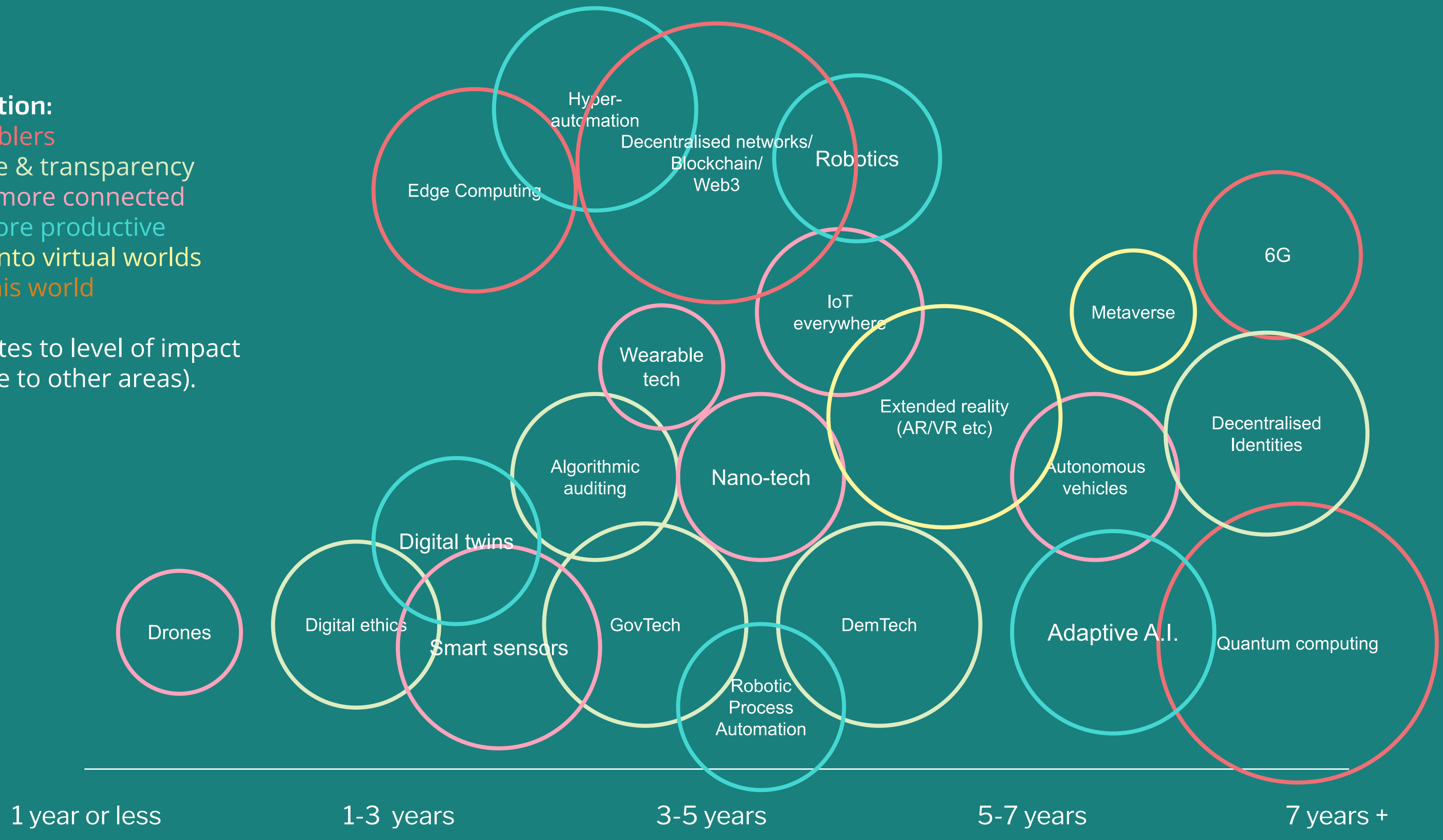

Time to majority adoption

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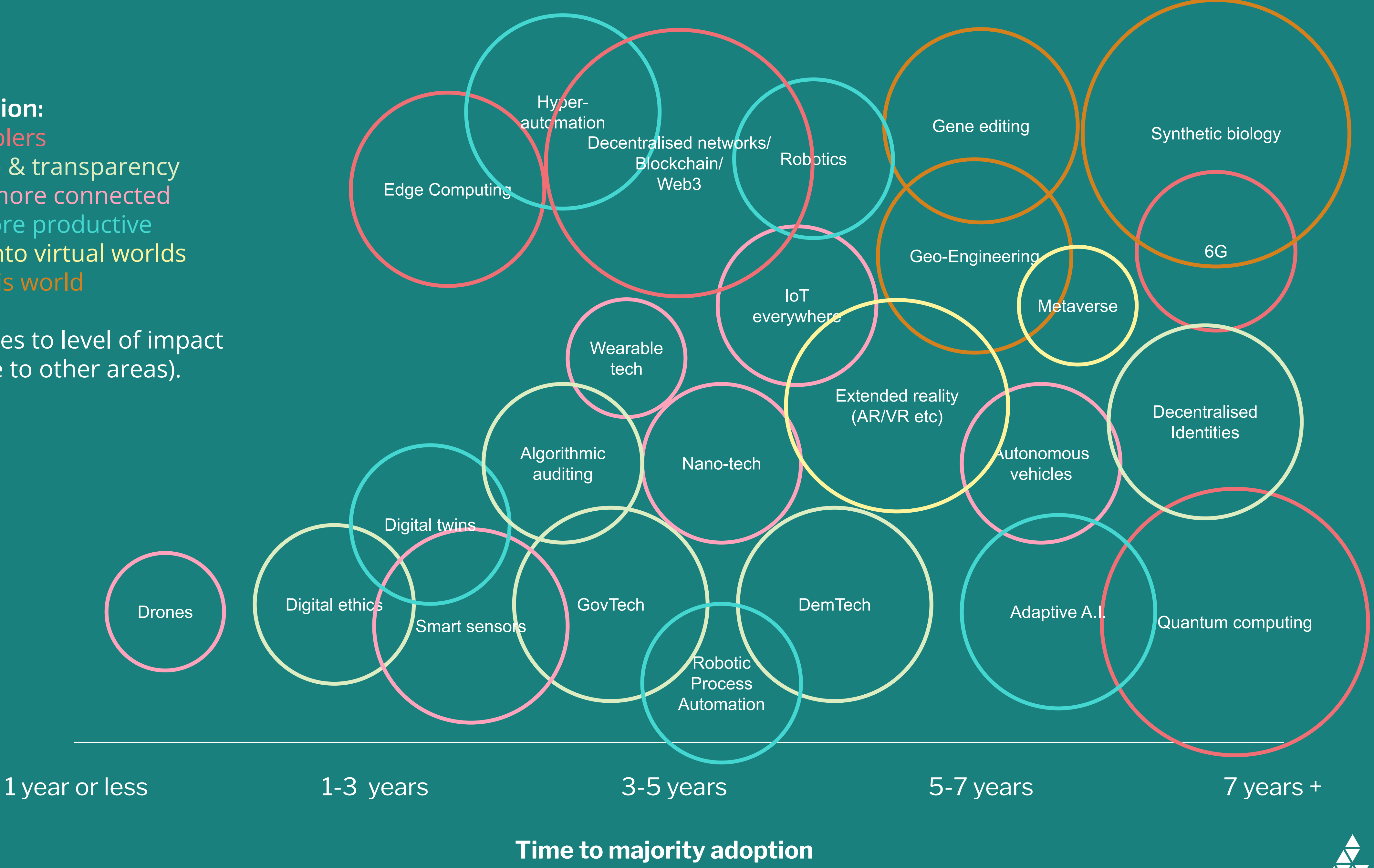


8 megatrends that will impact how those technologies evolve

The 8 megatrends that will impact the evolution of technology over the next 7 years

Exponential development

Innovations are building on each other in a positive feedback loop, resulting in an accelerating pace of improvement. Moore's law is no longer confined to memory capacity.

Convergence

As different technologies are being used in combination, complementary functions mean that technologies are combining to overcome limitations associated with each independently.

Increased integration

Increasingly technologies are considered as tools to integrate the digital into the physical world. This immersion is facilitating a fundamentally different way of interacting with the internet.

Hyper-connectivity

By 2030, 30 billion devices will be connected into the Internet of Things (half of those will connect in the next year), driving this is the rapid expansion of 5G coverage, allowing for speedier, more stable connectivity.

Sustainable technology

Society's growing environmental concerns and expectations are forcing organisations to utilise digital technology and data to drive sustainability goals and drive transparent supply chains.

Cyber-resilience

As tech infrastructures grow so do the risks of collapse by accident or deliberate attack. Governments and regulators are leading the drive towards more secure tech ecosystems via agreed standards.

Digital trust

As work practices and user expectations shift a proactive focus is required around tech ethics, resilience & open business models; and there's an increasing emphasis on shared ownership, assets and development.

National digital infrastructures

Digital technology architectures are seen as part of critical national infrastructure and increasingly countries are creating national assets that are enabled with advanced digital technology.

