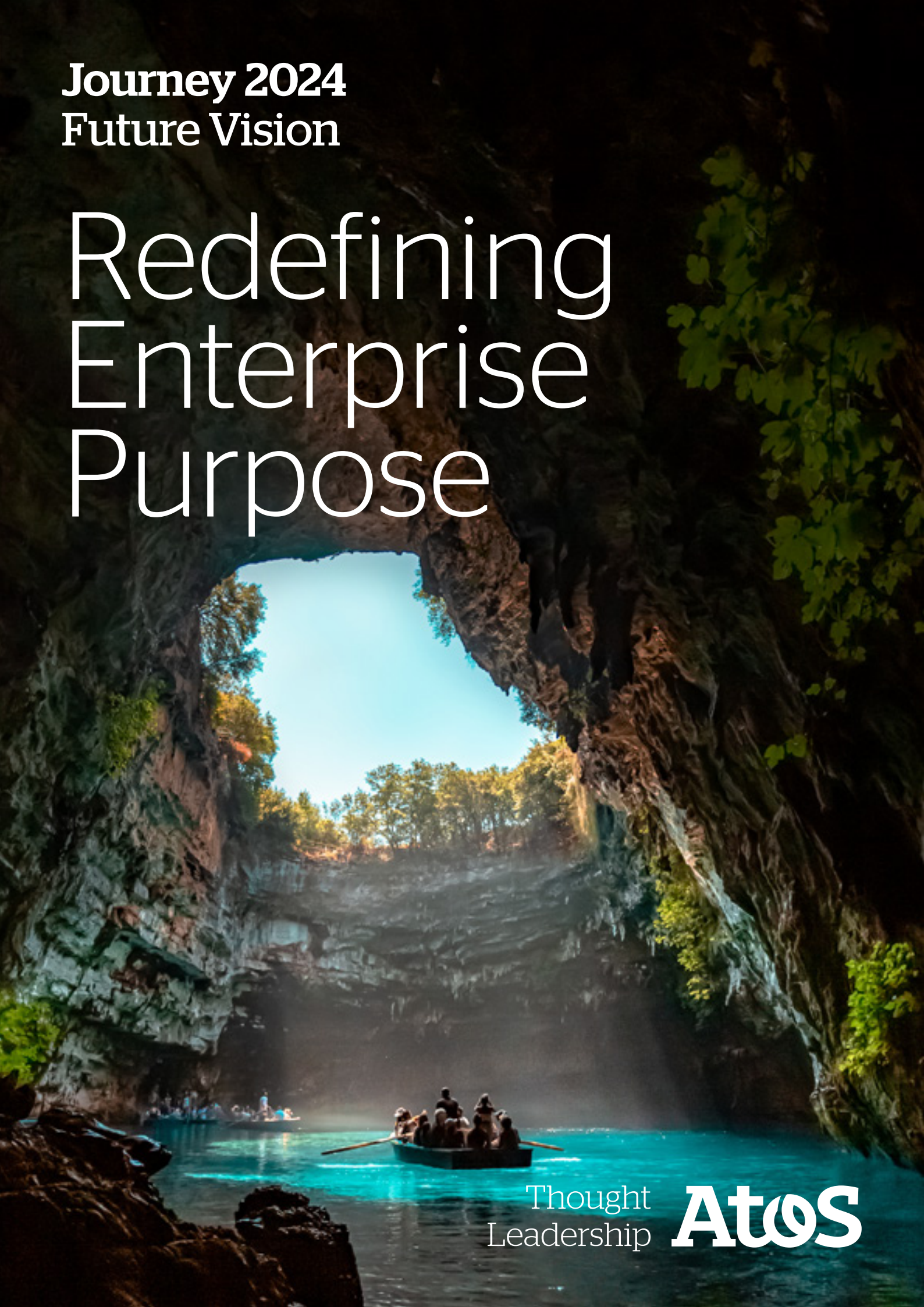
Journey 2024
Future Vision

Redefining Enterprise Purpose



Thought Leadership

Atos

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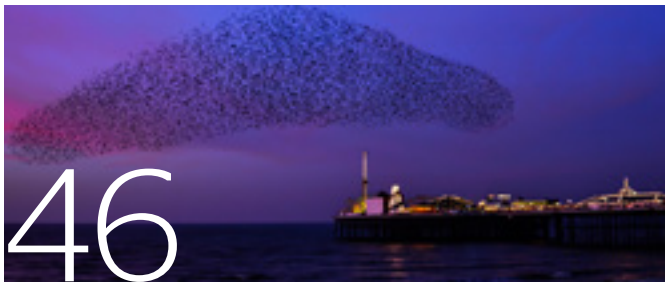


FOREWORD

Welcome to Journey 2024, our vision for the evolving world of business, society and technology. We hope it will stimulate and challenge your thinking about the forces that will shape enterprises over the next four years.

Journey 2024 is published at the end of June 2020, at a time when we are entering the post-COVID-19 era after a major pandemic. It is also a time when we are facing the collective impact of a number of other significant developments and uncertainties. Whether it is the rise of artificial intelligence, the first practical applications of quantum computing, or the growing imperative to address climate change and sustainable living, emerging opportunities and challenges are driving the need to rethink what is at stake and how we respond.

Our vision is built upon extensive research by our Scientific Community, who anticipates the technology and business trends that are expected to bring some of the greatest disruptions (both positive and negative) within a four to five years horizon. You will find a summary of their thinking within this paper. These trends reflect the growing significance of business model concepts like digital ecosystem platforms, and the need to rethink perspectives on user experience and the digital workplace. While Journey 2024 addresses the potential of a range of technology related areas, it also considers how they will combine and interact within the wider context of society and business economies. In particular, it covers the importance of cybersecurity, fraud prevention and trust, as well as decarbonization for sustainable operations. As we look ahead to 2024, we foresee a complex interplay of successive game-changing developments that make the accurate prediction of outcomes almost impossible. **We are likely to face perfect storms that will challenge the validity of conventional models and thinking, bringing new opportunities to reshape the very core of business and societal purpose.**

The COVID-19 pandemic has demonstrated how completely unanticipated events can turn apparently stable situations on their head – it has also shown the importance of a modern, digital approach to business-critical applications for ensuring resilience and agility in disruptive times. As we look ahead to the post-COVID-19 era, it remains to be seen whether we will transition to a new norm or experience a continuum of shifts that demand regular adjustments in purpose.

Our Scientific Community proposes that meaningful "paths to purpose" are rooted not only in somewhat inward-looking potential but embraces a collective mindset with a consensus among stakeholders that maximizes benefit for all parties. They have encapsulated that vision with the phrase **"Redefining Enterprise Purpose" – it is a clear prompt (particularly in relation to exploiting digital technologies) to understand what is necessary for businesses, governments and societal groups to maintain relevance and thrive in an ever-changing world.**

Elie Girard
Chief Executive Officer, Atos

"The COVID-19 pandemic has demonstrated how completely unanticipated events can turn apparently stable situations on their head."

KEY TAKEAWAYS FOR BUSINESS LEADERS

As we journey toward 2024, we expect that the impacts of deploying digital technologies will become less predictable and manageable. Significant and disruptive advances in technology areas such as artificial intelligence (AI), quantum computing and the Internet of Things (IoT), together with wider societal and environmental shifts, will lead to a variety of disruptions that we refer to as Cusps and Event Horizons. These have the potential to derail even the most established business models and ways of living.

Technology is not only a source of disruption but can also be an enabler of the flexibility and adaptability required to successfully negotiate the challenges of Cusps and navigate the uncharted territories of Event Horizons.

During the COVID-19 pandemic, we witnessed some businesses that were quickly able to repurpose their capabilities to respond to the crisis, and some that found themselves unable to effectively continue their operations. There were some who believed they had effective digital strategies, but who could not scale up in areas like remote-working, online-services and supply chains. Those businesses that had already embraced web-scale IT architectures and adopted platform ecosystem models (for resilience, data-driven automation and value exchange), were best placed to ride the storm.

The widely anticipated economic slowdown, market fragility, shifting attitudes away from globalization, and the environmental sustainability imperative will all contribute to future unpredictability. They will bring potentially dramatic shifts in business and society, and we are likely to see them materialize in areas such as:

- Redesigning of supply chains and value ecosystems (as a part of resilience and replacement strategies);
- Renewed approaches to data privacy regulations, allowing insights of critical national and global importance to be derived. This will need to go hand in hand with robust cybersecurity strategies;
- New business partnership models and disruptive merger and acquisition activity, together with an increased willingness to collaborate and co-innovate;
- A sharp focus on sustainability, decarbonization and circular economy models;
- An accelerated uptake of technologies like 3D printing and business automation to boost enterprise flexibility and agility;
- A shift in emphasis toward remote working and technology enabled skills augmentation;
- A reformulation of IT strategies, to deliver scalability, security and sustainability by design;
- A more deliberate and integrated approach to AI and knowledge management that embraces the need for explainability and ethical operation;
- A reassessment of what is considered to be essential and what might be dismissed as unnecessary luxury. Will we see a rebalancing of the current wealth divide?
- A re-evaluation of the core purposes that underpin enterprise, government and societal activities.

The question remains as to how business and society will respond to the challenges that lie ahead. How will economies respond to previously unseen levels of national and personal debt? What will be the result of anticipated advances in areas such as quantum computing and artificial intelligence? What skill sets (both hard and soft) will be most relevant in this ever-changing world?

It is likely that meaningful responses will involve enterprises rethinking the core of their nature and purpose, introducing a strength of alignment between 'Consensus', 'Collective' and 'Potential' in a context that is wider than ever before. The resulting underlying purpose will then embrace the kind of thinking which people can intuitively and emotionally align with, and which will enable the negotiation of even the most disruptive of Event Horizons.

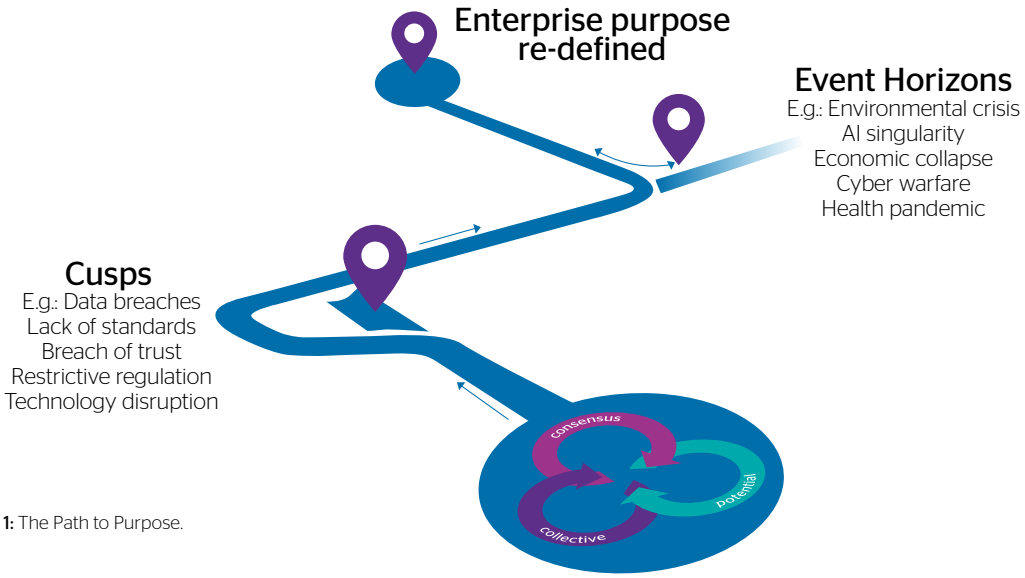
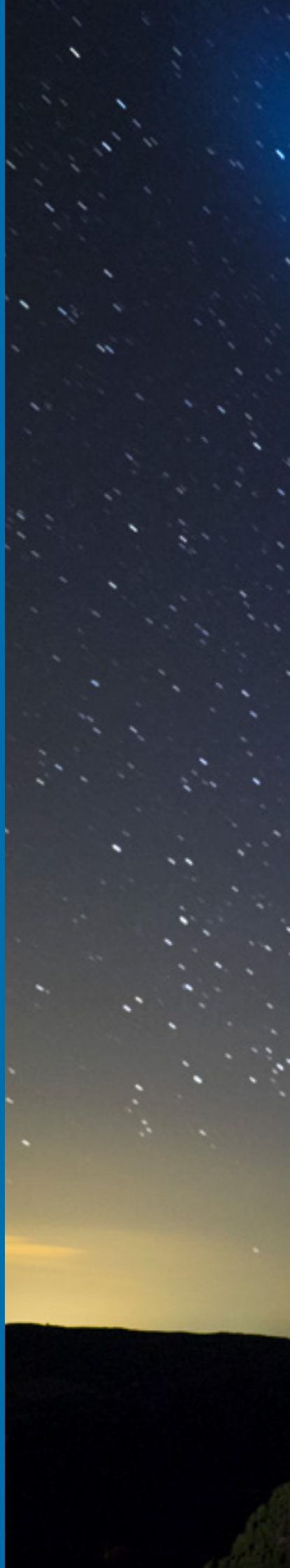


Figure 1: The Path to Purpose.

"It is likely that meaningful responses to the business, technology and societal challenges that lie ahead will require enterprises to rethink their nature and purpose."

VISION



THE NEED FOR REBALANCING

As we enter the 2020s, organizations across all sectors are becoming increasingly convinced of the need to re-evaluate their relevance and impact, with a more balanced perspective on business values and drivers. Public sector organizations recognize the growing importance of delivering citizen-centric and cost-effective services that meet the needs of individuals and small groups, not just the public as a whole. Private enterprises are looking to broaden their purpose beyond a primary focus on short-term value creation for shareholders. There is a growing impetus to realize sustainable value for extended ecosystems of stakeholders by working collaboratively with other organizations and society groups.

If efficiency means "doing things right" and effectiveness means "doing the right things", enterprise leaders are realizing that **obsession with efficiency can often be at the cost of effectiveness**. Optimizing quarterly results brings less value when done at the expense of longer-term corporate resilience and innovation or societal and environmental impact. Conversely, public sector organizations are realizing that their lack of efficiency is putting their efficacy at risk - it is no use doing the right things in what is perceived to be the wrong way.

All organizations need to carefully balance their energies and metrics. They need to fight the impulse to hurry into action with an opportunistic mindset (e.g. seeking to translate a particular geopolitical technology dominance into another region); or give in to inertia and relax into a late-adopter, risk averse mentality. The first impulse will result in nothing more than a few shallow quick wins that will not scale into sustainable transformation; the second impulse will result in increasing irrelevance and eventual demise. **A more meaningful, purpose-driven path will prevent straying into short-sighted targets and counter-productive measures of success.** It will help to maximize the potential that is promised by digital technologies, and lead to a sharing of derived value in a more equitable and sustainable way.

In Journey 2024, we explore some of the key influences that impact the success of given enterprise strategies and how they relate to our societies' grand challenges and megatrends. We align this thinking to the significant and growing uncertainty that is resulting from the ever-changing digital technology landscape, explaining the imperative for fresh thinking about the core purpose behind enterprise operations.

"For too long, businesses have tended to ignore the cost impact of "externalities" - new economic models allow for this imbalance to be addressed."

The impact of externalities

Throughout the twentieth century, most economic models had a clear enterprise centricity. They tended to ignore the effects that come from enterprise in the wider context: as part of a society, within a cultural, political and physical environment, and increasingly in a complex hyperconnected world. Certain factors were considered, such as governmental influence, regulation or taxes, however, many relevant effects or phenomena were disregarded as "externalities".

Externalities are indirect costs or benefits over which the impacted party has no control. They can be negative (such as air pollution from a nearby industry), or positive (such as someone's flowers being better pollinated by bees from nearby beehives). Conventional economic models tended to ignore externalities to avoid the cost of remunerating those who were "indirectly" impacted. Negative externalities only really surfaced when unexpected and often catastrophic events revealed their effects. For example: higher incidence of health problems due to poor air and water quality or sedentary and stressful work conditions; environmental disasters due to oil spills and nuclear accidents or the accumulation of toxins and plastics in rivers and seas; even community labor markets being depressed by monopolistic behavior of some enterprises.

When solely considering first-order economic effects, it is natural to focus on maximizing company profit - someone else (often the public sector) will take care of the externalities. Ultimately, such an approach is unsustainable:

- The public sector cannot solve all externalities, least of all for free, with personal and corporate tax increases often needed to finance the effort.
- The environment is damaged and depleted, providing fewer and/or lower quality raw material resources.
- The health and well-being of people can be negatively affected, with direct cost implications for healthcare systems and businesses.

In summary, negative externalities that are swept under the carpet will pile up. Sooner or later they create messes with substantial implications that are costly to resolve.

More recent economic models (e.g. the Value Balancing Alliance[1]) take externalities and wider organization interactions into account. **Enterprises need to realign their purposes to adapt to these advanced models and guarantee the economic sustainability of businesses** in the medium and long term.

[1] https://www.value-balancing.com

POWER REQUIRES RESPONSIBILITY

It might be said that technology is no longer always serving humankind, but that we are becoming the ones who serve technology. One of the most common examples is that of social network platforms where people need to provide the information that creates value - but the intricacies of this discordant relationship go much further. In fact, all **situations where people need to adapt to technology instead of the other way around could be considered suboptimal**. As digital technologies are embedded ever deeper into our everyday lives, their influence on humankind increases. Yet we seem to have grown accustomed to the limitations and demands of digital technologies and found ways to subconsciously cope with them.

This acceptance mindset has influenced the way we perceive what is necessary for digital technologies to enable true societal purpose. Somehow it has created a diffuse understanding of what digital transformation is about. Resolving dissonant opinions over the best way forward with technology requires organizations, customers, governments and regulatory entities to align. They need to make changes that embrace the responsibilities associated with the power of digital.

Today's digital transformations are generally targeted toward added revenue, better and more efficient processes, and better customer experiences. But in the wider context of our society, culture and environment, their actual impact might be far from optimal. From a holistic viewpoint their total cost may well outweigh the localized benefit. **The imperative is not merely to solve today's pressing business goals, but to tackle tomorrow's long-term challenges** concerning sustainability, decarbonization[2], inequality, security and the ethical impact of IT. Success will ensure that future generations will have at least a tolerable, if not a better world to live in.

An awareness of the need to tap into the full potential of humanity is already making its way into business boardrooms through new leadership development, employee well-being and diversity programs. Executives are coached to speak from their heart and listen to their gut, in addition to using their rational brain. However, we must ensure this is not just a thin veneer to make old business practices look better. It is time to redefine the core objectives of our technology decisions, beyond higher performance or limitless growth. We need to include objectives that create opportunities for people to thrive, supporting not only health, but also bringing satisfaction and meaning into the world through the way we do business. Diversity that engages all parts of our being, our mind, our intuition and our heart, is a key foundation for creating non-biased technologies and business models. In turn, this will influence the way we design products and leverage technologies to identify new potential and new causes to serve.

However, **the constant evolution of digital technologies is driving a trend toward less predictable outcomes,** and an ambiguity that challenges even the most established digital technology and business models. The nature and scale of the impending uncertainties demand new levels of thinking, feeling, intuition and strength of purpose that will allow enterprises to navigate the uncharted disruptions that lie ahead.

[2] The reduction or elimination of carbon dioxide from energy sources.

SMALL CHANGES, BIG DIFFERENCES

Small changes can make a big difference. Athletes understand this well, when a thousandth of a second or a few millimeters can mean the difference between winning and losing. The same is true in our automated, hyper-connected digital world, where seemingly minor changes can lead to major disruption. Such changes can materialize with a speed and significance that rivals the impact of some longer-term trends – and not always in ways that were intended or anticipated. A celebrity natural historian and a schoolchild speaking out against climate change can force changes to previously entrenched policies of governments around the world. A careless data security breach can destroy the viability of an otherwise successful business. A simple error in a stock trading algorithm can wipe out millions of dollars of value in a matter of minutes.

Some disruptions can be anticipated, modelled and even managed, but others will lead to outcomes that are unanticipated and uncontrollable. One way to understand these effects is by using Cusp catastrophe theory[1]. This is a model which has been used for over 50 years to describe situations such as the sudden buckling of bridge structures, avalanches and even human anxiety responses. It uses three dimensional surfaces to anticipate significant and sudden changes arising from small shifts in circumstances.

Examples of Cusp behavior might include vehicle drivers that suddenly experience irrational "road rage" triggered by what is seemingly the most innocent events; or parents finding themselves performing inexplicable feats of super-human strength to save their child from a perilous situation. What is it that causes the sudden switch to becoming enraged or powerfully motivated? What underlying stress conditions cause different individuals to react to similar situations in very different ways? And would the same outcome occur if the incidents that triggered the unexpected reactions had taken place at a different time, place or context? Referring to Figure 2, is it possible to anticipate and take the necessary actions to avoid the dangerous path 3, instead following the safer path 1? Or can the damaging impact of unavoidable Cusps be minimized through understanding their effects and making measured, incremental course changes (path 2)?

Cusps can describe potentially negative outcomes but can also model the ways that we might tap into the abundance of human capabilities beyond the rational. They can characterize the combination of sensing, intuition and emotional power that leads to collective expressions of joy or individual stands against acts of injustice.

Returning to the sports analogy, correctly balancing training, dietary and competitive engagement regimes, will allow an athlete to operate at, or close to, peak performance. Managing stress positively will lead to enhanced outcomes. However, the introduction of additional stressors such as excessive travel, tough press conferences and behind-the-scenes relationship problems, can result in a sudden and catastrophic drop in performance. Recovery from such a situation usually demands more than just addressing the changes which triggered the problem. **Understanding and anticipating why certain outcomes occur can help with the avoidance of problematic Cusps.**

We can usefully apply this same thinking to understanding the impact of digital technologies. For example, a lack of consensus on the perception of a particular technology can lead to unforeseen deviations from expected market behaviors. Enterprises need to anticipate where Cusps might occur in their business operations (at both a localized and wider societal level), avoiding them where possible and intelligently responding to their consequences where not.

As we head toward 2024, we expect to see complex combinations of non-linear changes across otherwise unrelated systems. Reflecting this and all the consequences (both advantageous and destructive) is essential for effective business strategy and operations. After all, the way we respond to such non-linear events is behind some of mankind's greatest innovations as well as its failures.