Specific technologies and initiatives that relate to those megatrends

Exponential development

EDGE COMPUTING

DECENTRALISED NETWORKS

QUANTUM COMPUTING

Convergence

AI + ROBOTICS

BLOCKCHAIN + IoT

AR + AUTONOMOUS VEHICLES

Increased integration

METAVERSE

IoT

WEARABLE TECH

Hyper-connectivity

5G

6G

'IoT EVERYWHERE'

Sustainable technology

CARBON NEUTRAL TECH

WEF's TWIN TRANSITION

ENVIRONMENTAL MONITORING

Cyber-resilience

EU CYBER RESILIENCE ACT

DIGITAL IMMUNE SYSTEMS

CLOUD SECURITY

Digital trust

EU DIGITAL MARKETS ACT

DEMTECH

ALGORITHMIC AUDITING

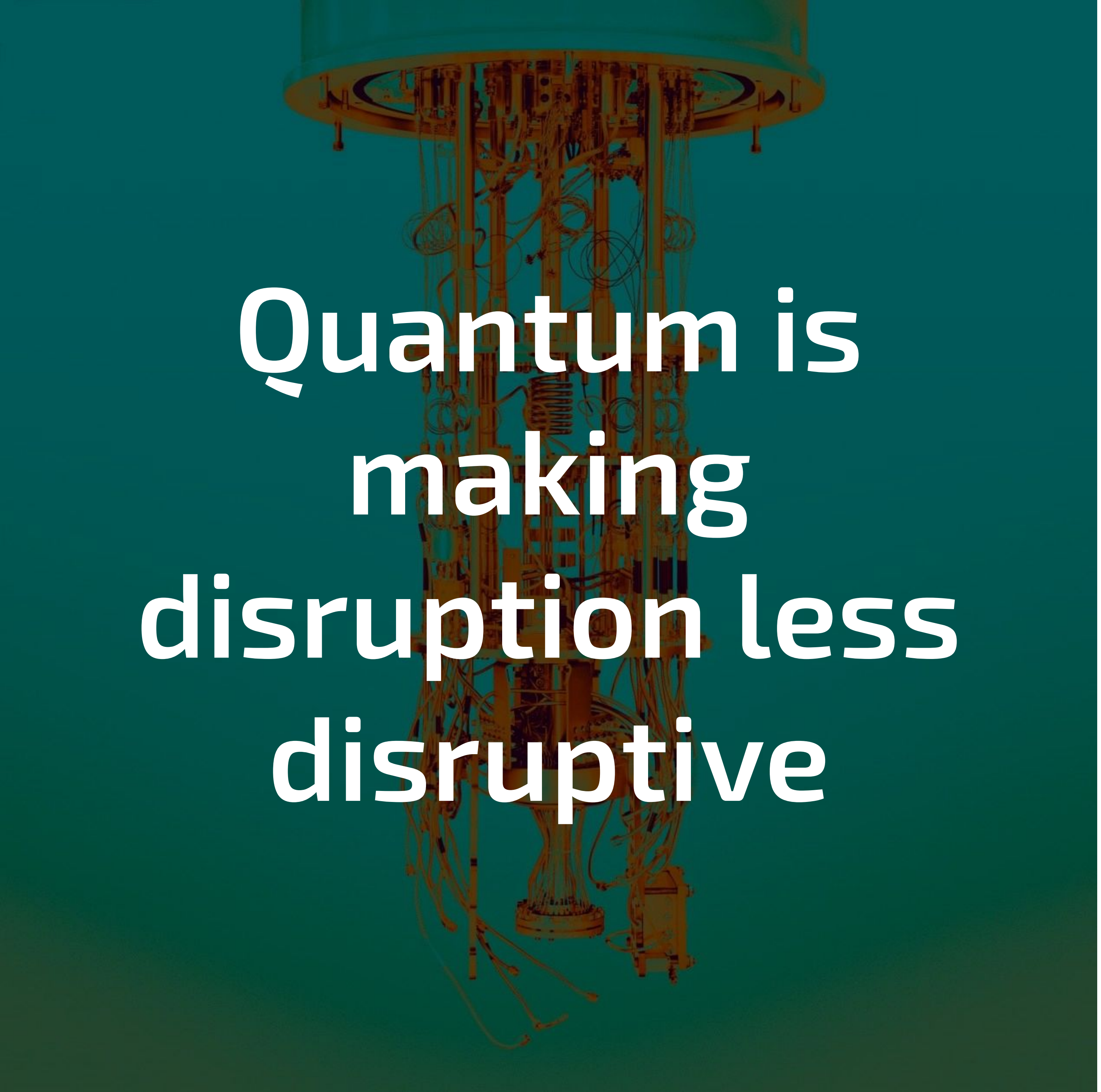
National digital infrastructures

UK'S CYBER-PHYSICAL INFRASTRUCTURE VISION

CENTRAL BANK DIGITAL CURRENCIES

DIGITAL IDENTITY SYSTEMS

How we see these frontier technologies evolving by 2030



Quantum is making disruption less disruptive

Critical enablers in 2030

Although the use of subatomic particles to process and store information cannot yet be called a truly mainstream technology, the past few years have seen a huge amount of R&D investment (from both governments and private corporations) and this has driven a number of significant leaps forward.

Following its role in the development of Covid-19 vaccines, quantum computing's ability to solve complex problems through parallel processing has powered breakthroughs in genome sequencing, the discovery of new drugs and materials, as well as the creation of vaccines and medicines (this pattern is being mirrored in the financial, insurance and infosec industries primarily).

However, there is also value being realised in bringing the power of quantum computing to bear on the extensive data streams and complex processes created by the mainstreaming of AI and IoT. Again, healthcare has led the way here as it has strived to incorporate other emerging and disruptive technologies into its existing processes and structures in order to deal with unpredicted health hazards.

As a result quantum processing is now being successfully rolled out at an institutional layer to drive organisational decision-making and solve operational challenges at speed and at scale, although the ethical and legislative issues surrounding this paradigm shift are still being discussed.

Biology happens by design

Adapting the real world in 2030

Synthetic biology (or syn-bio) is now a manufacturing paradigm. The construction or modification of biological systems to create and improve processes and products, means that biological systems can now perform tasks or functions not found in nature.

Thanks to developments in molecular biology, genomics, biochemistry and computer science; along with emerging tech such as gene editing tools, DNA synthesis, and 3D bioprinting, syn-bio has significantly disrupted multiple industries including healthcare, chemicals, textiles, medical devices, and electronics.

Bioproduction has also had a significant impact on the realm of geo-engineering as transformative technologies are brought to bear on the acute global environmental crisis caused by overpopulation, loss of biodiversity, greenhouse gas emissions and pollution.

Advances in systems-guided metabolic engineering and the integration of computational and experimental approaches in the field has led to innovations in the remediation of environmental damage and pollution control.

However, the area remains controversial and divisive and this has hampered efforts to effectively and consistently regulate how these new technologies are employed for both bioproduction and environmental management.

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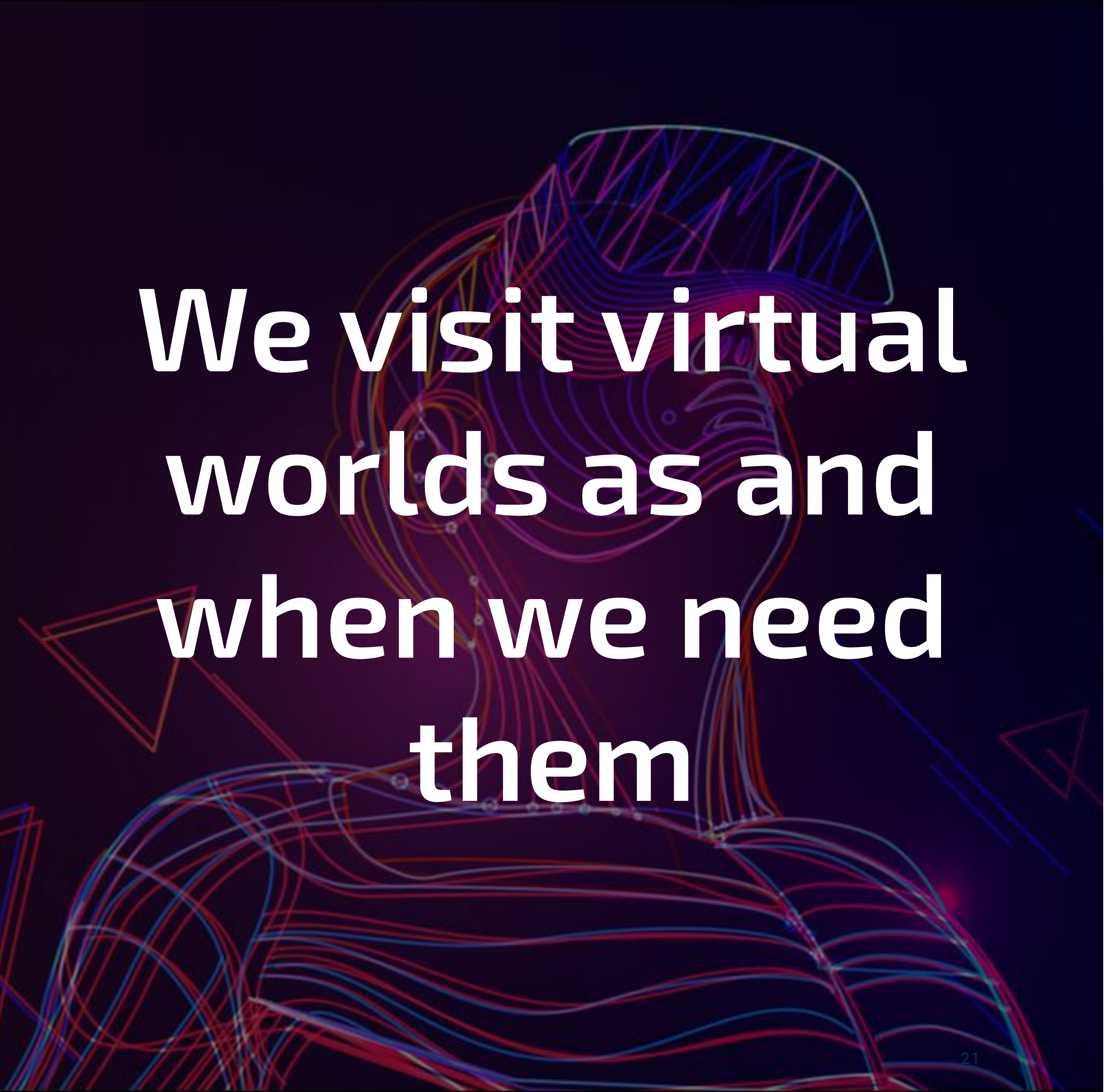