[1] E.C. Zeeman, Catastrophe Theory, Scientific American, April 1976

Possible operational outcomes:
1. Continuous
2. Disrupted
3. Discontinuous

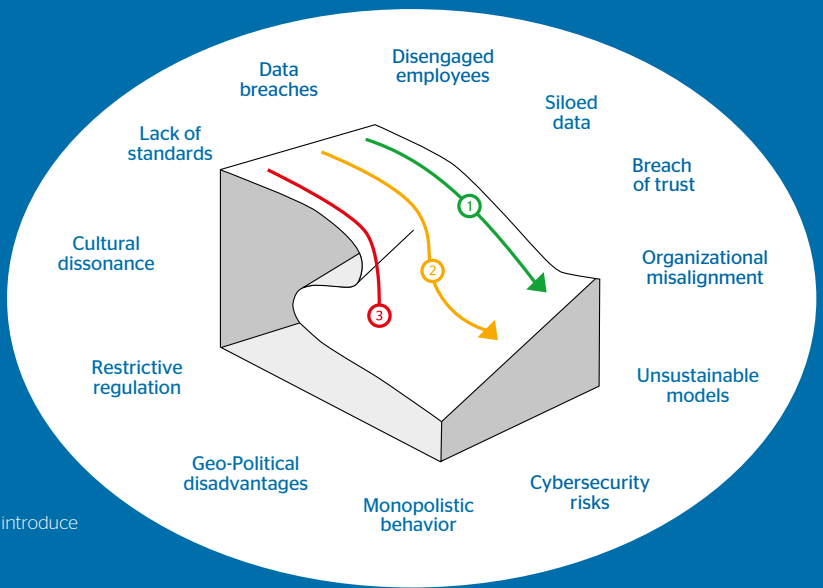


Figure 2: Examples of the factors that might introduce digital business operational discontinuities.

FAMILIAR JOURNEYS OR UNCHARTED TERRITORY

The evolution of digital technologies has usually followed measurable and predictable paths. Hardware has become progressively smaller, faster and cheaper; and applications have become increasingly data centric, context-aware and "intelligent". However, many commentators suggest that we may be reaching certain "tipping points" that will totally recalibrate accepted technology trends. We refer to such paradigm shifts as "Event Horizons" and anticipate that they will emerge not only through technology changes, but also in response to significant societal, geopolitical and human factors. They might be characterized in such concepts as the AI singularity[2], practical quantum supremacy[3] , "Earth overshoot day"[4], or the game-changing impacts that could accompany the maturing of technologies like 3D printing, edge computing and cryptocurrencies.

Event Horizons cannot be explained by discrete, definable Cusps. Their impacts are potentially so significant and complex, that even though they may be anticipated at a generic level, it is almost impossible to fully predict and prepare for what lies beyond. We associate Event Horizons with some of the grand challenges faced by humanity, such as the unsustainability of our resource consumption models; cyber and physical warfare; and health pandemics.

The recent COVID-19 pandemic is a stark example of how known generic risks can materialize in ways that were almost unimaginable. We have seen societies and economies thrown into disarray, with individual and collective perspectives on value and purpose being fundamentally changed.

Not only can Event Horizons lead to uncharted territories, they can also represent points of no return. Reaching an AI singularity might result in such a point, through introducing unintended consequences that cannot be reversed. Practical quantum supremacy could lead to a radical and unstoppable global powershift. And the widespread release of nanotechnologies could become an uncontrollable digital / physical chimera virus. There are some things which cannot be "un-invented", just as we have seen with other defining moments in history such as harnessing electricity, splitting the atom or creating the internet.

Event Horizons should not only be seen as dangerous boundaries to be avoided, they might also lead to positive outcomes if supported by widespread consensus and collective action. In fact, there will be some instances where bringing about an Event Horizon might be at the very heart of an enterprise's purpose. For example, with Tesla seeking to "Accelerate the transition to sustainable energy" or the Ellen MacArthur Foundation working to "Accelerate the transition to a circular economy".

Regardless of the driving forces, **it is important to understand which trends and behaviors might lead to an Event Horizon**, and how an enterprise's underlying purpose can help it and society at large survive the outcomes.

[2] The hypothetical future point where artificial intelligence surpasses human intelligence
[3] The point at which quantum computers are able to solve problems that classical computers practically cannot
[4] The date when humanity's demand for ecological resources and services in a given year exceeds what Earth can regenerate in that year.

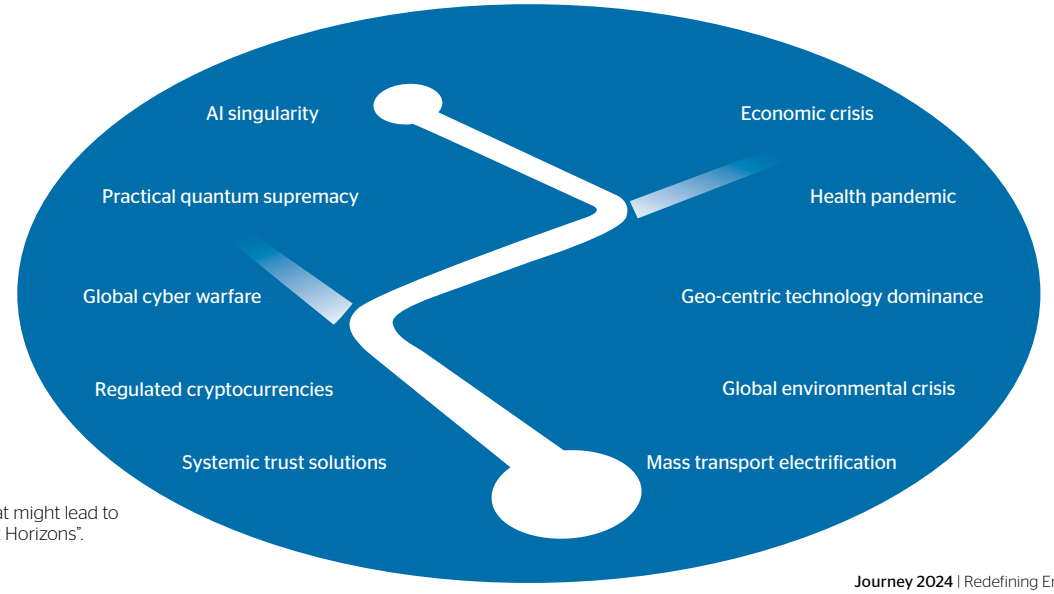


Figure 3: Situations that might lead to game-changing "Event Horizons".

THE INFLUENCERS AND JOURNEY OF PURPOSE

Much has been written and discussed about the importance of business purpose. Disfunction within organizations is often blamed on a lack of coherent purpose, and yet many business leaders wrestle with the challenge of articulating an engaging and motivating purpose behind what they do. Historically, the objective of making profit or adding value was deemed to be enough, but it is now clear that a wider perspective has to be taken. In response, some of the world's largest and most influential enterprises have embraced bold, world-changing mission statements. But is singularity of purpose sufficient when faced with an increasing array of uncertain business and technology related Cusps and Event Horizons?

Especially when we consider digital business, meaningful purpose needs to be far more nuanced, incorporating a balance of flexibility and adaptability. The challenge is to have a purpose that acts as a directional "north star", yet at the same time allows navigation through waves of uncertainty created by relentless changes in the "art of the possible".

In a digital context, we suggest that there are three main strands to purpose:

- realizing the potential of digital technology in its widest context;
- through collective behaviors that reflect fair value exchanges and;
- build consensus on application.

Each strand of purpose is inter-dependant, with strength of purpose being derived from the coherence of all three. A failure to achieve consensus on the way that a technology is applied will inevitably impact the ability to act collectively, which in turn will reduce is derived potential, no matter how compelling the overarching purpose might appear.

The journey along the 'Path to Purpose' is one which needs to negotiate a number of obstacles. Some of these may manifest themselves in minor deviations or Cusps, others may be more significant but less easily understood as their consequences are shrouded by "Event Horizons".

The obstacles referred to may be the result of things like regulation, legacy inertia, unsustainability and societal pressure. They may represent factors common to all businesses or may be specific to certain technologies and markets. Depending on the strength and relevance of the purpose you are following, you may be able to negotiate the obstacles - perhaps with a course correction – or you may be unable to make further meaningful progress despite much effort. The journey is rarely simple. There will be complex interactions between the influencing factors which are all subject to real-world discontinuities - and affected by the rate of change and impact of digital technologies.

Enterprises need to combine their short-term business goals with a long-term purpose and strategy that ensures our world doesn't end up in the sort of dystopian scenarios found in Science-Fiction. We must think more widely than the good or bad application of a single digital technology. Instead we need to consider how these technologies can evolve coherently to lead to positive outcomes for individuals and society, avoiding Event Horizon outcomes that are damaging for humanity.

In the following sections, we further consider the 3 key influencers of Purpose.

From Dilemmas to Purpose

In Journey 2022, we explored the "Digital Dilemmas" that arise from tensions between the digital "art of the possible" and the physical "art of the permissible". These tensions are associated with the way that we apply data-driven insights, business models and digital technologies.

Failure to achieve an appropriate balance (e.g. by breaching data privacy regulations to obtain insights used for commercial gain), inevitably leads to negative consequences.

The dilemmas persist, but their resolution will increasingly come from applying fresh, purpose-driven thinking.

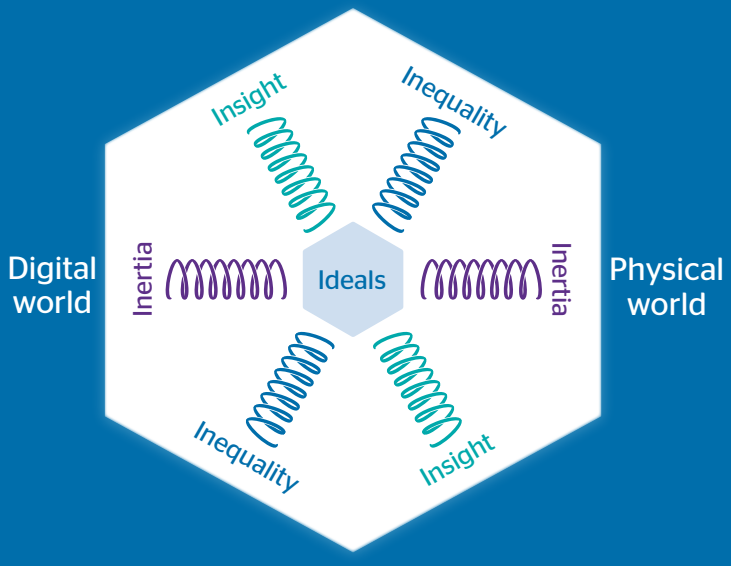


Figure 4: The dimensions of tension between the digital world and the physical world.

POTENTIAL

As we navigate the waves of disruptive technologies, we already see many topics that have moved from the hype of 'unlimited promises' and into the reality of them fulfilling their 'potential' with ground-breaking results. Many sectors have benefitted from harnessing innovative uses of digital technologies. They have fueled new waves of efficiency and value where people and machines work together to make businesses more responsive and intelligent.

We expect to see further transformation in the way that products are designed, making it easier to interact with technology through new user interfaces and experiences. Technologies like 'quantum intelligence' will overcome classical computing speed obstacles, bringing huge benefits to the field of AI (and vice-versa). But enterprises may well need to redress the balance between 'move fast and break things' to a 'precautionary principle' that values pace but not at the expense of things like privacy, security and ethical values. This becomes even more important when the trust of millions of individuals is at stake. **A rushed approach to technology exploitation that treats human-centric matters as an afterthought will introduce obstacles to progress and limit potential.** Respecting and reflecting cultural diversities will inevitably help reach a consensus over approaches to experimenting, changing, reorienting, or, if required, "pulling the plug" quickly.

As technology increasingly engages with our human being and not just our "human doing", it is more important than ever to ensure that capabilities such as AI are strongly human-centric, explainable, and democratically available. To realize the full potential of emerging technologies, we need to think beyond the raw technical capabilities of digital systems, processes and developments. We must continually evaluate their relationship with the dimensions of humanity, society, organizations, politics, economics and even psychology.

The potential offered by technology is not generally dependant on geopolitical affairs. But there are certain social, political, environmental and cultural aspects that allow some geographies and demographics to race ahead in the journey of digital exploitation. This will almost inevitably give rise to issues of power imbalance or misuse, which may ultimately lead to areas of geopolitical technology dominance. There is a risk of sub-optimal realization of digital potential in those geographies, with a resulting emergence of enterprises that suffer from political-cultural dissonance. Geo-political states and enterprises cannot use a single lens through which to view their purpose but require a granular and adaptive approach to assess and respond to various states of development, political systems, and cultures. To avoid further imbalances, organizations should seek to challenge and test pre-held assumptions about the demographics to which technologies should be targeted.

"To realize the full potential of emerging technologies, we need to think beyond the raw technical capabilities of digital systems, processes and developments."

COLLECTIVE

There is an element of truth in the concept of crowd intelligence[6], but there is also a degree of naivety in its coarser formulation. Any crowd is not able to solve any problem better than any individual - particularly where crowd concepts are orchestrated, hierarchical and top-down. However, the evolution and mass adoption of collaboration technologies is enabling grassroots and bottom-up behaviors that exhibit purposeful, collective, self-assembly crowd intelligence. Such groups might be for mutual support, creating a sense of belonging, or including the marginalized. Hierarchical organizations are tentatively exploring ways to replicate such behavior in controlled environments, with the objective of getting the best from their people.

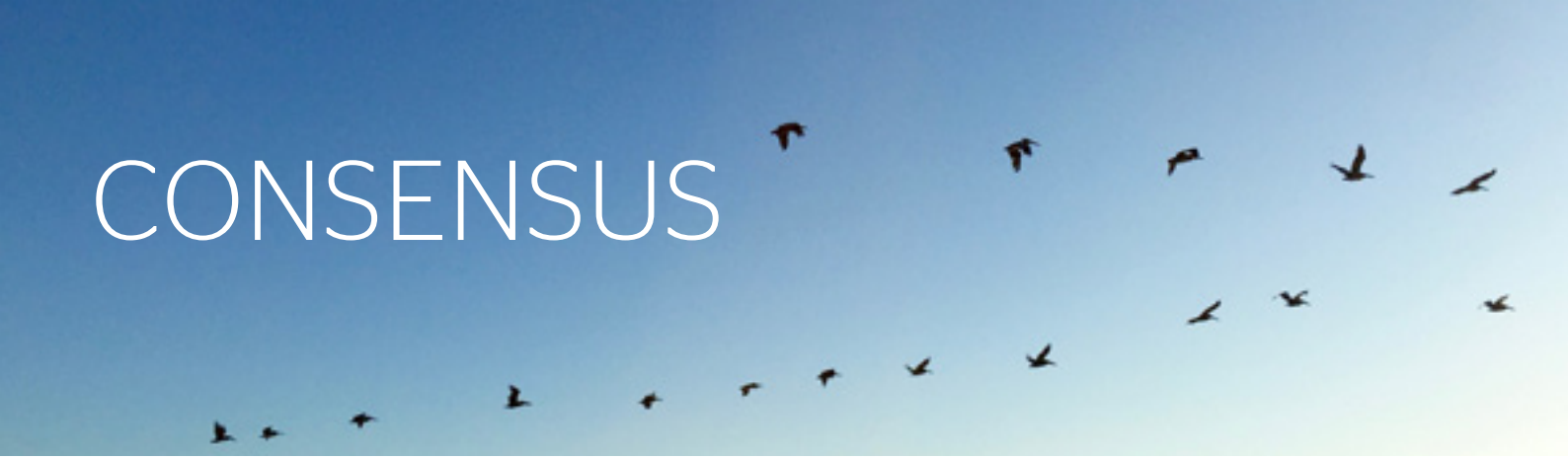
As crowds grow in size, repeating patterns often emerge - backbones of connection and communication link together clusters, which are in turn, composed of smaller groups with their own finer grained connection and communication. It is within the individual clusters that most of the sensing and activity take place: a pattern that is common to large networks of devices as well as to societal and political networks.

Societies discovered long ago the principle of subsidiarity, where decision and response (management) should take place close to where the action is - within the community. Hence, the different levels of public administration: district, municipal, regional, national and trans-national. Technology is rediscovering this "subsidiarity of intelligence" with Edge and IoT, where computing intelligence is pushed to the edge of the cloud, to the objects close to where the action (sensing and actuating) is. Swarm computing is enabling machines to display human-like team intelligence: by self-organizing and collectively compensating for individual failures or glitches, the fulfillment of a common purpose is sustained. Whilst human teams tend to exhibit such behavior naturally, businesses are having to adapt their traditional industrial structures to embrace flatter org charts, ad-hoc teams and other strategies. But most are yet to realize this in the context of a fully digital mindset.

Although collective machine intelligence at a macro, cross-organizational level may come in the form of networks of Industrial Data Platforms, the whole fractal picture is not complete without the micro-level insights from collaborating edge devices. Realizing the full potential of the collective requires appropriate access to relevant information and knowledge, which in part requires a solution to the problem of "Digital Wastelands". These are the result of fragmented data silos; data without attribution or veracity; and data which does not translate into knowledge. **Unlocking the abundant potential of the human collective demands a high level of consensus on how it will be meaningfully applied to realize a mutually beneficial purpose.**

"The impact of digital technologies is dependent on achieving collective critical-mass through value-driven network effects or "perceived need" mass adoption."

[6] The mid-2000s revival of collective intelligence



CONSENSUS

In recent years, we have seen significant examples of technology platforms losing the trusted relationship they had with the public, as a result of their failure to respect fundamental digital concepts, such as data ownership and privacy. As the pace of technology development increases and the art of the possible is stretched, definitive trust is becoming harder to establish and maintain. **It is now the consensus of engaged populations that is rapidly becoming the critical success factor for organizational trust going forward.**

At a micro-scale, consensus is built around the extent to which individuals feel a level of confidence in a particular technology or concept. This invisible force that guides our interactions is heavily dependent on personal context and environment – who we grow up with, what we see in the news, what our peers believe. It can be a very ingrained and resilient force, that is often only indirectly influenceable by gradual nudging and nurturing.

On a macro-scale, trust manifests itself in the consensus of the many, behaving in an altogether different way. Individual viewpoints coalesce into large swathes of public opinion that can shift one way or the other and can be subject to wild fluctuations and apparently random movements – rather like a starling murmuration[7]. Over recent years, technology has amplified the scale of these fluctuations as we become more rapidly and powerfully influenced by online insights and opinion. It is sometimes difficult to know whether fluctuations are based on reality or on artificially generated perspectives created to actively distract and disseminate distrust.

Organizations must identify how they will achieve and sustain a consensus of trust in the context of our changing digital landscape. They need to include the consideration of emotions (such as users' technology-related hopes and fears) into the design of systems so that they more intentionally support trust and adoption. They must grasp the opportunities ahead: ecosystems will arise that enable trusted interactions between peer organizations, unlocking the significant value of greater data sharing and collaboration. This will bring about a critical mass of consensus that helps ensure that true business collaboration can be viable.

Yet there are also the unknown factors. We will need to ask searching questions of how we manage and develop machines that behave autonomously and unpredictably. And we must prepare for evolving methods of fraudulent and malicious attacks on business and society. Doing so will test the strength of our trust in a world of autonomous machine intelligence.

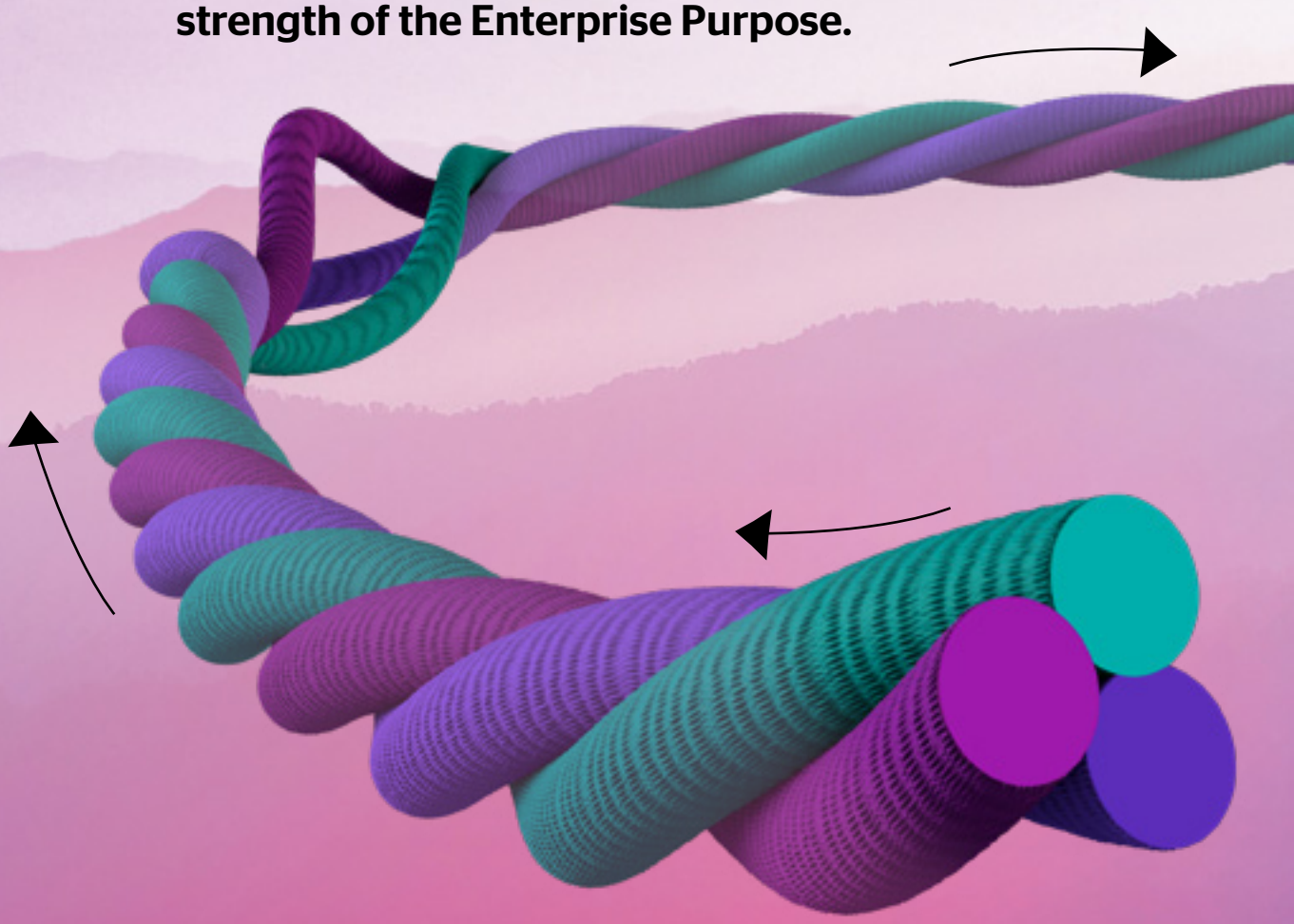
> "Digital relationships will increasingly be driven by consensus rather than explicit trust, as exchanges become more transient and frictionless."