Extending into virtual worlds in 2030

By 2030, the hype of the Metaverse has yet to be realised in any genuine sense, and the promise of mass migration to virtual environments still seems to be a distant dream.

However, over the last few years, there have been significant advancements in both extended reality (XR) and spatial computing, the most significant of which has been the widespread integration of these technologies into our everyday devices such as smartphones, tablets, and wearables. This has enabled a wider range of use cases beyond those aimed at entertainment and gaming; driving advancements in areas such as remote collaboration, and product visualisation.

XR tech is beginning to have an impact on healthcare, with AR devices now being used for medical training, patient education, and telemedicine and virtual rehabilitation.

In manufacturing, spatial computing is used to optimise design, prototyping, and assembly. Engineers and designers use VR to create and test products in virtual environments before building physical prototypes. Mixed Reality environments are used for assembly and maintenance tasks, allowing workers to see digital instructions overlaid onto physical objects.

In educational settings, virtual and augmented realities are starting to provide immersive, interactive learning experiences, virtual field trips and remote learning.

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Artificial intelligence has learned to learn

Faster & more productive in 2030

Robotic automation has combined with AI to drive hyperautomation, meaning that bots can now perform incredibly complex automation with unerring accuracy, exceptional speed and efficiency. As increasingly sophisticated 'digital twins' (virtual replicas of physical object or systems) allow for real time simulations of entire processes, integrated human/robot workforces have evolved capable of delivering a new wave of growth and efficiency, so organisations find themselves able to respond more quickly to changing market conditions, reduce errors, and improve compliance with regulations.

This widespread use of smart, automated systems has created a need for systems that can access and react to data in real time. In order to handle the never-ending flow of increasingly complex data, machine learning has evolved again; moving from a 'static' model to an adaptive one powered by autonomous learning.

As AI systems have become more adept at dynamically incorporating new data from their operating environment they are able to generate more accurate insights on a real-time basis, and this has had an impact far beyond the confines of 'driverless cars'.

Within healthcare, clinical recommendations have been optimised and personalised treatment plans have been developed. In education, personalised learning experiences are delivered based on individual learning styles and abilities. While in the finance and banking industry, adaptive AI's ability to learn from past examples and adapt to new patterns of behavior as they emerge is put to increasingly effective use in fraud detection.

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The Internet of Things is much more sensitive

Smarter & more connected in 2030

While the last seven years has seen a huge increase in the number of ‘connected devices’ (thanks to decreasing costs, widespread wireless connectivity and increasingly small transmitters and receivers) it is the accuracy, sensitivity, intelligence and cooperablity of these devices that has driven the greatest innovations.

The use of increasingly sophisticated, small, low-powered Microelectromechanical sensors has led to an extended network of autonomous sensors, that require no input from a human operator and which can run efficiently and reliably without constant monitoring or maintenance.

Advancements in the field of sensor fusion have allowed for data from multiple sensors to be easily combined, delivering more complex detections and improving the accuracy, reliability, and completeness of the data; as well as powering the extension of wireless sensor networks, which allow sensors to communicate with each other and other devices.

While edge computing has meant data can be collected and analysed quickly and at scale, AI’s impact on sensor technology has been even greater; allowing for patterns to be detected and predictions to be made. As a result we have a much more complete picture of our behaviours and actions and their impact on the environment around us.

Radical transparency has become the new norm

Governance and transparency in 2030

With AI and machine learning now underpinning so many of our industries, services and products, there has arisen a parallel need to ensure that these automated systems do not perpetuate bias, discrimination or other harmful behaviours.

Algorithmic auditing is now used extensively across sectors such as finance, healthcare, and law, to examine the inputs, processes, and outputs of automated decision-making systems.

As the standards, procedures, policies and guidance in this area have developed, a number of 'govtech' startups have emerged to create an external accountability ecosystem to provide guidance for the development of automated decision-making systems.

As these new architectures, infrastructures, skills and policies are put in place, the ecosystem has spread beyond algorithmic analysis to create a new era of 'open government' powered by initiatives like 'Rules as Code' (machine-consumable versions of some types of legislation), sensor registers and IoT regulation (developed to create trust in 'smart cities').

Similarly, the success of the 'Declaration on Building Trust and Reinforcing Democracy' has seen a huge surge in 'DemTech' and ushered in dramatic innovations across public engagement, and participatory processes.

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The impact these trends could have on the way we do development

How exciting and impactful are these technologies when applied to the world of development?

Scope: What range of technologies and potential innovations does this cluster contain? Is it limited to very specific technologies or is there a wider ecosystem of tools?

Impact: How many specific areas of development (and the related challenges) could these technologies be applied to?

Actionability: How easy or difficult might it be to apply these technologies to the relevant development challenges. How useful will that application be?

Time and trust: How long will it take for these technologies to reach the maturity required to and how accepting will the public be of these disruptive technoligies?

Smarter & More Connected

How exciting and impactful are technologies such as sensors, the IoT, nanotech and wearables?

Scope: This is undoubtedly one of the most exciting and promising set of frontier technologies from a development perspective as it encompasses a diverse range of related technologies, that are underpinned by their 'network functionality'. The inherent value of connected devices comes from their shared relationships with a wider ecosystem, and so the whole is far greater than the sum of the parts.

Impact: The range of development challenges these technologies can be applied to is endless as they largely serve the foundational purpose of data collection and transfer. In 2023, the issue is that there is still a large amount of human interaction required to analyse and action that data and the introduction of more data into systems can create more problems than it solves. However…

Actionability: Over the next few years we will see these devices becomes 'smarter', that is they will become increasingly autonomous so their function goes far beyond collecting data and begins to incorporate data exploration, information processing, pattern recognition, data modeling etc. By 2030 the use of AI in connected devices will allow them to 'learn' as well as 'listen' and 'understand'. Combine that with the cumulative power of the growing (and increasingly communicative) network and it's clear that there is huge potential here.

Time and trust: Sensors are a well understood and largely trusted technology that are evolving rapidly and don't require a significant leap to become truly useful. However there is some reliance on the evolution of AI technology and complex ethical conversations to be had around, for example, commercial autonomous vehicles and the use of nanotechnology in products such as food.

Examples from a development perspective

Smart Grids: The US government agency has just launched a call for proposals under the Off-Grid Energy Challenge. This initiative aims to increase electricity generation for unserved/underserved African communities through sustainable business model solutions.

Smarter networks: a temporary cellular network mounted on drones and easy to deploy that could make a major difference to first responders by enabling the network to track them wherever they go, outdoors or indoor, regardless of terrain.

Smarter people: Development of a low-power, long-term sweat sensor patch that imitates sensory neurons that can be used to detect acute diseases or their precursors, such as nocturnal hypoglycemic shock and heart attack

Faster & More Productive

How exciting and impactful are technologies such as robotics, digital twins and hyperautomation?

Scope: Similarly to the 'Smart & More Connected' group, the emerging tech in this area is often applied on a system-wide basis, increasing their relative value. Many of them are also replicable over multiple industries and development areas, giving them repeat value.

Impact: The most common use case for these technologies is the optimisation of existing systems and processes. While 'faster and more efficient' has an obvious gain in a purely commercial setting, it may be less obvious in a development context. However, any improvement across logistics or operations will likely create value 'down chain', and there is potential here for large scale industrial innovations to be applied in a more tactical, focused fashion. Finally, the application of these technologies in the advancement of the development sector itself shouldn't be ignored (innovation that drives more efficient innovation).

Actionability: These technologies are, by definition, incredibly practical. It should be noted though, that in order to create 'system wide' value, relatively complex and holistic execution will likely be required, and we do not see that changing drastically in the next seven years. On a similar note, application of these kinds of systems usually entails the convergence and synergy of multiple emerging technologies. There are few 'quick fixes' here.

Time and trust: Of all the technologies we've looked at, these are the ones that are most likely to evolve with the greatest velocity as they are driven by widespread, commonly-held private sector interests. Many of the innovations will likely cross over to majority adoption within five years.

Topline examples of where this technology could be applies

An automated 3D printing tool used to build life-size architectural forms such as houses, bridges, or other outdoor furniture and decoration. The blueprint or design of the structure is created virtually through specialized software, and the printing process needs human monitoring.