[7] The phenomenon that results when hundreds, sometimes thousands, of starlings fly in swooping, intricately coordinated patterns through the sky.

REDEFINING ENTERPRISE PURPOSE

THRIVING IN AN EVER-CHANGING WORLD

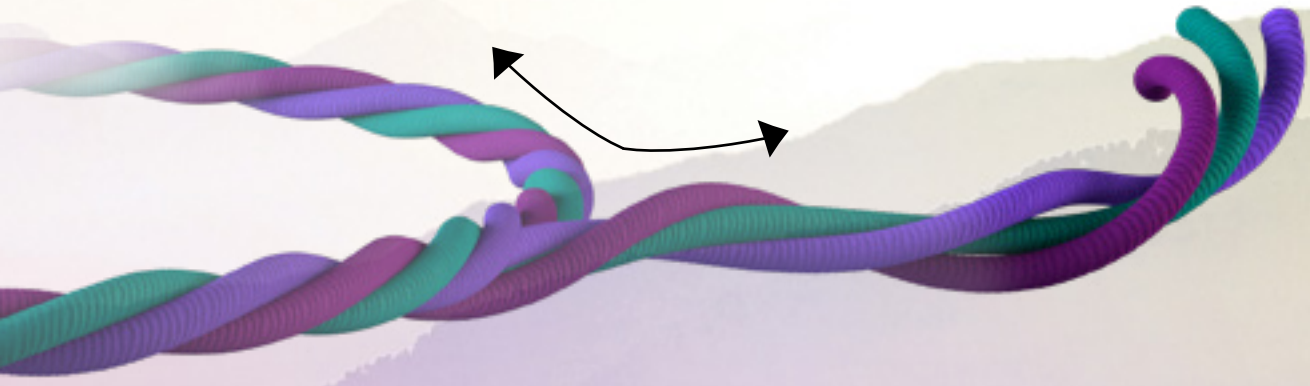
3. **Failure to maintain coherence between Consensus, Collective and Potential will dramatically effect the strength of the Enterprise Purpose.**



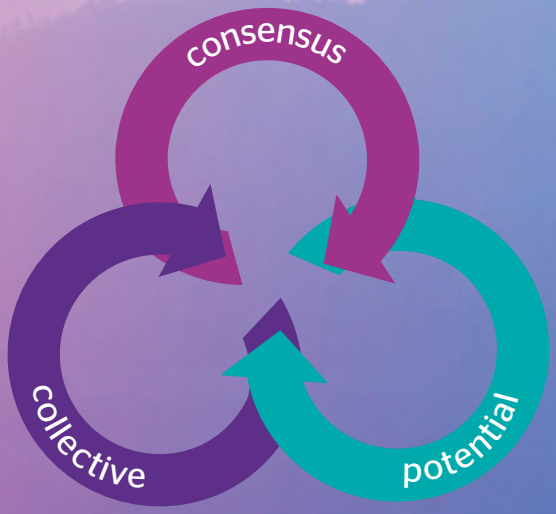
2. **The Path to Purpose is not a static one. There are twists and turns as we encounter a variety of disruptive influences or “Cusps”.**

5b. The way that businesses and society anticipate and respond to "Cusps" and "Event Horizons" will determine the ongoing relevance of purpose.

5a. "Event Horizons" can make or break purpose.



4. The Path to Purpose may encounter game changing "Event Horizons" that demand core changes to purpose.



1. Consensus, Collective and Potential can be seen as the three core strands of Enterprise Purpose.

LANDING THE VISION

The influencers of purpose within our model are inevitably strongly interdependent but have their own particular characteristics. For each influencer, we have conducted research into a number of technology related developments and trends. These topics are by no means an exhaustive list, but they provide valuable insights into the future drivers of meaningful enterprise purpose. Whilst we have nominally aligned each topic to a specific influencer of purpose, there are some significant overlaps. For example, although thinking **"beyond sustainability"** is essential for maintaining the potential to use the Earth's natural resources, success in this area demands clear collective action to realize the necessary outcome.

Within "consensus", we have grouped topics that will help engender trust, insight and truth, or that will potentially be a source of divided opinion. **Ecosystems of Trust, Federated Fraud Prevention, Invisible Security and explainable AI (Unpredictability and Machine Behavior),** are all areas that can help build levels of confidence in digital solutions. However, dealing with diverse ethical perspectives within automated systems may well bring consensus challenges, particularly when addressing privacy concerns associated with personalized digital solutions. We will explore how establishing the appropriate yardsticks for trust are essential for digital business ecosystems that are increasingly automated and therefore exposed to systemic risks of error or abuse. Particularly as artificial intelligence becomes more embedded into core operational activities, we need to understand and explain why automated systems respond as they do. If, for example, we are unable to understand why an autonomous vehicle caused a fatal accident, the transformation of an entire industry sector could be held back.

As digital technologies become more context aware, connected and "personalized", there are significant opportunities to create new sources of value. But this will only be successful if it is done in a way that users of the related services (both business and consumer) are willing to trust. **Creating solutions that demonstrably respect the rights of each party in digital exchanges will help overcome localized and even nationalistic attitudes**. They will facilitate the transformation of traditional pipeline business models to more collaborative and integrated ecosystems.

We have used the term "collective" to embrace those technology themes that enable connected ecosystems, or which are strongly dependant on collective behaviors. Future **Networks** are clearly the underpinning technology for our hyperconnected world, upon which things like **Edge & Swarm** and **Smart Dust** are able to build collective and collaborative intelligence solutions. **Smart Grids 2.0** explores the compelling need for a collective approach to managing electricity networks that are becoming increasing disjointed with the

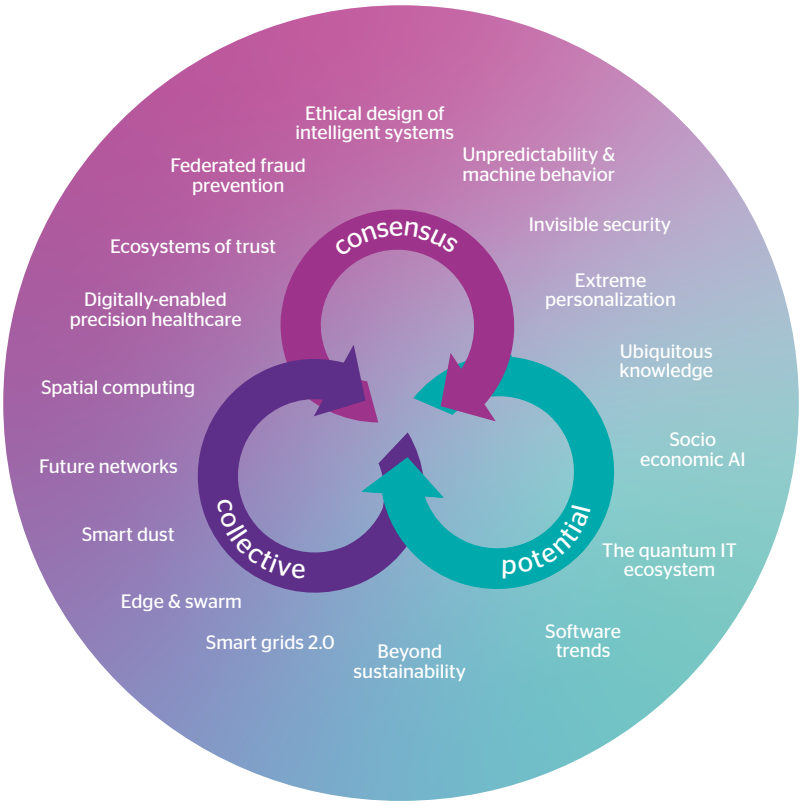


Figure 5: Alignment of our Journey 2024 research tracks to the core strands of purpose.

rise of sustainable generation and consumption models. **Digitally-enabled precision healthcare** explores what might be possible if current resistance to sharing sensitive personal health data could be overcome. The COVID-19 pandemic has clearly shown the value of health-related data in tracking and predicting the impact of disease. Could this event be the catalyst for a rethink over personal data ownership, bringing new levels of public-private cooperation over the use of such data for the greater good?

Spatial Computing explores the opportunities afforded by the seamless connection and integration of the digital and physical worlds. We consider the next anticipated transformational shift in the way that we interact with data, our environment and with each other – a shift that brings us intuitive and engaging representations of the digital world. These will augment our physically constrained insights and open up new opportunities in collaboration, understanding and skills enhancement.

Smart Dust offers an exciting glimpse into a possible more distant future where intelligent technology is progressively miniaturized and moved to the edge. Can we expect a wealth of new benefits in areas such as equipment and environmental monitoring, medical diagnostics, and self-repairing systems? Or will we see a dystopia of unseen surveillance, toxic pollution and uncontrollable rogue technology behavior?

The maturing of **Edge** intelligence is likely to be one of the more disruptive technology areas over the next 3-4 years. Autonomous capabilities in areas such as transport, retail, utilities and even defense, will increasingly exploit cooperative intelligence between connected devices and their surrounding ecosystems. The resulting architectures will introduce the concept of swarm computing where intelligent edge devices are able to self-organize and adapt to deliver a wide variety of tasks.

Finally, within the area of "Potential", we have aligned topics that demonstrate ways in which technology can drive efficiency and effectiveness. We consider artificial intelligence from the perspectives of Socio-Economics and business automation. We look at game changing **Quantum IT**, the untapped potential of data wastelands **(Ubiquitous Knowledge)**, and the importance of appropriate **Software strategies** for maintaining digital relevance. We also address the imperative of long-term sustainable and regenerative business models and show how digital technologies can be a key part of the sustainability solution rather than being a part of the problem.

All of these technology-driven topics can and need to be seen as influencers on the "path to purpose". They may introduce their own Cusps and/or Event Horizons, but may also bring the opportunity to anticipate and safely navigate disruptions as they occur. It is worth reflecting on the possibility that we may just be experiencing the tip of the iceberg of COVID-19 triggered Cusps, and we may be facing an Event Horizon that will radically alter the status quo. People, organizations and governments should all be on the lookout to detect and adapt to further disruptions that have the potential to change our lives forever.

Applying Cusp and Event Horizon thinking to the COVID-19 pandemic

The COVID-19 pandemic might be described as an Event Horizon. Whilst the world has experienced pandemics before, the full impact and fallout of this instance was totally unforeseen and has shown most governments and businesses to be very unprepared. Societies and enterprises have been forced to deal with a resulting series of potentially dangerous Cusps relating to areas such as healthcare system overload, economic recession, supply chain failures, mass unemployment and widespread mental health issues.

However, alongside the tragedy and suffering, we have seen the emergence of a new collective spirit in communities around the world caring for those in most need; a consensus that individual sacrifices need to be made for the greater good; and technology being applied to help unlock fresh potential as people adapt to new ways of living and working. As a result, a new sense of purpose has been unleashed in a wide range of businesses and societal groups.

The threat of severe economic slowdown, deglobalization and collapse of certain markets remains, but the ability to successfully navigate around the most severe outcomes of these Cusps (e.g. by flattening the infection curve, protecting jobs and maintaining key services), will help ensure that the most extreme Event Horizon scenarios are avoided. It could be that those that are successful in avoiding Cusp catastrophes will emerge with a renewed resilience and a redefined purpose that embraces a more collaborative approach to future value creation.

"The way that consensus, collective and potential intertwine and support each other influences the ability to achieve a meaningful and sustainable purpose."

POTENTIAL

"The potential of digital technology is considerable. However, its full realization is highly dependent both on how it is applied and how its application is perceived."

UBIQUITOUS KNOWLEDGE

In the last few years many organizations embarked on their digital transformation journeys. While a few have seen successes in automation, improved quality, efficiency and growing revenue, most have struggled to achieve the promised benefits.

Avoiding the digital wasteland

Continual waves of technology developments have left many enterprises with fragmented information ecosystems. Enterprise data and workplace / collaboration data is now typically spread over an ever-increasing number of data silos. Information is isolated not just by access rights but also by different technical infrastructures - and with no strategy to resolve this situation. There is a significant risk of companies heading toward a **digital wasteland**, where it becomes increasingly challenging to use information and knowledge to greatest effect.

Data silos are not just a source of inefficiency, they can result in a state of operational paralysis as digital business processes become more interdependant. Increased development and maintenance efforts, reduced security, poor data quality and restricted insights are all constraining innovations like machine learning, Edge computing and digital twins from reaching their full potential. Sub-optimal information sharing is one of the primary reasons that businesses don't achieve the promised benefits of digital transformation[1].

Digitalization vs digital transformation

As businesses seek to digitalize processes, tools and document libraries, they often neglect to consider intra- and inter-organizational exchanges that would contribute larger contextual knowledge graphs. In doing so, they are missing out on digitally transformed ecosystems that lead to value-adding intelligence efficiency.

Planners of transformation programs need to consider the kinds of data that are being transformed and avoid initiatives that stifle valuable data exchanges and create yet more silos.

The need for a new information paradigm

Many transformation efforts are based on today's **digital paradigm**, on making the right decisions for a specific innovation or technology. What is often overlooked is that new value often cannot be realized without integrating information from multiple sources, owned by more than one (commercial) entity and influenced by a complex interplay of access rights, rules and regulations. **A fresh view on information and knowledge is required**, one that will ensure that maximum value of the transformation is realized from the architectural, user experience and commercial perspectives.

Toward ubiquitous knowledge

These challenges need to be understood as part of the maturing process of information ecosystems. They reflect the trend to move away from conventional API enabled data silo's toward multi-sided platforms that engage networks of users. There is increased focus (and challenge) on information **ownership**, usage and regulation, which is causing a subtle rethinking of intellectual property and data privacy. In turn, this is re-igniting expectations of distributed ledger technologies (such as blockchain) for identity, trust, fraud prevention and content-centric DRM[2]. The challenges of fragmented data are a priority for start-ups and BigTech alike, as many new standards and exchange solutions are emerging with the promise of better information **interoperability**, both within and across organizational boundaries. Many businesses are increasingly using new ways of information **interlinking** - internally through Enterprise Knowledge Graphs and externally through new ontologies and semantics-based industry standards.

[1] https://thenextweb.com/growthquarters/2020/02/24/ digital-transformation-projects-dont-fail-because-of-a-shortage-of-tech/

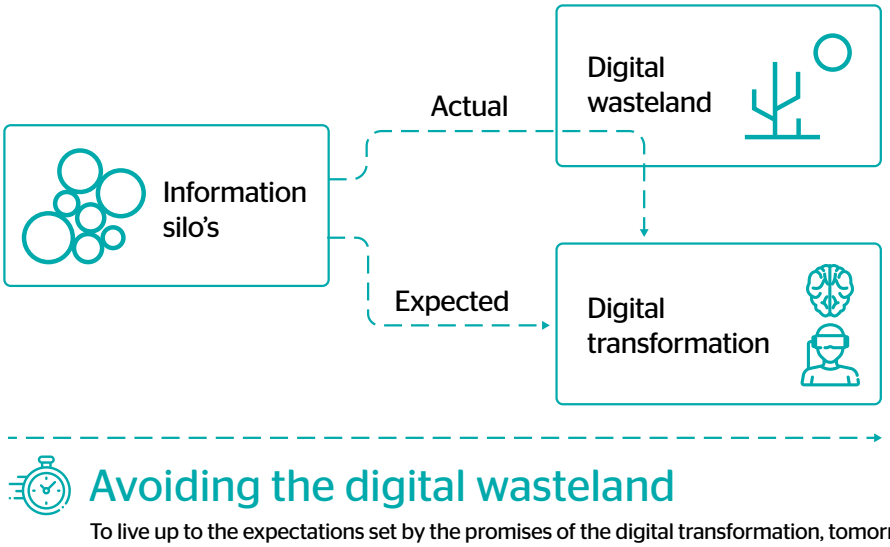


Figure 6: The unintended rise of digital wastelands.

Coopetition-based value creation

Transformation opportunities are often lost because of the inability to efficiently utilize knowledge and data. But far greater waste comes from enterprises failing to recognize the opportunities that come from sharing data across extended partner networks. Those fearing creative destruction should bear in mind that shared knowledge is often a trigger for innovations. Recognizing this potential can nurture new models of **coopetition-based value creation**[3], where there is far greater opportunity to enhance customer value and build loyalty. Such an approach is a necessary counter to the disruptive competition coming from technological companies (both startup and BigTech), which sooner or later will force a change in current business models. It is also clear that regulators will nudge enterprises toward collaborative data approaches, catalyzing the opening up of siloed knowledge[4]. Realizing this vision will drive a need for 'next-gen' frameworks and standards for data ownership, interlinking & interoperability.

Purposeful digital knowledge

As enterprises redefine their purpose in the context of digital transformation, the challenges of information ownership, interoperability and interlinking must be approached within the widest appropriate context. Only then will they be able to build the foundation of ubiquitous knowledge necessary to establish fair and honest consensus in a collective, dynamic ecosystem of coopetitors, customers, partners and regulators.

"Open data initiatives are emerging around the world. Their aims are to enable coopetition-based value creation."

[2] Digital Rights Management – a way to control usage and distribution of digital, copyrighted works.
[3] Cooperating competitors. A model often used in software and banking industries, amongst others. As described http://ecsocman.hse.ru/data/977/644/1219/coopetition.pdf
[4] Examples: Australia's public-private partnership https://www.opendataaustralia.org/ and the EUs Strategy for open data https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

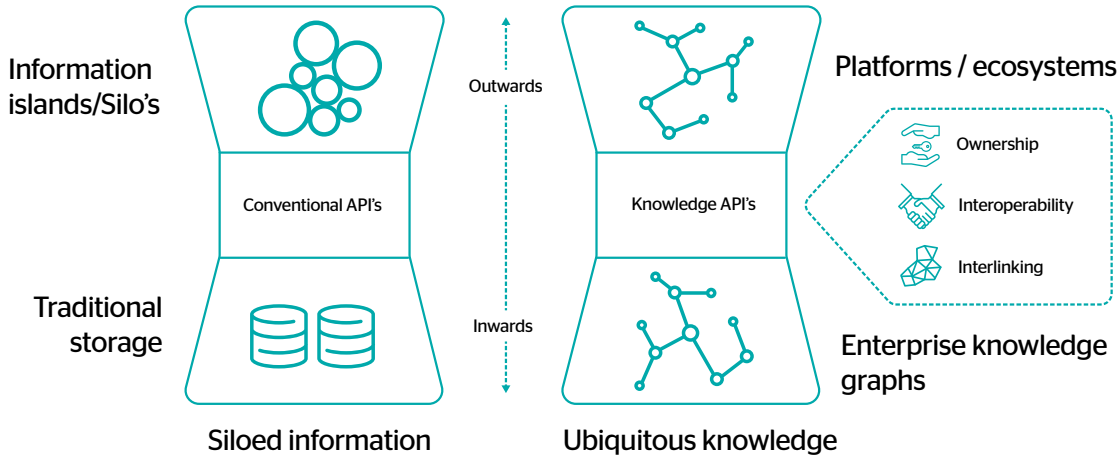


Figure 7: The shift from siloed information to ubiquitous knowledge.

SOFTWARE TRENDS

A 2019 survey[1] demonstrated that elite DevOps groups achieve more than 100 times faster "commit to deploy" lead-times compared to low performers, clearly highlighting the competitive advantage of good software development practice. Leaders in this area demonstrate mastery of new architectures, hire developers with relevant softskills, explore AI to boost efficiency, and push DevOps to new domains.

Redefining the software frame of reference

The world of software development is evolving at a relentless pace:

- Application boundaries are blurring, with extended business logic using exposed APIs, outcome-driven service levels and seamless lifecycle management.
- Software disaggregation is being exacerbated by micro-service architectures, containers and 'function as a service'.
- The proliferation of IoT and Edge devices, and the advent of 5G and swarm computing is accelerating spatial distribution along with the nature and scope of use cases.
- AI/ML and quantum computing are beginning to coexist with traditional programming. As a result, slow-moving standards bodies are being displaced by consensus from user communities, who promote and supersede de facto standards.

We expect established software models to be replaced by multi-layer models of hardware abstraction, mesh and communications management, resource management, security management, generic data processing, and customized business logic. Digital enterprises that strategically focus on those layers where their competence lies, and partner for the rest, will outperform their competition.

2024 developer role

Professional software developers are facing a productivity and predictability challenge, driven by the need to maintain a balance between ever-changing specialized technical capabilities and increased focus on business value.

This requires advanced, professional developers with broad technical and non-technical skills. However, with a growing demand for professional developers (doubling every five to seven years), 30% to 50% of those developers have less than five years of experience. Managing teams through standardizing on restricted subsets of programming skills and tools adversely impacts the potential to leverage new innovations, and so is a sub-optimal strategy.

Leading development teams will work together to re-structure their artifacts and leverage artificial intelligence to master the complexity and productivity challenge.

The rise of the co-engineer

We have already seen the rise of digital assistants in the consumer world and can expect similar AI-based assistive technologies to become virtual co-engineers, supporting software developers at every step of the lifecycle.

AI and ML are already widely used in software quality assurance and R&D processes automation. For software development, massive data sets (such as Github, which hosts more than 100 million code repositories) can already be harvested using ML and AI. We expect

[1] DevOps Research and Assessment (DORA, now part of Google), 2019. https://services.google.com/fh/files/misc/state-of-devops-2019.pdf

the rapid increase of intelligent recommendation[2] services that help developers write quality code and optimize application performance.

Over the next five years, we will see the steady evolution of virtual co-engineers. Starting with specific tasks like coding suggestions, they will extend to cover complex tasks like component-level code generation, visual design validation and identification of analysis deviation in design language or style. This will lead to new low-code platforms enabling developers to assemble AI-generated components with higher-level language constructs[3].

These techniques will not replace the need for skilled developers but will significantly accelerate routine development tasks. Virtual co-engineers will help re-focus developers on the tasks which only they can do. Experienced development teams will re-align their processes to maximize co-engineers for design, code, QA, and other SW lifecycle tasks.

DevOps embracing security, no-code, NoOps

The old paradigm of "bigger eats smaller" has changed to "faster eats slower". Combined with the co-engineer, Agile and DevOps will further transform into new organizational setups.

Security by design will become an integral part of the DevOps process to harden software against cyberattacks, complementing the live AI detection of anomalous behaviors.

"No-code" and "low-code" will be an integral part of DevOps cycles, enabling creation of business services without developer skills being the bottleneck.

With improved levels of maturity and acceptance, AI will be pervasive through the DevOps pipeline, and new methods will be continuously refined. AI will also replace human-defined rules by more autonomous and adaptative diagnostics, decisions and remediation capabilities - resulting in a change from DevOps to "NoOps".

The secret of success

Benefit realization from new technology is amplified by continuously adapting software development and operations practices. High-performing development teams will require the right balance of skills: domain gurus, fast composers (that reuse modules and services), and connectors (able to bridge multiple business domains and cultures). These craftspeople will rely on AI help to increase quality, usability and security. Businesses able to embrace such approaches will have the greatest potential for competitive advantage in the digitalized world.

[2] e.g. AWS codeguru, beta in 2019 (https://aws.amazon.com/codeguru/) or Codacy services (https://lp.codacy.com/)
[3] "Toward artificial intelligence that learns to write code", MIT, June 2019. http://news.mit.edu/2019/toward-artificial-intelligence-that-learns-to-write-code-0614

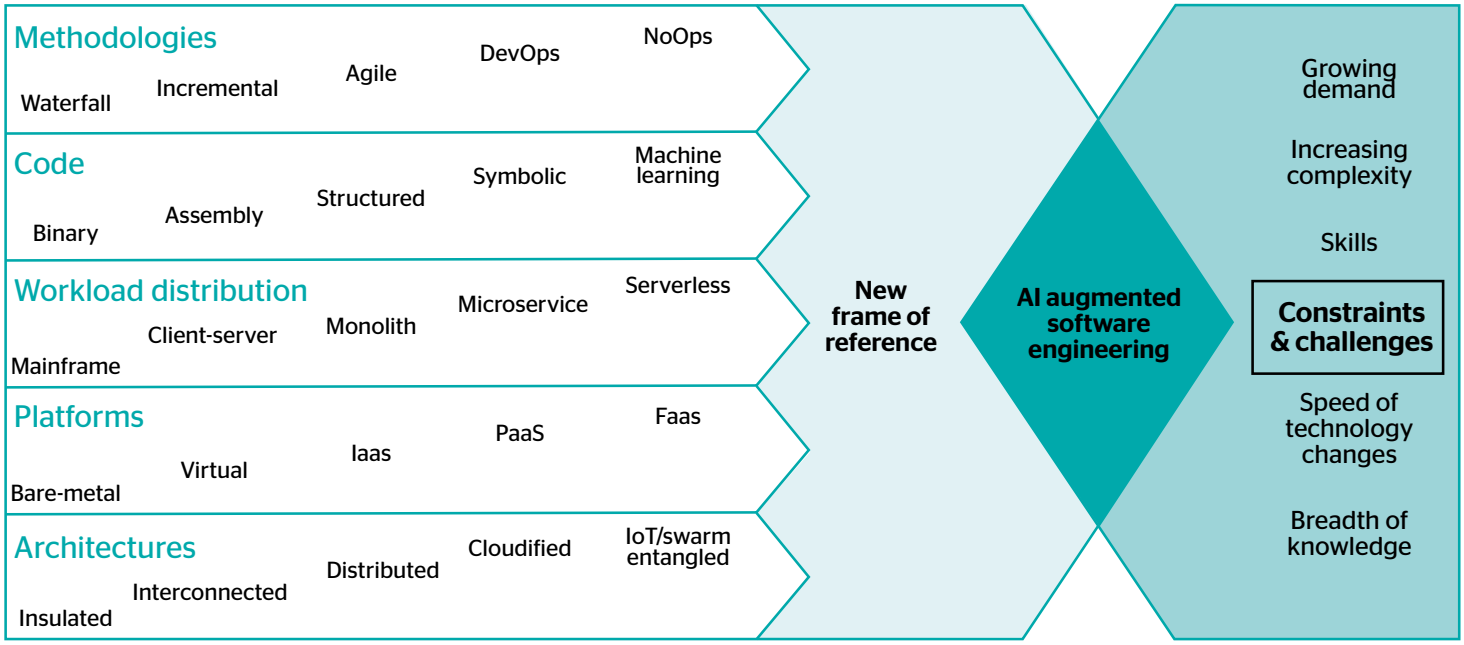


Figure 8: The evolution and convergence of software trends.

BEYOND SUSTAINABILITY

By 2024, it will be clear to organizations, citizens and governments, that efforts to retain conventional socio-economic norms are not compatible with sustainable models. However, businesses should already be pre-emptively thinking beyond sustainability; acting collectively to pursue regenerative models and enduring behavorial change.

It may not always seem to be the case, but the last century has brought positive humanitarian progress in many areas: extreme poverty has been reduced, some diseases such as smallpox have been eradicated and fewer people die in wars[1]. But progress has not always been to the benefit of all. The economic models that created health, wealth and prosperity in the past are not sustainable, because they have led to consumption levels that are outstripping the rate at which the planet's resources can be restored. This includes the problem of our Greenhouse Gas creation and the urgent need for decarbonization of operational processes.

To enable the transition from the polluting and damaging technologies of the past, businesses will have to develop new models and digital tools to predict their future environmental impacts. They will also need to help their customers and staff to see the benefit of embracing the required changes with more urgency.

Failure is not inevitable

There are many examples of regenerative practices that prove that unsustainable approaches can be avoided. Examples include re-wilding projects like the Masarang Foundation[2] in Indonesia and the Greening the Desert programme in Jordan[3] both of which have restored habitats and increased biodiversity. The impressive results of these programs demonstrate that it is possible to restore ecosystems and return profits and benefits to local communities.

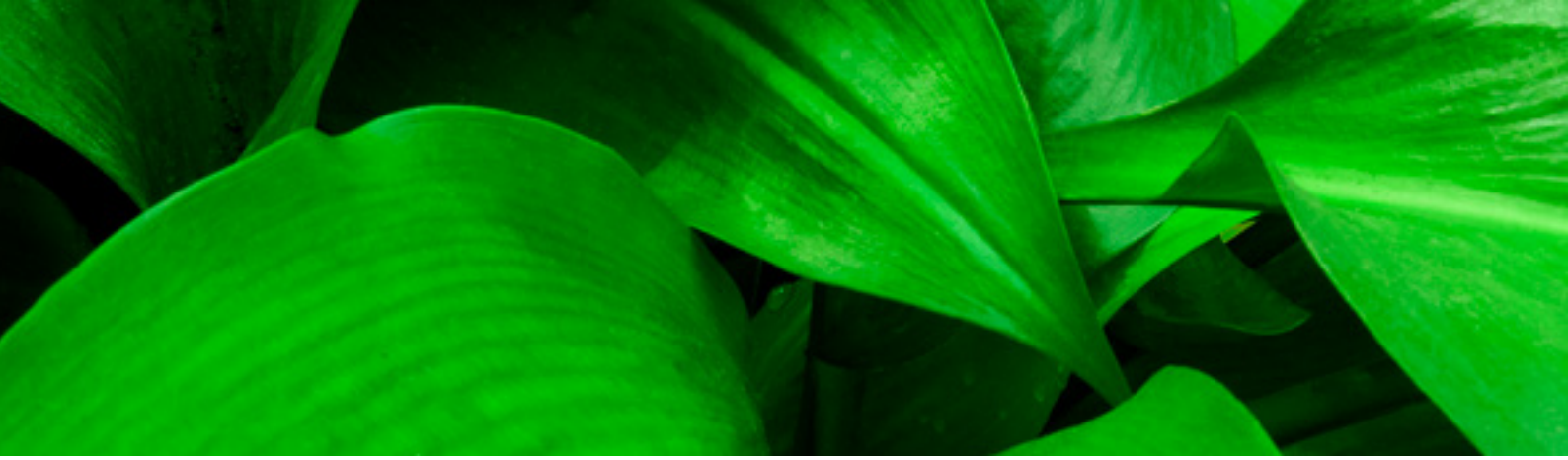
While these examples of small-scale programmes are inspiring, they cannot by themselves make enough impact to reverse the damage caused to the planet by human development. They raise obvious questions for individuals, governments and business, including:

- How can mindsets and behaviors be changed to unite efforts at a scale that make a real difference?
- How can business ecosystems be developed that will give field workers and local communities the necessary access to experts?
- What are the technologies, tools and techniques that will enable us to achieve change?

Can technology alone solve the problem?

Is it possible to change direction without losing the progress we have already made in health, wellbeing, education and prosperity? The response to the current COVID-19 pandemic would suggest that it is possible to make rapid and significant changes, when forced to. For example, the technologies deployed to facilitate homeworking are already having a positive impact on global emissions and the carbon footprint from business travel.

[1] http://www3.weforum.org/docs/WEF_Globalization_4.0_Call_for_Engagement.pdf
[2] https://masarang.nl/en/what-we-do/reforestation/
[3] https://www.middleeasteye.net/discover/desert-green-jordanians-frontline-climate-change-turn-permaculture



Beside this, some traditionally polluting industries steps are already being taken, such as the repurposing of the La Mède oil refinery to produce biofuels and clean hydrogen[4]. Technology can be an enabler, but it is human engagement that provides the inspiration for change.

Decarbonization

In today's linear economy, there is a disproportionately small cost impact to businesses that create unsustainable CO2 emissions. In the future, economic models will be required that reward regenerative and sustainable practices, including carbon capture.

But tackling the problem globally and comprehensively will need us to think differently. We will need to change economic models, regulations and wider societal value systems. In part, this can be achieved through:

- Developing new business models which intrinsically generate lower greenhouse gas emissions.
- Virtualizing and eliminating physical operational processes through AI, automation and Digital Twin technologies.
- Encouraging adoption of industry digital platforms that support new ecosystems for sharing and collaboration, and lead to multi-sided markets for GreenTech, surplus power or heat and new energy sources such as clean hydrogen.

A new way to measure economic success

The way that businesses target success needs to be changed. For decades, profitability and economic growth have been the primary measures of economic success. But if these measures reward organizations for creating the threat of damaging Event Horizons then new tools are needed - a shift from traditional metrics that reward growth and consumption, toward those that value a regenerative culture. The Value Balancing Alliance developed a model which aims to "empower decision makers to create and protect long-term value"[5]. With financial support from the EU, over the next three years, they will develop standards to value and measure the environmental impact of companies. The more that such standards become accepted, the greater the value of regenerative cultures in both emerging and technologically advanced economies. Successful corporations will be those that actively work toward restoration of ecosystems and environments, rather than those which solely consume them: Products and services must ultimately become Regenerative by Design.

In conclusion

Digital services businesses need to take a leadership role in developing and proposing tools and models which will deliver against decarbonization targets. This will foster a new business climate that focuses on actions that help reverse the effects of climate change and overconsumption of raw materials.

By leading the shift from technologies and mindsets which have created the problem, toward those which will begin to regenerate environments and ecosystems, we will create new jobs, tackle inequality, and help restore the future for generations to come.

[4] https://cleantechnica.com/2019/07/07/total-reopens-la-mede-oil-refinery-as-biofuel-facility/
[5] www.value-balancing.com

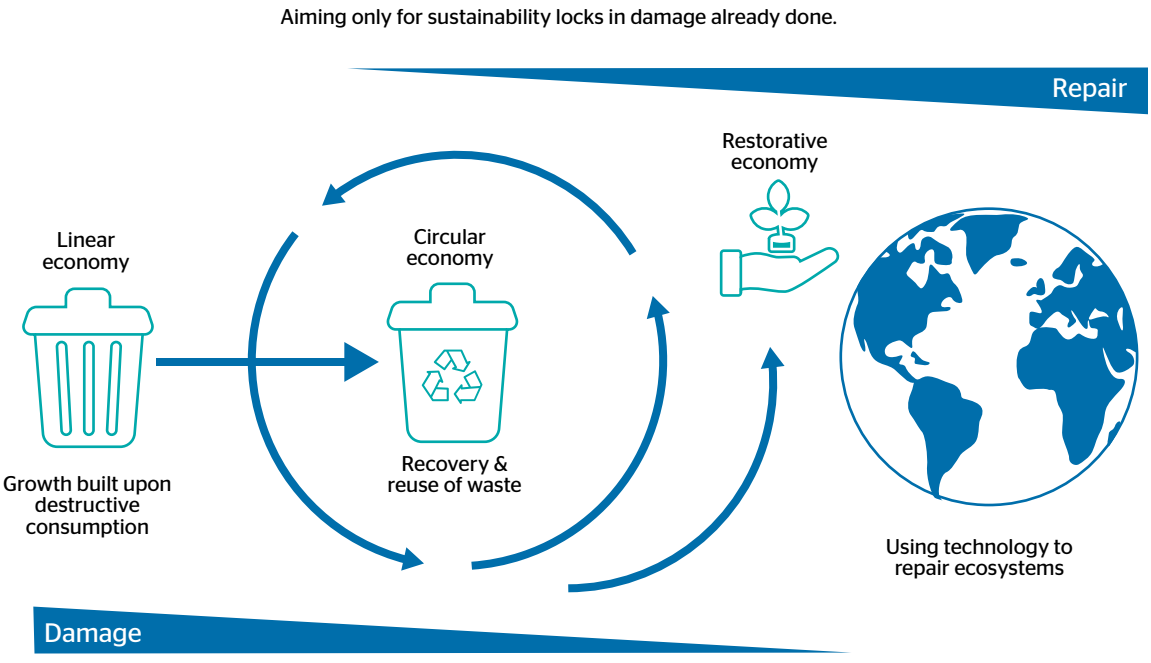


Figure 9: Moving to a restorative economy.

SOCIO-ECONOMIC AI

Artificial intelligence (AI) is becoming one of the most powerful and disruptive technological developments ever, with autonomous systems being increasingly perceived as key drivers for economic growth. Individuals and companies will need to determine how to adapt to, and benefit from, the new possibilities, whilst at the same time recognizing the threats and risks they present. This will require an understanding of social impacts such as the substitution of employees by automated processes, unfair decisions due to biased AI algorithms, traceability of outcomes, personal privacy, or even malicious use of automation.

In alignment with our core vision in this Journey, we need to rethink how and why we use AI. And with the accelerating capabilities and quality of AI technologies, we must understand their possible side-effects and incorporate measures for socio-economical consensus in our usage strategies.

Guiding the AI journey

The term AI covers a multitude of disciplines: assisting, enhancing and replacing human cognitive tasks in the next generation of intelligent automation, and bringing new levels of data insight. As we see various AI technologies becoming more sophisticated, there is an increasing trend to combine techniques from different domains, creating contextual AI that incorporates personalization and automation. This will make AI applications more powerful and capable of application in ever more complex use cases, but it also increases the responsibility on organizations to consider how AI will be used.

Although the aim of AI is often to enhance services and solutions for users, there will be significant questions to address in relation to wider impacts on society and economies. Toward 2024, AI will mature from a "trial-and-error" process in specialized and siloed domains, to a more industrialized and cross-domain approach, requiring new methods, guidelines and laws.

As AI technology domains expand and merge, it is important for each organization to evaluate its current position and development trajectory compared to other players in the market. Will the successful strategy for a particular use-case be that of an AI disrupter, leader, early adopter or smart follower?

Dimensions for the successful application of AI

There are six core dimensions that influence the wider Socio-Economic impact of AI adoption (see figure 10). These are complemented by increasingly important governance and ethics oversight. Taking this holistic approach to understanding the influence of AI and related technologies will enable organizations to navigate their AI journey in the most successful way.

To respond to such a multi-dimensional challenge, organizations will find it helpful to have toolsets that simplify the assessment of maturity and feasibility of AI programmes at key stages in a product's lifecycle. This enables teams to reflect on their current and expected future maturity levels, facilitate early identification of risks and evolve/share best practice. Maturity assessments also enable a product to

be positioned in the context of industry-wide trends and inform the need for, and compliance against, industry AI standards. This helps organizations to understand, plan, develop and deploy AI solutions for the most impactful socio-economic outcomes.

It will become a key responsibility of organizations to implement and maintain methodologies to fully consider the social and economic dimensions. This will require a maturity framework to incorporate lessons learned across a broad range of AI use-cases. As technology and access to data is progressing rapidly and people's expectations of AI change, companies will have to take extra care to maintain the balance of the socio-economic dimensions. These reviews will need to be validated at key stages to maintain the right balance throughout a product lifecycle.

What's next

AI will drive significant transformational change in the way that businesses operate and how their services are consumed.
We believe the current state of automation is a precursor to the "Intelligent Enterprise", where data-driven automation is applied at large scale, with ancillary functions and decision support progressively moving to semi-automated and trusted solutions. This will dramatically increase the speed at which decisions can be made and actions taken (we have already seen in Financial Services how manual stock trading has moved to algorithm-based High-Frequency Trading). Such levels of automation demand careful regulation and control to avoid unwanted side-effects.

We need to build trust and preserve empathy and humanity when automation is continuously learning and adapting. Confidence is essential when we encounter the unknown, and there should be possibilities to provide feedback and allow for manual intervention, where necessary for the greater good.

AI will increasingly be used to address some of the world's biggest socio-economic issues such as supporting environmental sustainability, and improving health and wellbeing. Organizations will need to continue developing increasingly mature and advanced AI-based solution methodologies and toolsets to balance the dimensions of technology and data with the social and economic implications - at the same time reflecting the impact of the levels of Automation Intelligence being applied and the target demographics.

"A successful adoption of AI is one where all dimensions are balanced and collectively deliver to the organization's purpose."

An imbalance in AI maturity results when, for example, an organization values technology and data progression over economic and social factors.

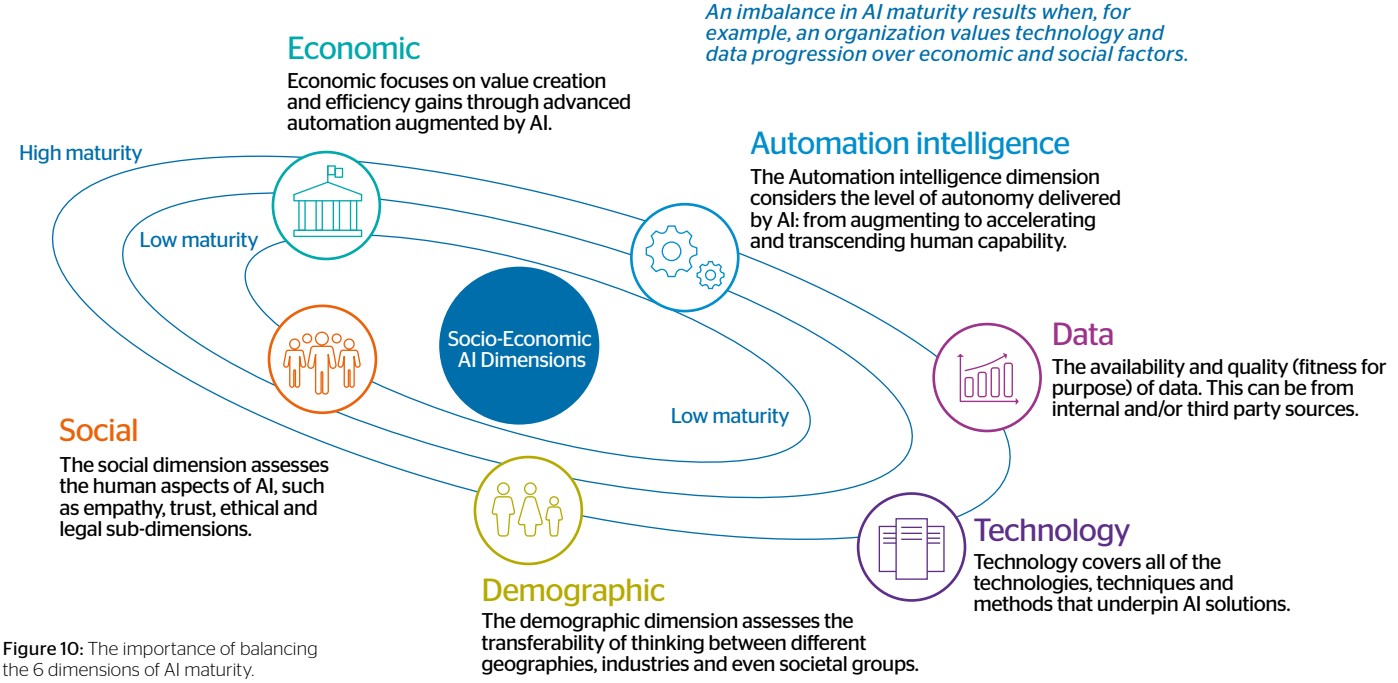


Figure 10: The importance of balancing the 6 dimensions of AI maturity.

QUANTUM IT ECOSYSTEM

At the start of this century, a benchmark was created to compare quantum computers (QC) with classical supercomputers using a 'fair' method that established a measure for 'quantum supremacy'. However, it did not take into account the practical usefulness of the problems being solved. The value of QC as an enabler for new technologies and concepts is determined by its capacity to perform useful work – and it is practical use cases which will drive the emergence of a quantum IT ecosystem by 2024. Successful applications will help re-kindle some of the previous wavering investments, bringing game-changing potential in the way systems collaborate, how security is maintained, and what we define as hard compute problems.

2024 will see the maturation of quantum technologies on many fronts: For example, understanding their limits, robust business cases, practical quantum programming languages, first quantum networks, and commercial applications of Hamiltonian solvers[1]. Initial feasible applications of QC might be seen in areas dealing with optimization challenges that require a lot of computing power. Other applications will simulate advanced chemistry, supporting pharmaceutical research and precision healthcare.

International life science company Bayer used QC clustering and optimization techniques to identify comorbidity causes and learn more about cancer cell behavior. First practical results showed significant performance benefits of QC and led to novel insights. This allowed further refinement of their Quantum strategy.

In Journey 2022, we used the term 'Quanta-ware' to describe the emerging quantum IT landscape; we now add quantum networks to this definition. The merging of classical and quantum computing landscapes will lead to a new set of practical challenges.