A machine-learning algorithm designed to prepare the entire supply chain to ship items to geographical areas where end-users are expected to place an order. Overall, the algorithm predicts the next order and conditions the logistic framework based on previous purchasing activity. Products are usually stored closer to potential customers for faster shipping, or the final destination can be defined en route, eliminating the need for secondary storage.

Vertical farming: Towers, high buildings, or shipping containers are used as urban gardens or greenhouses for in-city or near-city farming. The facility is mostly automated, and the vertically stacked movable trays of produce are nurtured with the right amount of light, water, and nutrients at the optimal temperature and humidity.

Governance & transparency

How exciting and impactful are technologies surrounding GovTech, DemTech, digital ethics and transparency?

Scope: While this cluster does not represent a specific type of emerging technology, it does represent the evolution of governance, legislation and guidance surrounding those emerging technologies, as well as the effectiveness and efficiency of a government's services and operations and the empowerment of its citizens. So while, on one hand, the scope here could be said to be limited to specific areas like algorithmic auditing and civic engagement apps, it could also be said to encompass almost every aspect of our daily lives.

Impact: Again, if we look at this from the viewpoint of impact on specific development challenges, then the only direct impact would come from strengthening and improving institutions. However the real impact in this area comes from the ability to shape the future implementation of all the other technologies we have looked at, creating development-focused frameworks for them to operate in and designing how they are brought to bear on the entire range of development goals.

Actionability: The key risks with this set of innovations are that it becomes too difficult to incorporate guidance and frameworks into actionable tools and real world applications; and that any progress is hampered by it's cross-cutting and interdisciplinary nature. For example, most GovTech and DemTech initiatives will involve big data analytics, cloud computing, AI and and open data at the very least; plus they will require involvement from various domains, including technology, governance, policy-making, and user experience design.

Time and trust: Much of the innovation in this area is well developed and the pace is picking up, especially around areas of digital ethics. However, while we've seen In high levels of trust and acceptance in some countries (such as Estonia and Singapore), there is still a high degree of skepticism elsewhere, particularly in the wake of concerns about data privacy and security.

Topline examples of where this technology could be applies

Quadratic voting: Plural Voting (also known as Quadratic Voting or QV) is a redesigned voting method reflecting the intensity of people's preferences in collective decisions. It greatly mitigates tyranny-of-the-majority and factional control problems.

SOL is a GovTech solution for community-level procurements that was piloted in selected projects in Brazil to show the potential to increase the efficiency, transparency, and governance of the procurement process. An app facilitated the connection between community associations and their suppliers and automated the full procurement process.

Last year, USAID's Equitable AI Challenge sought to support approaches that increase the accountability and transparency of AI systems in global development contexts, in order to produce more gender-equitable results. Five proposals received grant awards including a due diligence model that considers gender-inequity issues when designing inclusive finance algorithms and a tool that uses machine learning to build gender-differentiated credit-scoring algorithms.

Adapting This World

How exciting and impactful are technologies such as synthetic biology, gene editing and geo-engineering?

Scope: On one hand, the potential scope here is vast. After all, these are the fundamental building blocks of the physical world we are dealing with. On the other hand, for that very same reason, any application of this kind of technology tends to be highly targeted and specific. There is little repeat or transferable value in this area

Impact: From a development perspective, the potential impact here is, again, huge. Even just from a geo-engineering standpoint there are multiple applications across carbon capture, bioenergy production, climate-resistant crops and bio-remediation. There are also many obvious and far-reaching applications across sanitation, sustainable cities, responsible industry and agriculture.

Actionability: While areas like synthetic biology and biomanufacturing are expected to grow rapidly in the next decade, the opportunity to apply these technologies at scale in any meaningful way will depend on a complex set of wide-ranging factors beyond technological breakthroughs. The biggest of these is the resources required (there is no 'quick and dirty' bioengineering solution). But there are also factors such as regulatory frameworks and complex intellectual property issues around patent disputes and licensing agreements to consider.

Time and trust: Many of these technologies are still in their infancy and are extremely expensive and time-consuming to produce and bring to market. The debate around the ethics and governance in this area is similarly evolving, complex and heated.

Topline examples of where this technology could be applies

Genetically-modified crops with a herbicide-tolerant trait designed to improve environmental properties without the onus of heavy chemicals. This solution counteracts the herbicide-resistant weed problem present in many agronomic cropping systems. Species of soybean, cotton, corn, and canola are being developed with resistance to additional herbicide chemistries, including dicamba and 2,4-D in soy.

Autonomic self-healing polymers are a smart material that is able to repair itself when damaged without the need for manual intervention. The self-healing capabilities can be achieved by embedding certain polymers with microcapsules containing a self-healing material, such as Dicyclopentadiene (DCPD). The self-healing process takes place by capillary action when the microcapsule shell wall is ruptured in case of eventual cracks, scratches, or other damages.