Challenges of quantum computing

The end of the 2010s, saw a rise in practical applications of QC's, particularly in Health, Finance, Defense and Manufacturing. The ability to set apart the far-fetched PoCs and create concrete market applications, resulted in a stronger focus on use-case development, even from hardware producers.

Where we are able to bridge the gap between an understanding of technology potential and their application to business demands, we get true insight into the capability and limits of QC. Maintaining a strong business focus will facilitate QC adoption and even lead to "Outcome as a service" applications that utilize quantum computing power in the background.

With the increased adoption rate, a greater demand for mature programming languages arises. By 2024, investments in existing QC applications and a more 'quantum' mindset amongst programmers and computer scientists will have led to new practical guidelines for application and use-case development. They will have turned quantum programming into a mature and more accessible profession, with powerful programming languages far beyond today's gate play.

[1] A function used to solve a problem of optimal control for a dynamic system

Quantum computers perform calculations based on probabilistic superpositions of an object's state instead of using just 1s or 0s. They have the potential to simultaneously process all possible outcomes to a problem.

Advent of the quantum internet

Integrated energy company EDF developed better algorithms for optimizing electric vehicle smart charging and battery revenues. Using a high dimensional Quantum Approximate Optimization Algorithm and Rydberg Atom Arrays they were able to perform complex calculations exponentially faster than is possible with classical computers.

The first experimental quantum networks (QNs) are being launched in the EU around 2020/2021. Unlike QC, where a minimum number of qubits is required to perform practical work, a quantum network can operate with just a handful of qubits. This allows for applications such as; a universal end-to-end quantum key distribution network, long term (~weeks) storage of quantum information (See Figure 11), and other quantum cryptographic and synchronization protocols.

QNs stand to solve some existing challenges today but will also introducing new game-changing concepts for how we use IT to communicate, secure and understand data. Just imagine what we might discover if we were able to interconnect radio telescopes equipped with quantum sensors, to create a zero-noise detection array.

Most current practical use-cases for QN's in security, and synchronization are "few qubit applications" which will work even with rudimentary enablers. QNs will therefore see a faster adoption rate than QCs. The rich possibilities of QN encryption schemes, and other quantum cryptography applications, are a strong motivator for quantum network deployment.

Diversification of the quantum IT ecosystem and improvement of its networking components enable further quantum applications to become a reality. For instance, the relatively young 'quantum neural network' concept, would allow for a new type of AI. Such 'Quantum Intelligence' is both encouraging and frightening to imagine.

Conclusions

2024 will see the adoption of diverse quantum technologies, driven by business impact. Quantum networks will begin to reshape present day cloud infrastructures, and, leveraging this same infrastructure, QCs will cause a software-driven revolution in practical applications. The quantum IT ecosystem will solve practical challenges not yet addressable and will discover new ones. Quantum Supremacy is a strong contender for a technological Event Horizon, but only if it manages to practically address and solve real-world societal and business challenges.

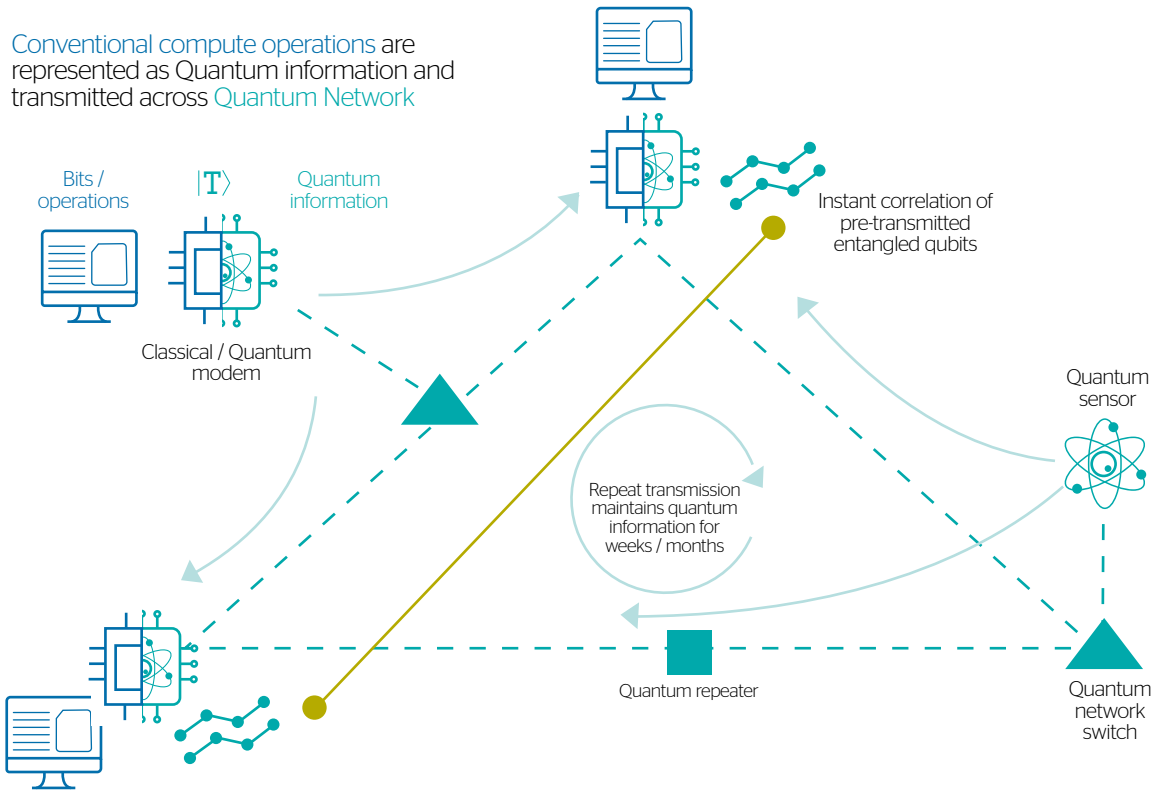


Figure 11: A conceptual representation of the quantum internet.

COLLECTIVE

"Connection, sharing and network effects are the hallmarks of many systems of digital value. Scale of adoption is a critical success factor for the effective and efficient application of digital technologies."

SPATIAL COMPUTING

The fourth shift in interaction with data, our environment and each other

Spatial computing involves digital integration of the virtual and the real, via rapidly evolving technologies. Its impact will be so significant that it is best described as the fourth shift in the way people interact with the digital world, following the personal computer, the internet and the smartphone.

What is spatial computing?

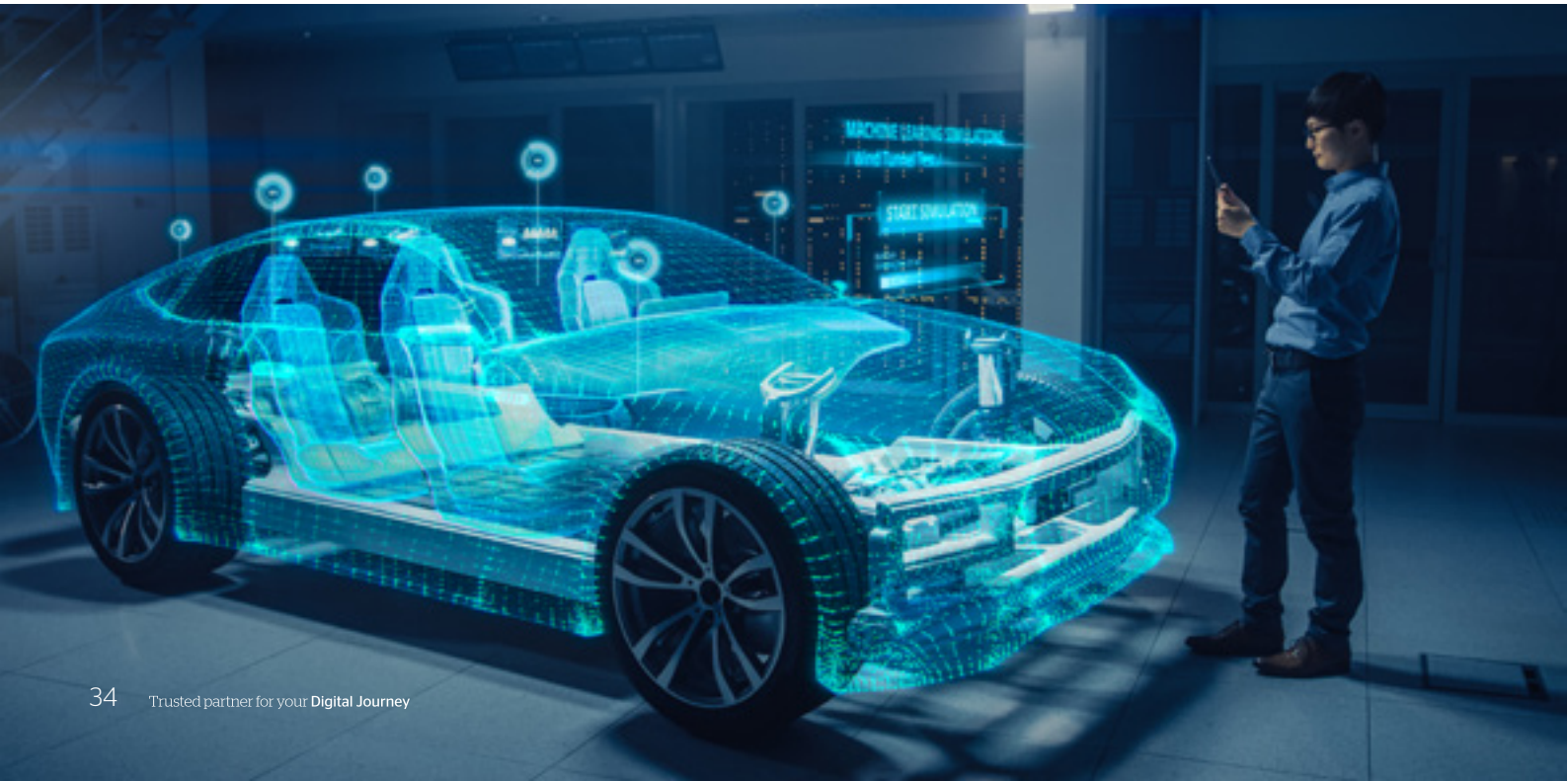
Spatial computing builds on the visionary idea of "The invisible computer", originally introduced by D. A. Norman in 1998. Norman proposed a generic information appliance which meets specific user needs in an intuitive but non-invasive way. The appliance's design becomes an integral part of the task, with hardware becoming almost imperceptible, and the Spatial Computing software layer left as the primary point of user interaction. Such a vision demands an immersive user experience that blends virtual compute interfaces into the physical world. It will use technologies like augmented and mixed reality but will take them to a more profound and comprehensive level for business applications.

Spatial computing will have five major foundational capabilities:

- **Spatialized visualization/augmentation** allows spatially aligned volumetric visualization of virtual content blended into a physical environment. Smart glasses (such as Microsoft Hololens) already enable on-the-fly spatial mapping of physical environments and facilitate virtual content placement within the user's field of view. In the future, environmentally integrated technologies are expected to support natural sensory experiences, where the device itself becomes embedded into the user's physical surroundings.
- **Context aware adaptability** uses feedback from the user and their situation to autonomously adapt virtual content to changing needs.
- **Natural user experience** allows interaction with applications and virtual content using gesture-, voice- and eye-tracking interfaces. This helps transform software and its content into lively spatial information objects, allowing users to trigger content animations, dynamic process visualizations, and virtual model decomposition.
- **Service integration** supports the interaction of Spatial computing software and virtual content with other digital sources and remote IT services. It enables a very natural user interface for a wide variety of data related services. Integration of remote rendering overcomes some of the computing limitations of local devices by using shared compute resources to present large virtual models and scenarios. Spatial computing will become one of the best suited UI technologies for digital twins and other types of data lakes.
- **Shared immersive experience** allows the collaborative sharing of virtual content in real-time. Collaboration sessions will bridge augmented, mixed and virtual reality space, even allowing remote participants to be visualized as avatars.

Where are we today?

Spatial computing is still in its early infancy, both from a technology and business application perspective. However, with some key-technologies already available (e.g. real-time spatial mapping, eye and hand gesture tracking, natural language processing, diffractive optic smart glasses), the journey has started.



What to expect in 2024 and beyond?

By 2024, Spatial computing is expected to reach technological and commercial maturity. It will provide dynamic and interactive photorealistic models, augmenting our physical environment and interlinking both digital twin and local environmental appliances.

Automotive industries will be one of the early adopters of such technologies, offering navigation and information support for car drivers through spatial head-up displays. Virtual content visualization will be spatially aligned with the driver's environment giving a more natural presentation of information.

Engineering and Manufacturing are also expected to be early adopters using virtual prototyping to cut down development costs and time-to-market. With the ability to blend real-size virtual models into a real-world environment, virtual prototypes have the potential to replace their physical counterparts. Virtual model dynamics and Hardware-in-the-Loop simulation will facilitate fully digital testing and product demonstration. Collaborative engineering, remote marketing and even sales activities will be transformed.

Healthcare and Life sciences will quickly follow, utilizing the potential of spatial computing to transform patient files into patient digital twins. These avatars will be constructed using data from body scanning technologies and monitoring devices. They will allow remote patient consultation and care using shared patient models to improve the understanding of medical treatments. Holo-overlays of patients with avatar models will facilitate surgery preparation and remote support for operations.

Defense industries have launched large R&D programs to support mixed reality collaborative battle-spaces to increase information superiority and shared situational awareness. By 2024, we will see applications such as shared holo-maps for preparing missions and briefing commanding officers in joint operations. Front-line soldiers will get "field of view" situational information, offering tactical advantage within the battlespace.

Other industries like Telco, Energy & utilities, Smart cities, Gaming and Entertainment will adopt spatial computing to remarkable effect.

With the wide range of applications, we do not expect a common platform or unified technology stack for spatial computing. Instead open reference architectures, standards, products and software development kits will emerge. The resulting capabilities will be a strong differentiator to enhance products, offerings and business services.

"Tomorrow's advances in visualization and digital interaction will be radically different from what we have grown accustomed to through conventional interfaces."

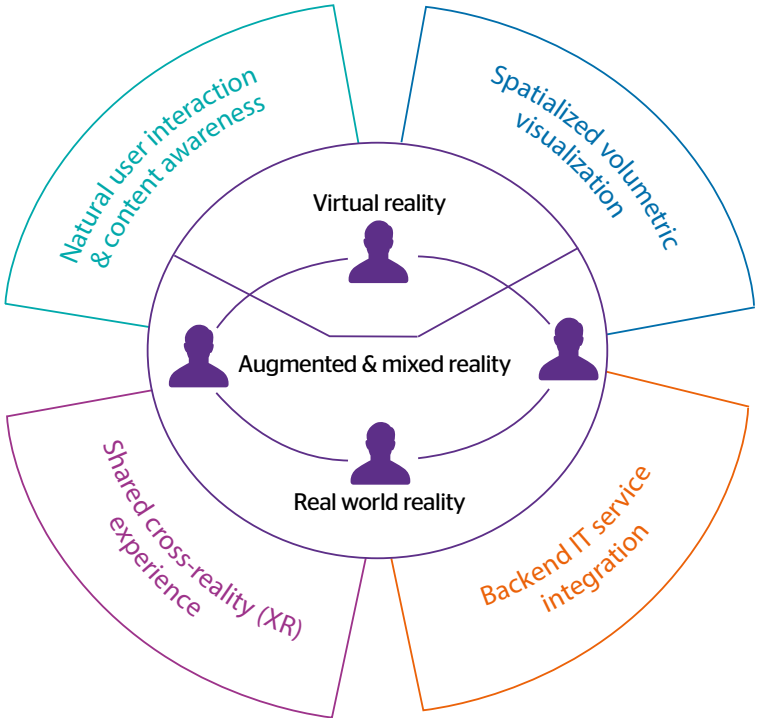


Figure 12: Making digital media feel physically present in a cross-reality environment.

DIGITALLY-ENABLED PRECISION HEALTHCARE

For some time, the healthcare industry has been challenged to develop new strategies to meet the demands of a growing and rapidly aging population with an increasing number of chronic diseases. We now see an additional and urgent focus on public health to manage pandemic episodes.

It is increasingly evident that technology is a key enabler that helps bridge the gap between research and healthcare delivery. High Performance Computing (HPC) capabilities are giving a better understanding of the influence of environmental, behavorial, psychological and biologic factors on health outcomes – this will be further enhanced through Quantum Simulation. The Internet of Things (IoT), AI and analytics enable connected and contextual monitoring and care. Robotics and nanotechnologies offer transformational ways to administer personalized treatments.

In addition to the technology-driven opportunities, there are transformations in models of care through new reimbursement structures and provision approaches, brought on by changes in provider-to-provider and provider-to-patient engagement strategies. Furthermore. evolving views on data privacy as well as accountability for health-impacting behaviors are influencing approaches to healthdata sharing and utilization.

The data dilemma

Many healthcare providers and consumers already recognize the potential value of sharing data. But, the post-pandemic digitally-enabled world may well allow personal medical data collection and sharing in ways that defy previous norms and beliefs. Such a change could bring more accurate and timely diagnosis and treatment of diseases, and a better understanding of the impact of behavorial and social determinants on an individual's health. However, it would also raise very difficult ethical and procedural challenges. Data vulnerability in this digitally-enabled scenario must be mitigated by solid cybersecurity that protects the privacy, integrity and confidentiality of individuals.

If these opportunities and challenges can be appropriately reconciled, we will move toward a world of data-enabled precision medicine that is **predictive, preventive, personalized and participatory.**

Predictive

Omics technologies (e.g. genomics) play an integrated role in healthcare and pharma environments. They will lead to preventative strategies and the acceleration of drug developments based on individual genetic profiles. **Fast whole-genome sequencing** will help save the lives of unborn and new-born babies suffering from rare syndromes, where swift diagnosis is a key factor for survival. Predicting the outbreak and spread of diseases (e.g. through contact tracing data) will permit early interventions that may help prevent catastrophic health and economic impacts of the likes we are seeing with the COVID-19 pandemic.

Preventive

Actionable health strategies will be informed by social, behavorial, clinical, image and omics data, enabled by **IoT, edge computing and analytics**[2]. These will allow healthcare ecosystems to be segmented according to the level of risk in developing diseases, or anomalous

[1] https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---01-june-2020
[2] Provided that consensus in data privacy best practice can be attained.

events in the case of diagnosed patients, allowing treatments to be adjusted accordingly. Analysis of differences in the immune response of viruses from different patients, will allow the spread of viruses to be mapped, and the emergence of new strains to be tracked. The availability of digitally-enabled medical devices will move some elements of disease diagnosis, treatment, clinical trial participation, and care management into the hands of the patient.

Personalized

Precision medicine is characterized by the ability to give the right treatment to the right patient at the right time. Pharma and biotech companies have begun to use Quantum Simulation techniques in the pre-clinical stages of the drug discovery process - starting to accelerate the discovery and optimization of lead compounds. **AI methodologies** in the clinical research phase of drug testing are further assisting the clinical trials recruitment process, facilitating the safe testing of new drugs. This is done through monitoring treatment adherence, preventing adverse drug interactions in multi-medicated patients, and supporting pharmacovigilance activities.

HPC simulation allows the dynamic re-creation of virtual scenarios to test drugs and clinical or surgical procedures. It helps reveal specific risk factor combinations, enabling patient-centric care to be incorporated into evidence-based practice. Junior surgeons can train using **virtual and augmented reality (VR/AR)** and robotics systems before performing surgery in a real operating theatre. Invasive procedures are more easily approved as human error is reduced by practicing in virtual rooms. Patient outcomes can also be improved using personalized prostheses produced with **additive manufacturing.**

Participatory

Patient engagement and accountability is essential for improved health outcomes - consider the potential of applications used to collect symptom data and support contact tracing for pandemic management. We anticipate a growth in **persuasive motivational design through mobile apps** to help alleviate pain and promote recovery and support the management of mental health. Patients with chronic conditions will be **monitored with connected digital objects**, including wearables, connected objects and sensors deployed in homes. Such commitment and direct data exchange between the patient and other parties will foster a multi-sided-market "win-win" that is expected to revolutionize the current healthcare ecosystem and operating models.

"The worldwide COVID-19 pandemic is proving to be an Event Horizon that will bring lasting change across the healthcare ecosystem including public health, research, funding, and care delivery entities."

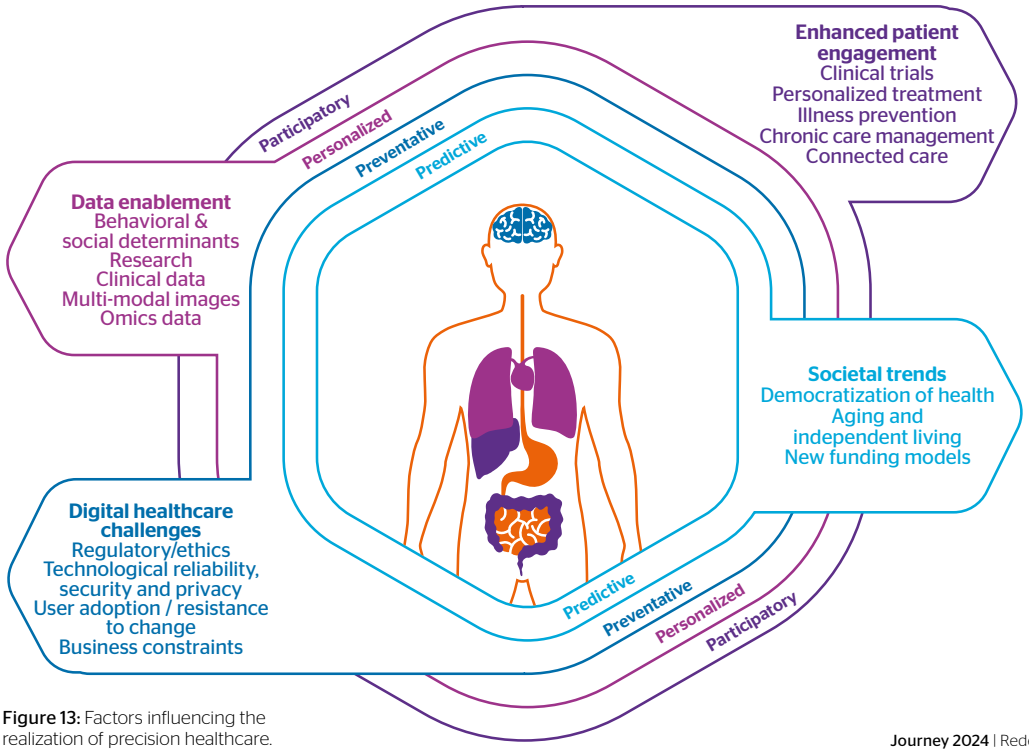


Figure 13: Factors influencing the realization of precision healthcare.

NETWORKS

We are moving toward a hyperconnected world where everything that needs to be connected, always will be connected. Networks are continually upgraded both at the core and at the edge to give more bandwidth, enable increased device density, and reduce latency. This network transformation is a significant enabler of new business models, productivity and efficiency, and also has the potential to support a more sustainable world. The COVID-19 pandemic has made this more relevant than ever by shaking up the way people connect, and businesses operate.

To address the massive scaling issues that result from explosive data growth at the edge, we need a fundamental change of core internet technologies. We believe that by 2024, network technologies will further converge with other digital enabling technologies such as Cloud, IoT, Edge computing and AI, providing hyper connectivity everywhere. This transformation will be led by the rollout of 5G and WiFi 6.

Trends and potential challenges

Business models have evolved. We have learnt to expect low cost connectivity and freemium services. New economic models have been built around the ability to reach billions of users through their connected devices. These online models are now extending to all parts of the economy in the form of digital business platforms. Networks have become critical infrastructures for industries that depend on high availability, low latency and instant recovery from failures.

Upgrading existing networks is no longer enough. To manage the continuously increasing traffic, Connectivity Service Providers (CSPs) will have to extend their networks with new micro sites or small cells, adding further cost and complexity for providers who are already having to simultaneously accommodate up to 3 generations of technology.

The pace of technological developments for network solutions, virtualization and end-user applications is increasing rapidly. The latest access technologies are enabling the rapid growth of new convergent services. Information Centric Networking will help overcome some of the limitations of host-based IP networks and address the massive scale and security challenges coming from IoT[1]. Intelligent **network, service orchestration & virtualization** will be essential for managing increased complexity - and will force CSP's to build in the context new organizational capabilities and become much more agile.

Regulation and standardization will continue to play important roles in ensuring interoperability and competition within the industry. Technological development must be set in the context of social and environmental responsibility. While interconnectedness will drive the development of technology and business models, there is a need for standardization and regulation through the work of bodies like 3GPP and ETSI. Platform ecosystems will emerge which will help support and enforce standards & regulatory frameworks.

Plans to install new infrastructure for 5G and other future networks may meet resistance. Radiation norms set by local governments can be a barrier to the deployment of new networks. Scale, speed, reliability and quality must be balanced against human health and environmental impacts. Governments will have to consider these concerns and align regulatory frameworks and the granting of spectrum licenses to reflect an appropriate balance.

The environmental impact of hyper-connectivity shouldn't be underestimated. More bandwidth will inevitably further increase the demand for high quality streaming services, and consequently cloud datacenter power consumption.

[1] https://hal.archives-ouvertes.fr/hal-02189504/document

Business impact and benefits

New co-operative business models will encourage CSPs to share infrastructure with other players. We can expect a wave of new disruptive solutions that look to exploit the resulting "virtualization" of communication services. There will be a re-balancing of value propositions from CSPs, cloud, content and application providers as new partner ecosystems are formed to delivery truly end-to-end services.

Operators will need to look beyond existing business models as margins for B2C network services are progressively squeezed. We may see a shift to B2B2X models, where e.g. 5G services are provided to partners for bundling into other services, with the resulting value being shared across the ecosystem network.

The low latency and massive device density offered by 5G extend the potential for collective ecosystems to concepts like smart cities. Connected infrastructure will be orchestrated in real-time to respond to specific needs e.g. improve managing people or vehicle flow to reduce congestion and improve safety. Industrial automation will move to a new level of efficiency through the networking of Edge computing, industrial IoT, and Digital Twins.

For consumers too, there will be benefits of reliable connectivity that supports more deeply immersive experiences through new applications in areas such as health, remote maintenance, gaming and collaboration in the workspace.

Conclusion

Converged connectivity solutions are at the heart of digital business. As user experience is increasingly determining the success or failure of digital services, end-to-end connectivity from the user to the provisioning ecosystem must become an integral part of service design.

Infrastructure upgrades are likely to lag behind the growing demand, and need to be compensated by intelligent orchestration of connectivity through innovations such as Information Centric Networks. Network service providers need to adapt their structures to deliver highly segmented, industry solutions that provide the necessary resiliency, security and performance.

"Digital industry brings new competitors to the Telco industry resulting in a delicate balance between multiple stakeholders looking to find viable business cases."

SMART GRID 2.0

Sustainability is a topic that is moving from being a hygiene factor for responsible businesses, to a fundamental driver of strategy, policy and culture. But in the Energy sector there is related set of megatrends that also demands a response:

- Decarbonization of energy supply to reduce contributors to climate change.
- Digitalization of energy networks and connected devices.
- Mass electrification of transport, heating/cooling and industry[1]
- Energy network decentralization to increase network efficiency.

As patterns of generation and consumption change, the approach to maintaining a balance between supply and demand must adapt. This will be very evident in the mass electrification of transport, particularly cars, lorries and trains, but eventually airplanes as well. Even a modest number of 100 electric vehicle rapid-charging points at a motorway service-station, requires a 5MW supply (roughly what is needed for 2000 households[2]). Achieving this within the constraints of established legacy networks is a significant challenge. In response, we will see the emergence of energy networks that are no-longer dominated by a discrete number of large producers, but where businesses and consumers become prosumers[3]- generating and consuming heat and power throughout a network of microgrids.

The rise of micro-grids

Microgrids are power installations that can run independently from, or in tandem with national grids, typically by harnessing "local" clean energy sources such as solar, wind, biofuels, etc. Advances in renewable energy generation technology continue to drive down their cost of installation and management, in fact new modular microgrid designs use shipping containers to enable faster deployment by eliminating expensive on-site installation and wiring. The growth of sustainable microgrids will bring a transformational change in the energy ecosystem.

The initial focus of smart grids was the incorporation of intermittent renewable electricity generation into national transmission and distribution grids. Notable projects have achieved power grids with over 80% renewable contribution (Denmark[4] for instance) – something that was thought impossible a few years ago. Of course, many challenges remain, including the integration of large offshore windfarms that require high voltage transmission corridors with storage capacity for managing the variability in generation output.

Utilities are increasingly recognizing the need for new microgrid models that are not limited to electricity supply, but are also able to integrate district heating, cooling, and power-to-gas (giving new impetus to hydrogen fuel-cells). Such approaches are too complex to be managed at a global network scale. Instead, cities and large

[1] increasing overall electricity demand by 18% over 10 years - EC data
[2] https://www.nrc.gov/docs/ML1209/ML120960701.pdf
[3] A person which consumes and produces a product (https://en.wikipedia.org/wiki/Prosumer)
[4] https://www.greentechmedia.com/articles/read/does-denmark-hold-the-key-to-integrating-large-amounts of-intermittent-rene

enterprises are beginning to champion local initiatives that seek to deliver smart approaches to energy provision e.g. Toshiba in Japan[5], Paris with the Olympic games[6], and the Stanford project[7].

The need for decentralization

The interoperation and balance between global transmission networks and microgrids will be heavily dependent on emerging edge (IoT) technologies and effective and secure use of the resulting data. The need for a holistic view of such data may be the catalyst for establishing multi-sided industry data platforms for sustainable energy supply and service innovation. For example, "Consumer to grid", "Building to grid" and "Vehicle to grid" services piloted in the Salzburg Smart Grid Model, integrate a range of datasets in a comprehensive information model. Derived insights enable management services for apartments and vehicles, including billing portals, scheduling of maintenance appointments, and building-load management.

The security challenge

The decentralized nature of power generation sources, distribution outlets and digitally-connected consumption devices, opens a whole new set of possible security attack vectors. It is crucial not to make the same errors as with the world-wide-web, where security was essentially an afterthought. Assets that were previously deemed to be secure because they were in a physically secured environment, must now be protected against a wide array of attacks. Small and highly distributed edge devices must be identifiable and able to establish trustworthy connections. Just imagine a malicious attack on millions of devices which are abused for synchronized charging and discharging of power collectors– similar to the hack of millions of home internet routers, which were used for Denial of Service attacks. This could severely damage not only the electricity grid, but also put enormous strain on heating and cooling networks connected to it.

However, distributed microgrids will also bring their own security benefits: when thunderstorms struck Germany in 2020[8], small distributed photovoltaic power plants were able to switch to "local mode" and continue supplying electricity to local households until damaged powerlines were fixed.

A long-term vision

This vision for a new digitally-enabled microgrid network is ambitious but is a critical part of addressing the decarbonization challenge. As with most long-term investment scenarios, early action brings the greatest benefit. Steps taken in the next 4-5 years will be critical to achieving declared 10-30 year carbon emission targets. This demands a strength and commonality of purpose, across governments, industries and consumer communities - one that exploits the potential of digital technologies as being part of the solution, instead of just part of the problem.

[5] https://www.toshiba-energy.com/en/env/index.htm
[6] https://www.paris2024.org/en/a-pioneering-ambition-for-the-environment/
[7] https://sustainable.stanford.edu/campus-action/energy
[8] https://www.pv-magazine.de/2020/02/12/e3-dc-speicher-sichern-notstromversorgung-der-haushalte-waehrend-sturmtief-sabine/

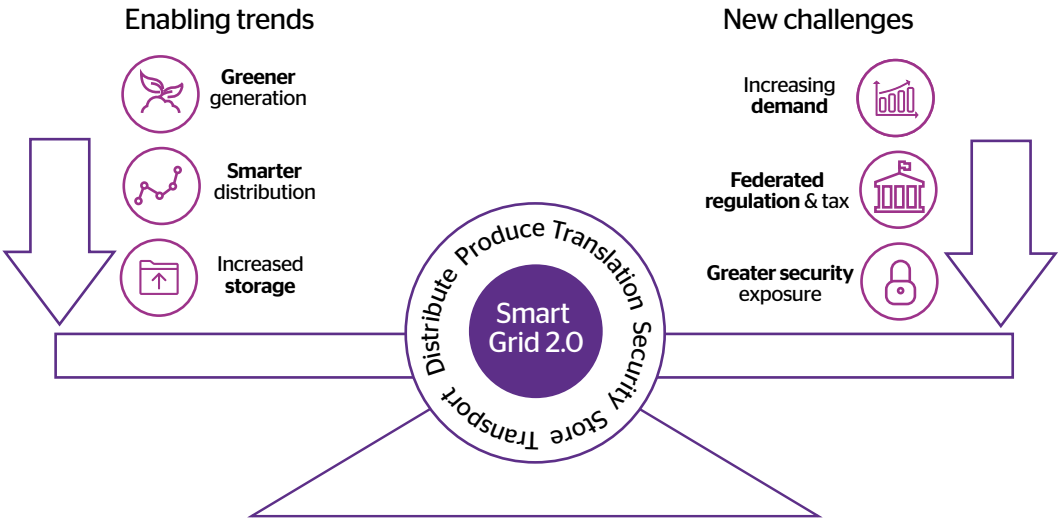


Figure 14: Balancing the challenges and opportunities of future energy management.

EDGE & SWARM

Cloud and Edge computing has already transformed IT services, providing rich computing environments on-demand and with pay-per-use models. Now we are witnessing the emergence of the next wave of disruption: as Edge computing evolves to swarm intelligence.

Edge computing breaks the barriers of the data center, intentionally spreading compute and data resources to locations near to data origins, e.g., IoT sensor installations. This proximity minimizes latency challenges and avoids the drawbacks of large data transfers. This helps enhance system performance and address certain data regulation issues. **We see Edge computing as the first step toward an even more decentralized model: Swarm computing**[1], which we anticipate to be the next breakthrough innovation in digital infrastructures. Swarm computing brings together edge components (e.g., smart objects, dedicated edge compute nodes, micro data centers), and multiple cloud platforms in continuous co-operation[2]. Applications are executed by ad-hoc self-formed and self-organized teams of distributed and different objects.

Cloud, Edge and Swarm computing enable a more extensive diversity and distribution of applications and services, through emerging AI eco-systems, e.g., by Edge execution of AI models developed in the Cloud.

Swarm intelligence

Conventional Edge computing thinking tends to treat IoT devices merely as sources of data. However, advances in FPGAs, GPUs and TPUs are transforming IoT sensors into smart objects, with increasingly sophisticated capabilities that offer considerable compute intelligence and storage power. Exploiting these advances, swarms embrace the concept of the collective collaboration of heterogeneous resources achieving consensus for self-management within a common purpose. **A Swarm is an autonomous entity that orchestrates and embeds distinct autonomous objects, embracing the power of the collective and acting according to a common goal.**

Together with our **strategic partner Siemens**, we have shown how decentralized, self-organized interaction between Edge computing devices, autonomous guided vehicles, and computer vision applications can bring new levels of dynamism to the Industrial field. With Swarm, the need for devices to be pre-configured can be avoided and will deliver plug-and-play scalability.

Other cooperative system developments in artificial intelligence have been the main inspiration behind the Swarm Computing concept. It will mature further to become more self-contained, i.e., exhibiting features such as self-adaption, self-healing, and self-configuration.

Swarm computing will begin to emulate instances of **swarm intelligence**[4] that exist today in areas such as the optimization of factory operations[5]. For example, the management of multiple paint booths in a truck manufacturing facility uses mechanisms that are inspired by the way that bees allocate workloads. Every paint booth is seen in the role of a worker bee, queen bee, or nursing bee. In the event of (e.g.) an unscheduled interruption, the paint booths achieve consensus to alter their defined roles to complete the required task - just as in nature where nursing bees feed hungry worker bees for the collective benefit of the hive.

[1] https://atos.net/en/blog/computing-beyond-edge-welcome-swarm
[2] Atos presented a reference architecture for this Swarm Concept in Journey 2022 - https://atos.net/wp-content/uploads/2018/12/atos-swarm-computing-white-paper.pdf
[3] Field Prgrammable Gate Arrays, Graphical Processing Units and Tensor Processing Units
[4] https://atos.net/wp-content/uploads/2020/01/atos-swarm-intelligence-white-paper.pdf
[5] https://www.educba.com/swarm-intelligence-applications/

Evolution of Swarm

Our research has focused on the application of the Swarm concept in vertical industries (Manufacturing and Retail) and on the analysis of different dimensions that cover the maturity and evolution of swarm solutions:

- **Instantiation** - analyzing how objects are empowered to participate in swarms.
- **Operation** - dealing with mechanisms and processes for effective resource orchestration; Service swarms have to inherit self-organization, self-management, and auto-scaling of service quality.
- Swarm **Environment** takes into consideration data privacy, security, and energy footprints.
- **Tasks** address the task objectives and the interrelation between compute swarms and AI.
- Systematic development, configuration, and operation of swarm-based systems will be supported by a **Digital Twin for swarms**, defining mechanisms for modeling, simulating, and testing task behavior before and during physical realization.

Anticipated adoption roadmaps

We perceive Edge intelligence and Swarm will reach the first level of maturity and adoption by 2024, in particular, for infrastructure driven use-cases.

- Edge in Manufacturing and Utilities will allow pre-processing of large data volumes to predict and optimize processes close to the IoT sources. New swarm use-cases will emerge for connected factories, robotics, and automated guided vehicles.
- Telco companies, which are key enablers of Edge-Swarm, will also have their operational use cases, e.g., Network Function Virtualization.
- Transport and Logistics will see self-driving systems and smart roads combine as a connected transport environment.
- Public Sector and Defense will see changes in the way that citizens interact with public services (Smart Transportation or Smart Waste), or in the deployment of Autonomous Defense Systems.
- Healthcare and Retail will use smart edge devices to improve customer interaction and personalization.

Despite the current lack of standardization and credible security frameworks, technology providers from startups to hyperscalers are entering the Edge market with a rapidly evolving set of solutions and services. By 2024, we expect a degree of consolidation of reference architectures, which will include the derivation and execution of ML algorithms at the edge, Improving reliability, privacy and efficiency. Use cases will expand and incorporate enhanced analytics and AI features. The impact of the 5G network rollout will undoubtedly alter the Edge-Cloud balance again, further building the case for swarm.

Figure 15: The evolving dimensions of swarm computing.

SMART PARTICLES

The smart particles of 2024?

On a quiet Sunday in 2024, a group of college students sets off on a caving expedition. They venture a mile into the belly of the earth, when suddenly a part of the tunnel collapses behind them. Fortunately, in case of emergencies just like this, the students are equipped with "smart rescue particles". The house-fly sized mini-drones are released and work their way through the cracks between boulders, rocks and other debris that are blocking the way out. The smart particles choose their pathways independently but keep in touch with their swarm via a lightweight, limited range transmission protocol, creating a network throughout the cave system. As the particles work their way out, they collaboratively inspect the cave walls and ceilings, exploring fissures, cataloguing their structural make-up and capturing information about the layers surrounding the blockage. Data is eventually transmitted back to a rescue control hub and used to create a virtual representation of the cave system. Simulations are run to discover how tunnelling through the blockage can be safely accomplished. With a rescue plan devised, twenty-four hours later, the students are leaving the cave safe and sound.

Other smart particles are working at an airport nearby, entering a turbofan that is under maintenance. They inspect internal engine components, stitch together captured images, and update parameters in the plane's digital twin. Once the plane is back in use, In-flight data from the engine's standard telemetry, allows digital twin simulations, running on the aircraft's onboard computers, to predict stresses exerted on the fan blades under prevailing flying conditions. This allows the plane to be flown within the safest and most fuel-efficient parameters.

2020: Where do we stand?

Whilst the above stories may seem far-fetched, such things as "agribots" already exist, capable of independently roaming fields, monitoring and predicting potential crop yields, removing weeds and killing parasites. They work in coordination with drones that survey and analyse environments from above. Drones are also currently deployed to gather intelligence on battlefields, measure temperature and monitor high risk and inaccessible areas.

By 2024, we anticipate a potent mix of self-learning intelligence, miniaturisation and independent communication, accelerating the cost-effectiveness of smart particles and expanding their use-cases.

"Imagine: Swarms of tiny smart sensors, moving independently in coordinated action ..."

Technology trends toward 2024: ever smaller and smarter

We can assume that for the next decade, smart particles will remain visible to the naked eye. The next phase, true smart dust, depends on several technological developments coming together. Processors have become steadily and exponentially smaller; and we have seen massive advances in micro electro-mechanical systems (MEMS). Transducers (sensors and actuators) are already available in the micrometre range and the field of nanotechnology continues to attract high investment.

However, our research shows that the real challenge is with the energy density of batteries, which has only been improving by around 3% per year. There are hopes that quantum computing applied to quantum chemistry might bring the required breakthroughs in the not too distant future[1]. Research and development in swarm and edge may also accelerate innovations in smart particles.

Beyond 2024: Opportunities and risks of true smart dust

By the 2030's, smart particles may develop to the point where they are invisible to the casual human eye - imagine a small grain of sand 0.1mm in diameter. At smart dust size, more use-cases will become possible. For instance, in healthcare, smart dust could enter the circulatory system for micro biopsies, targeted drug delivery, or microsurgery.

However, a future with smart dust could be somewhat dystopian if the associated risks and potential for misuse are not controlled:

Privacy is one of the more obvious risks - in fact, the concept of Smart dust[2] originated with military surveillance. The potential of smart dust that can lodge itself on clothing or enter private residences undetected, transmitting audio, video, and other information about their surroundings would be real.

How will smart dust (or even smart particles) be collected after their usefulness has ended? Will smart dust simply become a new form of pollution? If smart dust can drift or flow in an uncontrolled manner, how will we ensure it does not end up in food chains, or human physiological systems? Should those who release smart dust be responsible for its safe and ethical reclamation? What kind of governance is needed to monitor and control such responsibilities?

Ensuring innovation readiness

Timeframes for the adoption of technology are governed by a complex mix of technical feasibility and commercial, political and social viability. Enterprises should track the technological precursors, keeping miniaturization and the concept of smart dust on their innovation radar. Mainstream applications for smart particles and smart dust require innovative readiness and strategic choices, but they could turn out to be game changers.

[1] https://www.cell.com/joule/pdf/S2542-4351(18)30182-X.pdf
[2] "Smart Dust: BAA97-43 Proposal Abstract, POC: Kristofer S.J. Pister". berkeley.edu.

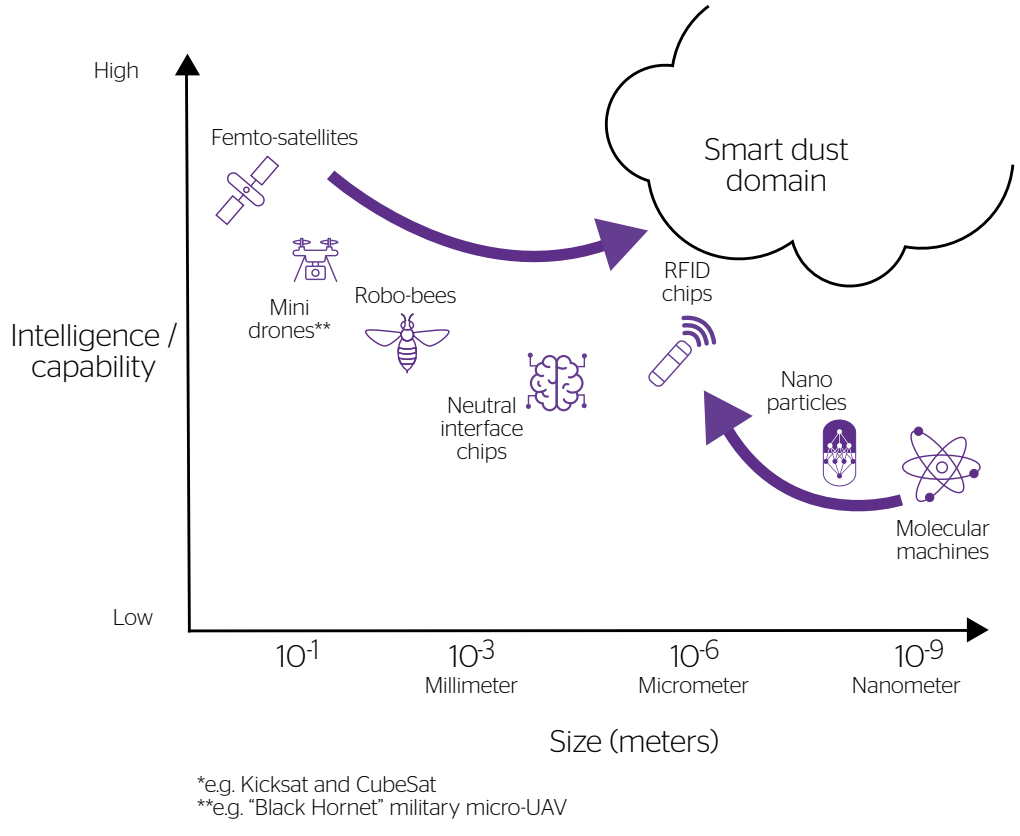


Figure 16: The paths to "smaller and smarter".