Extending into virtual worlds

How exciting and impactful are technologies surrounding AR, VR, and the metaverse?

Scope: Compared to the other areas we have considered, this cluster of frontier technologies is relatively limited in its scope, simply because it is less systemic in nature and more focused in its application. This is only true, of course, if we accept that the metaverse will not become the defining technological paradigm of the next ten years, as some have predicted. Although, even if that does come to pass, we would suggest that, from a purely development perspective. the potential will be limited, as least in the near term.

Impact: In the past, 'extended reality' tools have often been seen as solutions looking for a problem, and it's true to say that, outside of gaming and entertainment there have been few notable applications. Although there are undoubtedly more practical and consequential virtual tools being developed right now, they are largely focused on reducing error and expense in highly complex systems and processes. Outside of very basic implementations (such as remote collaboration) it's hard to see where this kind of benefit could be readily applied at scale in a development context.

Actionability: Many applications of extended reality depend on predictable, replicable environments and consistent behaviours. Whether it's directed at closing the space between people or creating virtual models of real world objects, XR is much harder to implement when it is dealing with the unknown and the unpredictable. As many development environments are, by their very nature, unpredictable and ever-changing, it's hard to see where this kind of technology could be implemented effectively and efficiently.

Time and trust: There are few issues of trust surrounding these technologies, although public perception is still very much focused on their entertainment value. Although the field is developing quickly, the hardware is still expensive and 'mass market' experiences are at least five years away from becoming a reality.

Topline examples of where this technology could be applies

AR-enabled headsets and AR software allow surgeons to view 3D images as true 3D objects in space. This allows them to more naturally interact with content. For example, the surgeon would be able to tilt their head or walk around an actual 3D reconstruction of the patient's anatomical structures, reducing the need for cumbersome manipulations on a monitor, enabling quicker and more intuitive understanding of potential surgical plans and procedures, and more generally reducing the cognitive load required to process the visual information.

In 2022 CGI, a provider of IT and business consulting services, announced the launch of 'CGI Sense360', acloud-based, smart analytics platform that utilizes augmented reality (AR) to give emergency responders holistic and accurate situational awareness in the event of a disaster.

Veative Labs in India, is a provider of VR education and learning simulations for schools and industry. The Veative Labs STEM library contains over 500 educational modules, and a portion of its content library is open-sourced and accessible via WebXr (an alternative method of accessing content directly via the web and thus facilitating distribution).

Critical Enablers

How exciting and impactful are technologies surrounding quantum computing, decentralised networks, edge computing and next-generation wireless networks?

Scope: Obviously, the potential scope inherent here is huge, as these areas represent the foundational structures of the next technological era. Quantum computing or Web3 alone are set to be hugely transformational not just in the way use and perceive technology but in every aspect of of the way we live and work.

Impact & Actionability: The paradox here is that, the bigger and more consequential a technology is, the harder it is to see how it can be applied. We might as well ask how we might make best use of gravity or kinetic energy. So, although we can be certain that (all else being equal) these fundamental frontier technologies will have a considerable impact on how we approach development challenges; we also have to admit that it's almost impossible to know how that impact will play out in any detailed sense.

Time and trust: While edge computing is well underway, they is still some uncertainty and complexity associated with edge computing, particularly in terms of the security and management of the devices at the edge, and the 'learning curve' associated with deploying and managing edge computing systems is very steep. Similarly Blockchain/Web3 is part of the popular conversation, but not always for the right reasons, and there is an awful lot of misinformation and hype surrounding it, and a successful, crossover use case that moves that conversation beyond cryptocurrencies has yet to arise. Meanwhile quantum computing and next-gen wireless networks are still many years away from mass adoption and acceptance.

Topline examples of where this technology could be applies

Blockchain: At COP27 the Ethereum Climate Platform (ECP) was formed. Its mission is to incentivize and fund the development of real-world projects that will mitigate greenhouse gas emissions and deliver positive environmental and social impact long into the future.

Quantum: D-Wave Systems Inc., a leader in quantum computing systems, software, and services, has given free access to its quantum systems via the Leap quantum cloud service for anyone working on responses to the COVID-19 crisis.

This month IBM announced the launch of the Quantum Computational Center in collaboration with Fundación Ikerbasque in Spain. This is the latest addition to the IBM Quantum Network, a growing global community of around 200 members working on advancing quantum computing and exploring its real-world applications. The newly-introduced center will work with the Basque country government, businesses and academic partners to develop innovative quantum technology solutions to facilitate regional scientific advancement.

To speak to the team, or join our exploration of the future of frontier tech for development, contact:

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