CONSENSUS

"Trust is a key enabler of digital interactions. As data-value ecosystems become more distributed, diverse and transient, trust is increasingly established through consensus."

ECOSYSTEMS OF TRUST

Globalization is often a contributing factor to complexity in business relationships: rules of cooperation can be unclear and dynamic environments make it difficult to maintain trust and transparency in transactions. Whilst business leaders may recognize the potential of exchanging data insights with partners, customers, regulators and even competitors, their desire to control processes and value in such exchanges brings into focus the perceived risks of collaboration. Open distribution of data lacks basic trust mechanisms, often creating friction in multi-stakeholder processes, and leading to knowledge silos. Conversely, trusted ecosystem collaboration can enhance agility and innovation, streamlining business models and costs.

This conflict has created one of the greatest dualities of the digital age: **control versus collaboration.**

Ecosystem platforms

Ecosystem platforms are technology environments which facilitate trustful exchanges of data, services and value between otherwise distrustful parties. They facilitate services beyond one single value-chain or organization, creating a common language for infrastructure, networks, data and process rules. This allows ecosystem platforms to enable services such as data analytics, API management and machine learning beyond traditional enterprise boundaries.

To collaborate around shared services and value it is usually necessary for interacting parties to achieve consensus on the current state of transactions. This traditionally requires a neutral intermediary to incentivise and manage the sharing. However, ecosystem platforms attempt to establish a baseline level of trust through explicit accountability, transparency and ownership of value, enabling transactions to take place in a frictionless and collaborative environment. The diagram in figure 17 classifies ecosystem platform characteristics against these requirements:

- **Distribution of control** – ensuring that ecosystem governance is not monopolized by one single party. This avoids the negative influences coming from owning a majority of the data, customers, or value-added services within an ecosystem.
- **Validity of data** – ensuring that data is accurate, authentic, tamperproof and regarded as the single source of truth for all ecosystem participants.
- **Traceability of transactions** – ensuring visibility of relevant data and processes for permissioned parties. This enables greater levels of collaboration and trust when sharing value.

The past decade has seen progression in both the technical maturity and business cases of the solutions identified in figure 17. It is their application within ecosystems which is expected to disrupt business models as we venture into the new decade.

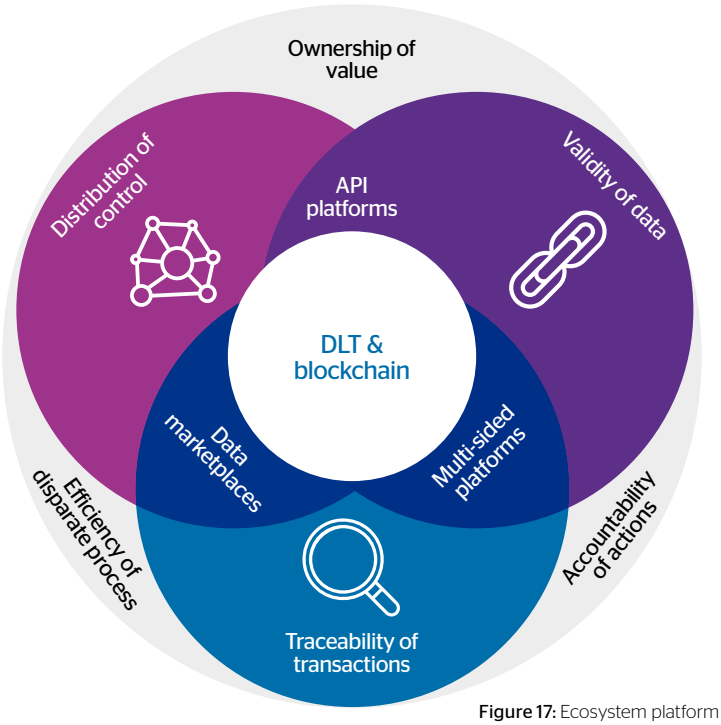


Figure 17: Ecosystem platform categorization.

Bridging the trust gap

Businesses are not traditionally accustomed to thinking in terms of ecosystems. The culture of companies has tended to competitively control processes and maximize their own value in each exchange. Relinquishing control increases risk. This has been the dominant culture for centuries and is a difficult mindset to overturn.

Despite this, we are starting to observe a growth in emerging consortia, like B3i[1] in insurance, International Data Spaces, and Origin[2] in food supply-chains. Even when formal consortia are not involved, projects like OpenAPI bring standardized APIs to encourage the creation of ecosystem services. Nevertheless, the cultural shift is slow, and benefits from collaborations should be monitored closely to boost further consortia adoption.

The change in mindset will be significantly influenced by regulators - they will attempt to incentivise collaboration through legislation that encourages ecosystem thinking. For example, financial services regulators have already laid the foundations with the introduction of PSD2 in Europe[3]. Over the coming decade, the value derived from this directive will come into fruition and other industries will adopt similar models for their own markets. Collaboration focused regulations can provide the certainty that companies require new approaches and foster innovation. But it may be that some jurisdictions lack the risk appetite, leaving it to industry organizations to take the lead.

Basic business platforms are relatively simple to govern, usually bringing together a set of stakeholders with a similar vision. When you elevate such platforms to an ecosystem level, a new set of challenges appear through conflicts of interest and power struggles between different participants. Ecosystems that fail to articulate a consistent purpose will not realize their full potential. To ensure mutual purpose, a governance structure that reflects the following considerations must be adopted:

- Balance accountability and responsibility between members of the ecosystem.
- Design an incentive mechanism that keeps the ecosystem evolving and thriving.
- Manage participant lifecycles: onboarding, conflicts, sub-parties, exit strategies.

A way forward

Redefining the construct of trust to meet the complexities of today's business landscape is essential. Only then will organizations successfully balance collaboration and control, addressing problems at the ecosystem rather than parochial level. This is the bedrock from which trust ecosystems can flourish.

A technology solution for trust:

Distributed Ledger Technology (DLT) is a ledger-like data structure synchronized across multiple parties. Blockchain is a sub-variant of DLT which bundles transactions on the network, enabling verification of data, and providing trust in peer-to-peer interactions.

[1] https://b3i.tech/what-we-do.html
[2] https://origin.bureauveritas.com/
[3] https://www.finextra.com/blogposting/17438/psd2-what-is-it-and-what-does-it-mean-for-fraud

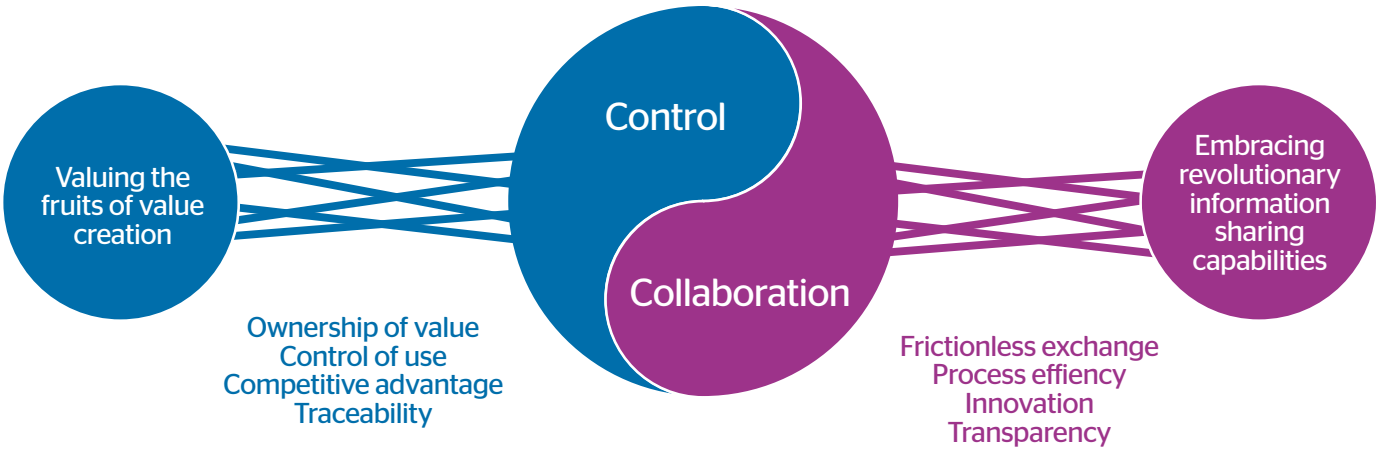


Figure 18: Duality of the digital age.

EXTREME PERSONALIZATION

The desire to personalize our environment for aspects such as comfort, efficiency, accessibility and safety is a part of human nature. Historically, achieving this was relatively labor intensive and limited to physical features. However, technology developments, are making the reconfiguration of both physical and virtual environments easier, faster, more extensive, and less costly. Some degree of customizability is now an expected norm in many aspects of our daily lives.

One consequence of the proliferation of consumer centric technology is that each individual user will probably interact with several customizable devices, each of which must be configured and managed separately. "shared economy" models will add further complications as objects need to be re-configured to suit each different user's preferences. The seamless and efficient orchestration and customization of a wide variety of devices, while remaining ethical in the way that individual's data is managed and used, will be a major challenge.

Extreme personalization in action

Environments that adapt to an individual's needs has been a goal of accessibility and assistive information technology for many years. The vision is of a device agnostic roaming profile that automatically configures user interfaces to meet personal requirements.

This might be in terms of the way information is presented (e.g. font-size and contrast, audio output, and haptics) or input (e.g. keyboard configuration, voice control, and physical gestures). Advances in "smart devices", sensors and network connectivity allow this goal to be extended to a wider range of physical objects.

Imagine an office space that responds to the needs of an individual. Could the space be context-aware and adapt in real-time, as required by individuals, groups or changes in circumstance? Imagine a scenario where you arrive at an office and the hot desk adjusts the ambience to meet your pre-defined preferences. Or meeting rooms automatically adjust their layout to cater for meeting type and number of participants; whilst AI analyses participants' engagement levels and stress, adjusting the ambience accordingly. Such smart offices can be expected to promote productivity as the digital workplace concept evolves beyond the limitations of the "one size fits all" approach we have been constrained by to date[1].

Extreme personalization will also become the norm in transportation. Vehicles will allow automatic driver specific adjustment of seat configuration, controls, mirror position, air conditioning settings, dashboard display, navigation preferences and even suspension and engine modes. While some of these features are currently available in high-end models, more mainstream adoption will become particularly important with the growth of the shared economy and the decline in personal ownership.

[1] Ayral et. al., Smart Desks to Promote Comfort, Health, and Productivity in Offices: A Vision for Future Workplaces. Front. Built Environ., June 2019. https://doi.org/10.3389/fbuil.2019.00076

Enabling extreme personalization

To realize the potential of extreme personalization, several factors will have to be addressed such as: user identification, authorization and privacy; data standards; security; and overall user confidence.

There are several ways in which end-users can authenticate their identities, including biometrics, NFC (Near Field Communication) tags, and online user credentials. The principles of password free authentication are well addressed by the FIDO2 project[2], but creating a seamless personalized experience across multiple disparate environments adds further complication.

A multi-sided "service personalization" platform is a potential solution to protect and manage the use of sensitive data across multiple configurable environments. The platform will have to support two types of objects: network-connected objects which will interface directly with the platform, and nearfield communication objects which will access it via a proxy (typically a smartphone app). Regardless of access method, the platform will generate configuration instructions specific to a user and target object. For example, a desk identified by a given NFC tag will receive a request to adjust for a specific "desk height".

[2] https://fidoalliance.org/fido2/

The platform will use AI to interpret unknown or undefined parameters. For example, the "desk height" may not be explicitly stated but can be inferred from the user's preferred "chair height". The platform will learn from the user's behavior: if it estimates the desk height incorrectly (causing the user to subsequently adjust it), then the platform will store the new "desk height" preference, and also improve its predictive algorithm.

To ensure appropriate levels of data privacy, users will need full control over how their data is shared, used and retained, and whether specific authorization is required before it can be accessed. A user might be happy that their preferred desk height is shared without explicit confirmation (to provide the most seamless experience), but they may require that other more sensitive information is only shared with their explicit consent.

While many of the technology building blocks required to move from smart devices to extreme personalization already exist, there is currently no overarching infrastructure design in place to support extensive use case realization. But the blockers are not insurmountable and by 2024 we expect extreme personalization to be the norm in many aspects of day-to-day life.

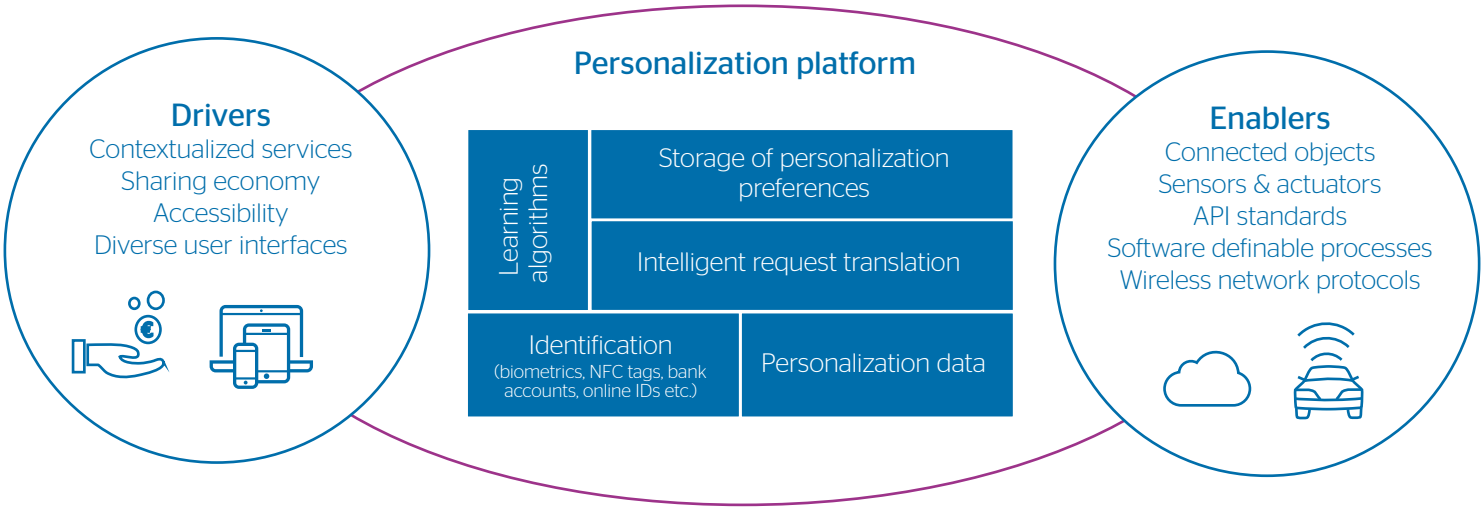


Figure 19: Drivers and enablers of extreme personalization platforms.

ETHICAL DESIGN OF INTELLIGENT SYSTEMS

Ethics driving the redefinition of enterprise purpose

The focus of Information Technology has evolved over the last two decades from being mainly a business support function to an essential driver for business value transformational. This trend will only increase further as artificial intelligence and intelligent systems are more widely adopted.

As intelligent systems start to become deeply embedded in the critical processes that govern our businesses and lives, the potential impact on our societies is both unprecedented and unknown. New "hybrid" organizations that combine human and artificial intelligence in automated business models will demand a re-evaluation of the basic elements of ethics like trust, consensus and fairness.

Organizations will need to advance beyond a mere "formalization" of Ethics by Design methodologies for individual solutions, into a broader scenario that requires a **redefinition of enterprise purpose**. Purpose should be defined in a context of the **organization's principles of ethics** and reflected in its **ethics corporate policy statement** and corporate governance.

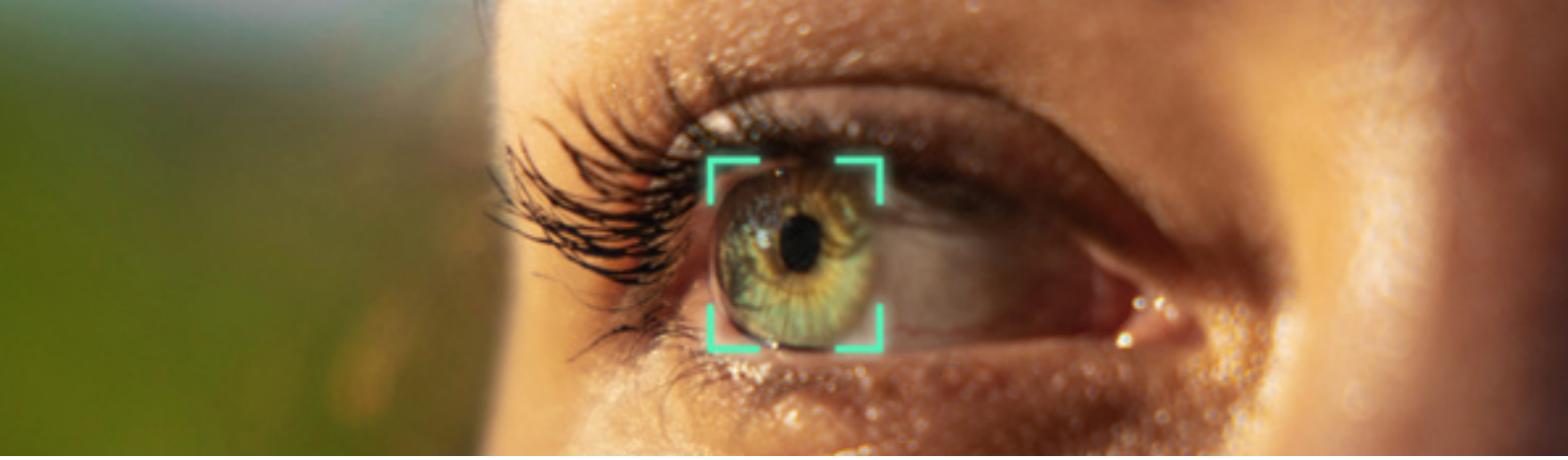
The goal is to offer internal guidelines for the organization, which incorporate the views and values of the collective organization, but also serve to engage with society in a flexible way, as ethics and values evolve over time.

Combining design thinking and ethics

Organizations must put ethics at their core, to ensure a balanced perspective on strategy, tactics and operations. Figure 20 represents the lifecycle that guides the transformation of Enterprise Purpose, driven by an Ethics by Design approach. The entire process is cyclical and iterative, and should embed ethics principles at all stages, always reflecting on "for what purpose are we doing this?".

Organizations will branch out from strategic redefinition to tactical implementation of the transformation through product developments and new services. This will require adoption of Ethics by Design implementation methodologies that address the different dimensions of Intelligent System development. These might include new AI tools (for bias detection or AI explainability), Data Science methods (guidelines and checklists), corporate governance (such as ethical advisory boards for AI) and even internal cultural change programs (addressing topics like inclusion and accessibility).

This transformation cycle will be influenced by external dynamics. New technology solutions (facial recognition, citizen tracking, health analytics, autonomous vehicles) will be progressively adopted, requiring governments to actively formulate relevant new laws and regulations. In the short-term, coping with situations like COVID-19 may involve thorny ethical debates (e.g. the legitimacy of contact tracing apps). Longer-term, generational changes in society may fundamentally reshape our ethical perspectives.



A framework for "Ethics by Design"

To incorporate ethics into the process of designing intelligent systems, it is helpful to work with a set of tools and practices:

- A set of **ethics principles**. As a starting point, these may be derived from existing frameworks, like the *"Ethics Guidelines for Trustworthy AI"*, by the European Union or the OECD Principles on AI[1]. Nevertheless, organizations must maintain a critical approach when deciding which principles to adopt, as they need to be in sync with their own corporate values and vision.
- Tools to support project execution in relation to artificial intelligence and intelligent systems. An initial approach may involve the use of **ethics checklists**, either internally devised or derived from publicly available ones (like DrivenData DEON[2]). These checklists can serve as a "guided inspection" for potential issues in use-cases and their related data sets, as well as for the models that are developed.
- An **ethics dashboard** can be used to monitor the performance of the organization in relation to compliance and realization of its purpose against defined ethical principles and policies. In the future these will become a mandatory part of corporate audits, as new "AI ethics compliance certifications" are introduced in some geographies, like the EU.

These are just some of the practical instruments that can assist in the design and implementation of intelligent systems. It must be noted that whichever Ethics by Design practices are selected, they must be properly embedded in the corporate process and culture. This can only be achieved with the support of a strong change management program, where openness and feedback from employees is an integral part.

Toward the ethical design of intelligent systems

Ethics are not only a means to comply with regulation or gain acceptance by society, they are a key contributing factor to the creation of genuine value for all impacted stakeholders.

Failing to incorporate ethics as core components of the organizational vision, that are meaningfully reflected with operational processes and systems, risks a dangerous "evolution". One that makes a corporate system's governing logic, processes and outcomes unacceptable in our society. This in turn will translate into regulatory non-compliance, a loss of trust from clients and users, and a lack of alignment with the intended company culture, values and vision.

Conversely, companies that successfully embed ethical principles into their enterprise purpose, and embrace ethical design within their products and services, will **help positively lead an era shaped** by intelligent systems.

[1] https://www.oecd.org/going-digital/ai/principles/
[2] https://deon.drivendata.org/

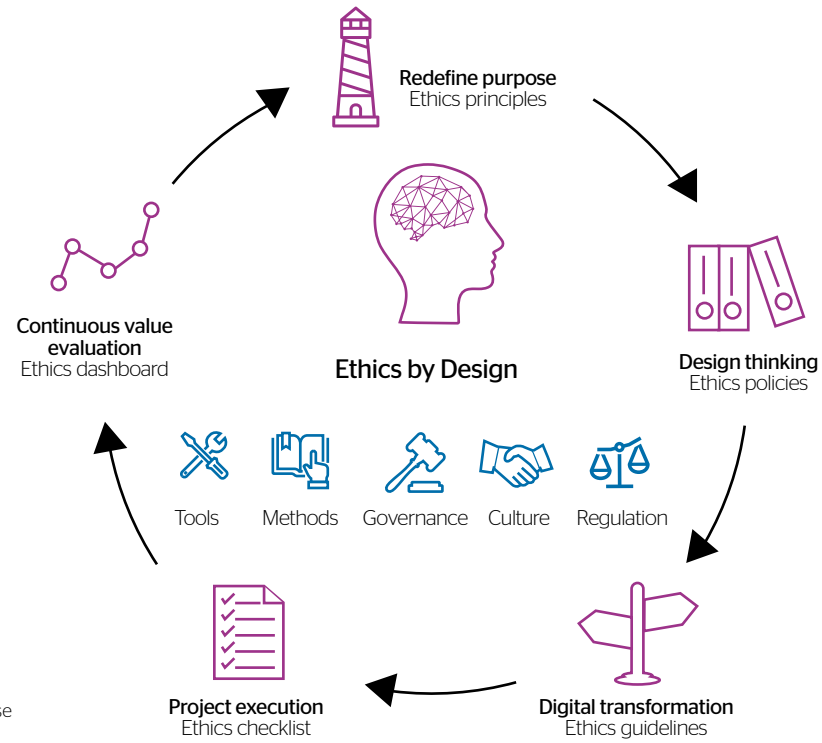


Figure 20: Transforming enterprise purpose with ethics by design.

INVISIBLE SECURITY

The geopolitical divides which our societies are facing have transformed cybercrime into an extremely lucrative business. Its "border-less and visa-free" characteristics are being further fueled by increasing global inequality in wealth and the scale of digital processes, connections, devices and exploitable data. At the same time, cybercrime techniques are increasing in complexity and sophistication thanks to a growth in computer skills and education programs, and global access to technology and networks. Attacker tools are being commercialized and commoditized, with vast improvements in user interfaces, training and support.

In this complex political and economic context, the addition of emerging technologies, such as artificial intelligence, will open another dimension within the cybersecurity playground. Increasing maturity in AI capability is potentially creating unprecedented attack scenarios, catching defenders completely off-guard. As a result, the negative impact of cybercrime on businesses and societies is expected to grow exponentially.

Security practitioners are overwhelmed by the amount of information

Despite the marketing messages around security automation, the reality of day to day cybersecurity operations is still highly human-centric.

Enterprise networks can generate billions of potential security events per day from a wide range of data sources, including security devices, network appliances, connected objects and mobile applications.

This ever-increasing volume of alerts puts an unsustainable strain on security analysts and diminishes the speed and accuracy with which they can process threat data.

This is further aggravated by the worldwide shortage of appropriately skilled security practitioners. A deficit that is currently growing 25%[1] a year, from a cybersecurity workforce gap of 4 million in 2019.

Make the visible invisible to make the invisible visible

AI techniques are now being applied to assist with the prioritization of security alerts and automation of responses, with machine learning models being trained to identify unusual behavior patterns that may not be identified by pre-set rules. Such approaches will significantly reduce the workload on security teams.

AI will help drive cybersecurity to the next level - the Invisible Security paradigm. The previously overwhelming levels of visible information will be dealt with automatically, releasing human security analysts to make previously invisible but critical information more visible.

Cybersecurity will have to be decentralized with security intelligence and automation for decision-making

In a world, where digital connections are no longer confined to traditional IT infrastructures, but are able to span multiple industrial and social environments, cybersecurity will have to be decentralized. Security intelligence and decision-making will be automatic and

[1] https://www.isc2.org/Research/Workforce-Study# (2019)
https://www.isc2.org/-/media/ISC2/Research/2018-ISC2-Cybersecurity-Workforce-Study.ashx (2018)

executed close to data sources. This will allow the rapid self-adaption of controls to cope with ever-changing threat landscapes, different regional data privacy regulations and the devious skills of cybercriminals.

Classic concepts of strict architectural control and technology governance will no longer work with edge computing that is based on decentralized heterogenous mechanisms. Centralized information security, monitoring and policy enforcement approaches will reach their limits and won't scale as needed.

Decentralized "early stage" detection, reaction and effective counter measures are essential to address the fast-growing number of single attack events, and the complexity of inter-networked infrastructures.

Invisible security will adopt AI in a distributed model across all environments

As the capacity and capability of AI decision-making far exceeds those of human analysts, they will inevitably be exploited, leveraged and orchestrated across multi-agent systems that involve a wide range of other technologies. For such a model to become mainstream and efficient, it needs to be integrated into the layer of Invisible Security that runs efficiently "under the hood" both in centralized and decentralized contexts.

Security intelligence and automated decisions will then serve the continuous evaluation of risks and their treatments[2] according to the impact on delivered services. This process is described by NISTs[3] 5 concurrent and continuous functions: Identify, Protect, Detect, Respond, Recover.

While AI for cybersecurity has largely focused on the Detect and Respond functions until now, it will begin to impact other areas via specialized AI agents:

- **Identify AI,** building a comprehensive view of IT configurations and highlighting their risks,
- **Protect AI,** balancing risk versus services levels, and performing acceptable changes,
- **Detect AI**, differentiating attacks from acceptable behaviors,
- **Respond AI,** performing immediate reactions to identified attacks,
- **Recover AI,** establishing cyber resilience and restoring compromised business functions.

In addition, **Orchestration AI** will provide integration and coordination of all of the above functions in the context of customer business, risk and resilience objectives.

These 6 **Cyber AI** functions will be specialized by IT domains, industry verticals and regulations, and will deliver multiple layers of collaboration between organizations that share common interests. Rather than focusing solely on detecting attacks, this framework will help AI for cyber-defense prevail over AI for cyber-attack.

A distributed AI approach that makes the invisible visible, will bring enterprises an unprecedented understanding about their information systems. It will provide invaluable insights into optimal approaches for visibility, protection, attack detection, response and resilience.

Invisible security will foster technical progress and the evolution of commercial and industrial digital ecosystems, sustaining and safeguarding the advancement of society.

[2] Risk treatment can be mitigation, acceptation, transfer or avoidance.
[3] National Institute of Standards and Technology.

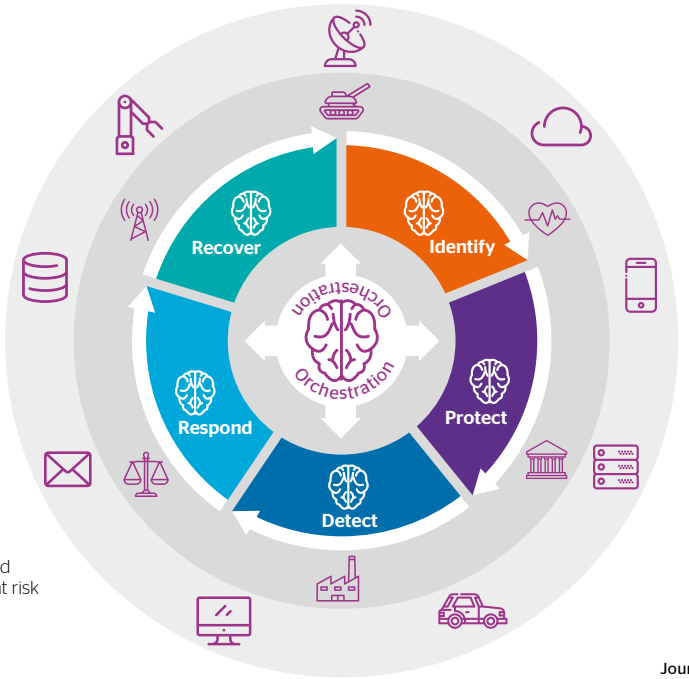


Figure 21: The five concurrent and continuous functions of intelligent risk evaluation and treatment.

FEDERATED FRAUD PREVENTION

Evolution of fraud

As technology develops, so does the potential for exploitation by fraudsters. AI, machine learning, and bots can be applied both in the execution of fraud and its prevention. There is a constant race to see who can harness and deploy new technology more quickly and effectively. Cross-domain fraud in our ever more connected world of open banking, digital government, smart homes and remote healthcare raises concerns about how to protect not only individuals, but society at large.

Based on a current figure of £3.24 trillion[1], we estimate the global annual cost of fraud will rise to over £5 trillion by 2024. Without effective and coordinated Fraud Prevention this will quickly become unsustainable.

Fighting fraud will be a **regulatory** and **technology challenge**, as well as a **major societal and behavorial challenge**. It will demand global cross collaboration and federated systems that could begin to challenge conventional views of data privacy.

The regulatory dilemma

A federated and AI-driven approach to fraud management is not a new concept. But while banks already use automated systems to assess money laundering risks[2] , major data protection and privacy roadblocks prevent the implementation of federated approaches. The lack of legally-binding standards and guidelines governing information exchange between Financial Intelligence Units hinders cross-border fraud management[3].

This has to be addressed, and we predict that by 2024 a standardized legal framework will be created to enable effective federated fraud management between multiple parties and across borders.

> "Fraud has the potential to influence and even change world order."

[1] Jim Gee & Mark Button at Crowe Global* The Financial Cost of Fraud 2018 report
*Crowe Global, previously Crowe Horwath International, is the 8th largest global accounting network in the world
[2] Savona, E.U. and Riccardi, M., 2019. Assessing the risk of money laundering: research challenges and implications for practitioners. European Journal on Criminal Policy and Research, 25(1), pp.1-4.
[3] European Payments Council, 2019. 2019 Payment Threats and Fraud Trends Report. Brussels: European Payments Council, pp.6-91.

Federated fraud prevention platform

One of the remaining dilemmas is how to share and analyze data while ensuring privacy for the data subjects. Privacy Preserving Computation techniques will help resolve this dilemma by analyzing and operating data without exposing the raw information. They will use technologies like data fingerprints, trusted execution environments and homomorphic encryption.

Operators of Federated Fraud Prevention Platforms will not have access to raw data, sensitive information or personal data, but will detect fraud signals by matching and analyzing anonymized information from various sources. Detected fraud signals will be fed back to data owners who can investigate further using its protected raw data.

AI models are geared toward capturing patterns and relationships in data and operate most effectively if those patterns are represented within the model's training data. Without access to sufficient training data from (e.g.) financial agencies, traditional AI models cannot reliably predict or detect fraudulent patterns[4].

Governments and banks should take a lead in federated fraud prevention

There is a need for a regulatory landscape that acknowledges the new digital realities of financial fraud and encourages the sharing of fraud intelligence between different financial bodies. Some commendable strides have been taken toward **formulating indicators of cross-border and crypto-related fraud** that do not necessitate the use of groundbreaking technology[5] – for instance, inferring fraud from several data points provided by tax departments, banks, and telco companies. However, the critical legislative and IT infrastructure that is needed to uphold multi-party cooperation is almost absent. The issues that need to be addressed include:

- Elimination of paper-based exchanges between financial intelligence units,
- Creation and implementation of global guidelines on the transfer of personal data between geographic regions,
- standardizing national confidentiality laws among federated members vis-à-vis fraud intelligence,
- fostering inter-agency trust, standardizing report templates, and providing adequate infrastructure for transmitting large volumes of data between agencies[6].

We believe that by 2024 local governments and finance ministries will spearhead efforts in federated fraud management, legitimately applying citizen IDs and insights regarding income, assets, taxes, and expenses. Such insights will be supported by inter-company and inter-country **federated platforms** that will become instrumental in identifying, deterring and preventing fraud relating activities.

[4] Verma, D., Julier, S. and Cirincione, G., 2018. Federated AI for building AI solutions across multiple agencies. arXiv preprint arXiv:1809.10036.
[5] OECD (2019), Money Laundering and Terrorist Financing Awareness Handbook for Tax Examiners and Tax Auditors, OECD, Paris.
[6] European Commission (2020). REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL assessing the framework for cooperation between Financial Intelligence Units. Brussels: European Commission, pp.1-15.

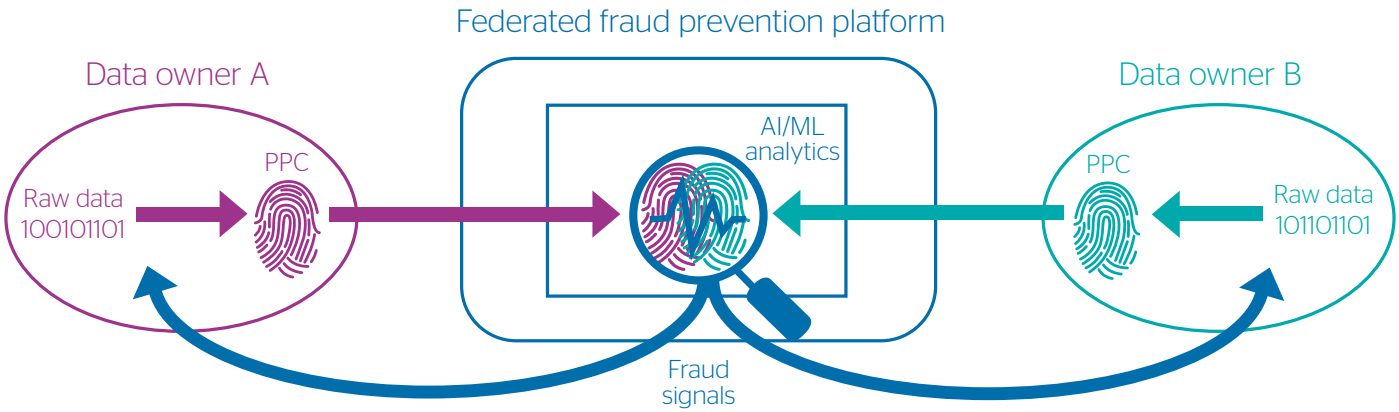


Figure 22: Federated fraud prevention platform using privacy preserving computation (PPC) techniques.

UNPREDICTABILITY AND MACHINE BEHAVIOR

Artificial intelligence (AI), more specifically Machine Learning (ML), has boomed over the last decade. In some narrow applications like image recognition, machines have surpassed human performance. ML begins to be widely used in business, and the trend is accelerating.

Far from the monolithic, superhuman systems characterized by the media industry, ML will become pervasive as an ingredient in a myriad of everyday systems, solutions and applications. Enterprises will soon rely on systems that integrate multiple interconnected learning components. This leads to a very interesting but very challenging feature: machine behavior.

Systems and applications will no longer behave predictably and homogeneously. They will be trained, interact, learn and adapt in sometimes indeterminate ways.

Explainable AI

For centuries, science and engineering have modelled the real world, verified those models through experimentation, and exploited the results. It was straightforward to validate results against known equations, models and – later - computer programs.

With AI solutions, patterns can be detected in highly dimensional data by calculating an astounding number of interwoven parameters. But such processes cannot usually be simply explained by sets of rules appropriate for human understanding or formal proofs, making fully transparent AI seemingly impossible. Such lack of transparency is raising concerns over reliability, fairness, ethics and ultimately trust in AI-ML solutions. These characteristics are critical in highly regulated domains such as healthcare or finance.

Several techniques aim to provide context around the outcome of AI solutions, helping to validate the learning process and detect potential biases or weaknesses. These techniques, such as LIME[1], SHAP[2], PDP[3] or Anchors[4], are collectively named Explainable AI (XAI).

There is rising interest in XAI, with leading technology firms starting to propose solutions such as Google's What-If tool. By 2024, XAI techniques will become more abundant, mature and widely utilized.

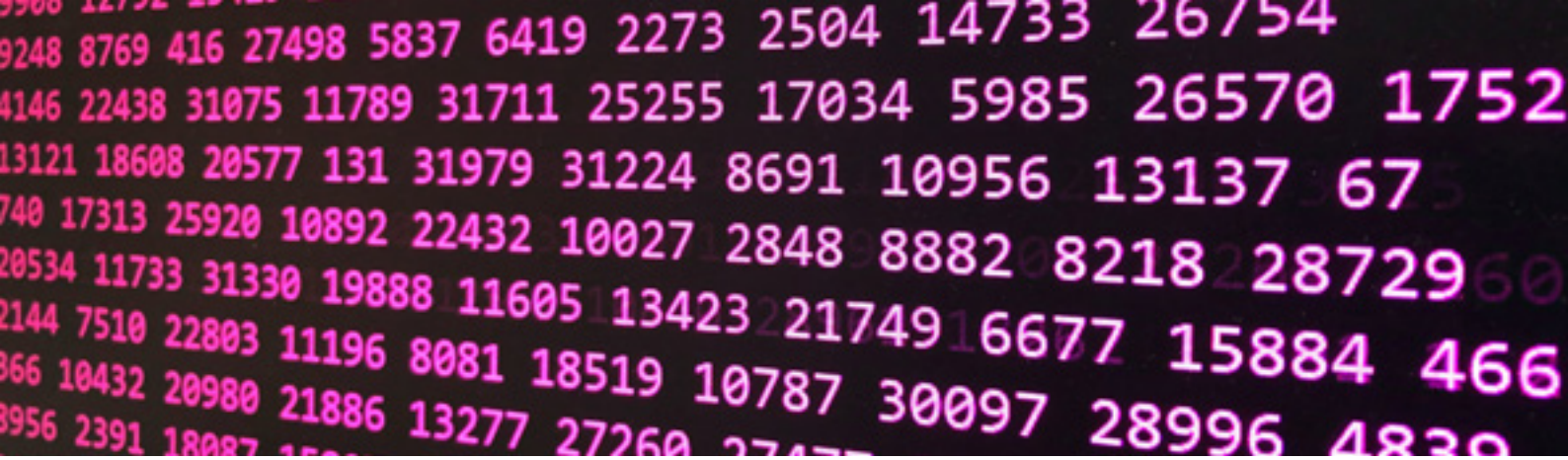
Unintended consequences. The human in the loop

Machine behavior takes place within a spectrum, between two extremes:

- **Pure rationality:** ignoring 'irrational' human behavior and acting on universal facts, ultimately ignoring human ethics, morality or accustomed behaviors. E.g., a hospital's AI system could decide to stop life-support systems for particularly high-risk patients in order to optimize performance.
- **Adopted irrationality:** reinforced irrational behavior may drive outputs in unexpected ways, as when Microsoft's bot Tay turned offensive after interactions with trolls on Twitter.

Unlike AI-ML models, humans tend to display unconscious common-sense rules when solving a problem. If these rules are not contemplated in solution design phases, AI-ML models may find new,

[1] https://www.oreilly.com/content/introduction-to-local-interpretable-model-agnostic-explanations-lime/
[2] https://towarddatascience.com/shap-a-reliable-way-to-analyze-your-model-interpretability-874294d30af6
[3] https://christophm.github.io/interpretable-ml-book/pdp.html
[4] https://homes.cs.washington.edu/~marcotcr/aaai18.pdf



surprising ways to solve problems. One such example is AlphaGo Zero teaching itself to play Go and defeat the world champion by using "outside the box" tactics discarded centuries ago by human players. But surprise behaviors can also be negative, such as AI's "cheating" at games, using tactics that humans consider against the rules. The problem is that those rules may be unwritten and taken for granted, so they need to be part of the design of AI-ML models.

Examples of unintended consequences in AI systems are where recommendation engines propose ever more violent video content or increasingly narrower filter bubbles, because violence and anger seem to be effective drivers for short-term engagement. Price collusion is another example: to maximize profit, two competing AI's could carry out strategies that raise prices in anti-competitive ways without ever explicitly communicating.

Managing the spectrum of machine behavior requires control points that bring together the efficiency of automation and the sanity check of conscious beings. The human-in-the-loop approach helps address this need.

Validation & certification

From the early days of software, testing and certification has been crucial to assess proper functionality and performance. For critical systems, full-scope testing and certification have been mandatory steps before deployment.

Machine behavior poses a huge challenge. As systems evolve and 'behave', it is not possible to perform accurate testing and certification as before. In order to minimize risks whilst keeping up with the fast pace of technology, AI models will have to follow specific regulations and certifications to enforce basic principles that minimize the impact of potential evolutions.

System providers will be required to provide clear interfaces for direct testing of AI-ML components in deployment, to ensure that guidelines and principles are respected. There may be requirements for regular self-check compliance reports.

Organizations will have to implement proper controls, including ethics and maturity controls, to guarantee trust in their systems and solutions. Targeted training of engineering and product teams will be a prerequisite.

Conclusions

As AI-ML is increasingly used by organizations - data will no longer be the "food" for systems: data will be part of the systems themselves!

Businesses must understand the challenge of machine behavior, starting with explainable AI techniques and continuing with human-in-the-loop approaches or AI-ML-ready validation & certification processes.

Machine behavior must be factored in as organizations redefine their purpose.

Organizations that fail to successfully adopt such techniques will experience a significant competitive disadvantage and face regulatory or societal backlashes.

"Can we better codify our common sense and moral values? Can we create AI that understands what those values should be?"

ABOUT THE SCIENTIFIC COMMUNITY

The Atos Scientific Community crafts the Group's vision for the future of technology in business, and anticipates the upcoming trends and technologies that will shape businesses and society in the years ahead. Its global network comprises more than 160 of the top scientists, engineers and forward thinkers from across the Group. Together they represent a rich mix of skills, experience and backgrounds.

Through regular blog posts, white papers, thought leadership reports[1] and above all the biennial Journey publications, the Scientific Community has established Atos as a thought leader and helped our clients safely navigate the challenges of the digital age.

Scientific Community members are "creators of change", taking a proactive approach to identify and anticipate game-changing technologies. They also play a major part in patent creation, and develop a wide variety of cutting-edge proofs of concept. As mentors of the Atos IT Challenge – an annual competition for universities around the world, they help nurture the next generation of IT talent.

Working together with the Atos Expert Community, Atos R&D Centers and the Group's external research partners, members of the Scientific Community help to bring groundbreaking concepts and services such as quantum computing into the Atos portfolio. This ensures that our clients enjoy early access to the revolutionary technologies that will transform their businesses.

Follow the Atos Scientific Community on atos.net/scientific-community and @AtosInsights on Twitter

[1] https://atos.net/content/2020/atos-report-what-the-world-will-look-like-after-the-covid-19-crisis.pdf

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Let's start a discussion together

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