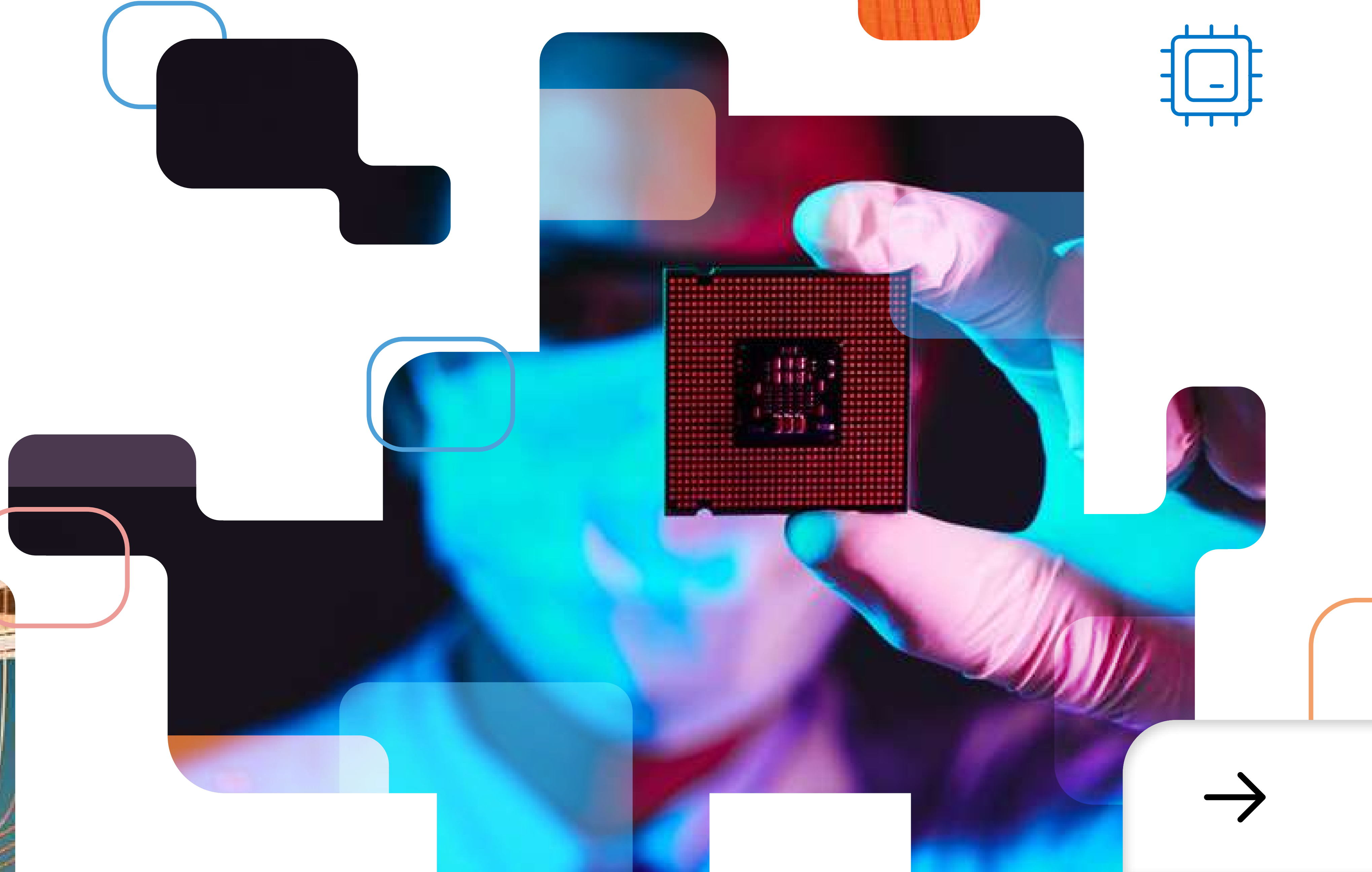
SURF TECH TRENDS 2023



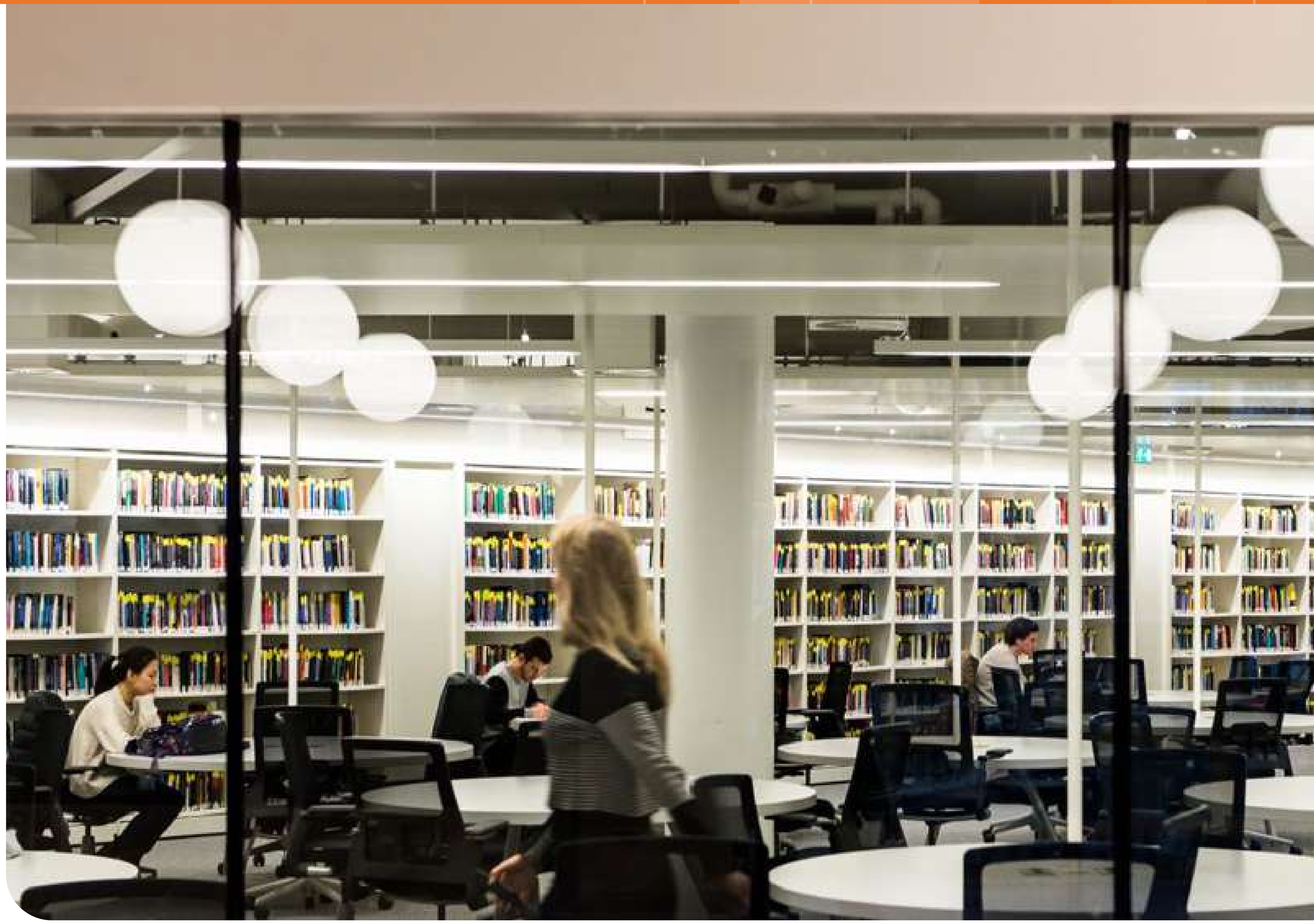
SURF

Preface

SURF as a cooperative has as a mission to make reliable and innovative IT facilities possible, to allow Dutch education and research to excel. Next to our role as service provider and association, our role as innovation workplace requires us to build and share knowledge on future developments with our members. This links this trend report with our strategy. We drive innovation together by participating in joint initiatives, with our members in their role as research institutes and SURF in the role as knowledge sharing facilitator. We aim to provide a report that is interesting to read by both board members and information technology professionals.

With the content provided by the technical experts of our members and guidance of our Scientific and Technical Council, we will continuously improve and expand the discussed topics and format in the years to come.”

Jet de Ranitz, Hans Louwhoff and
Ron Augustus (Board of Directors SURF)



Contents

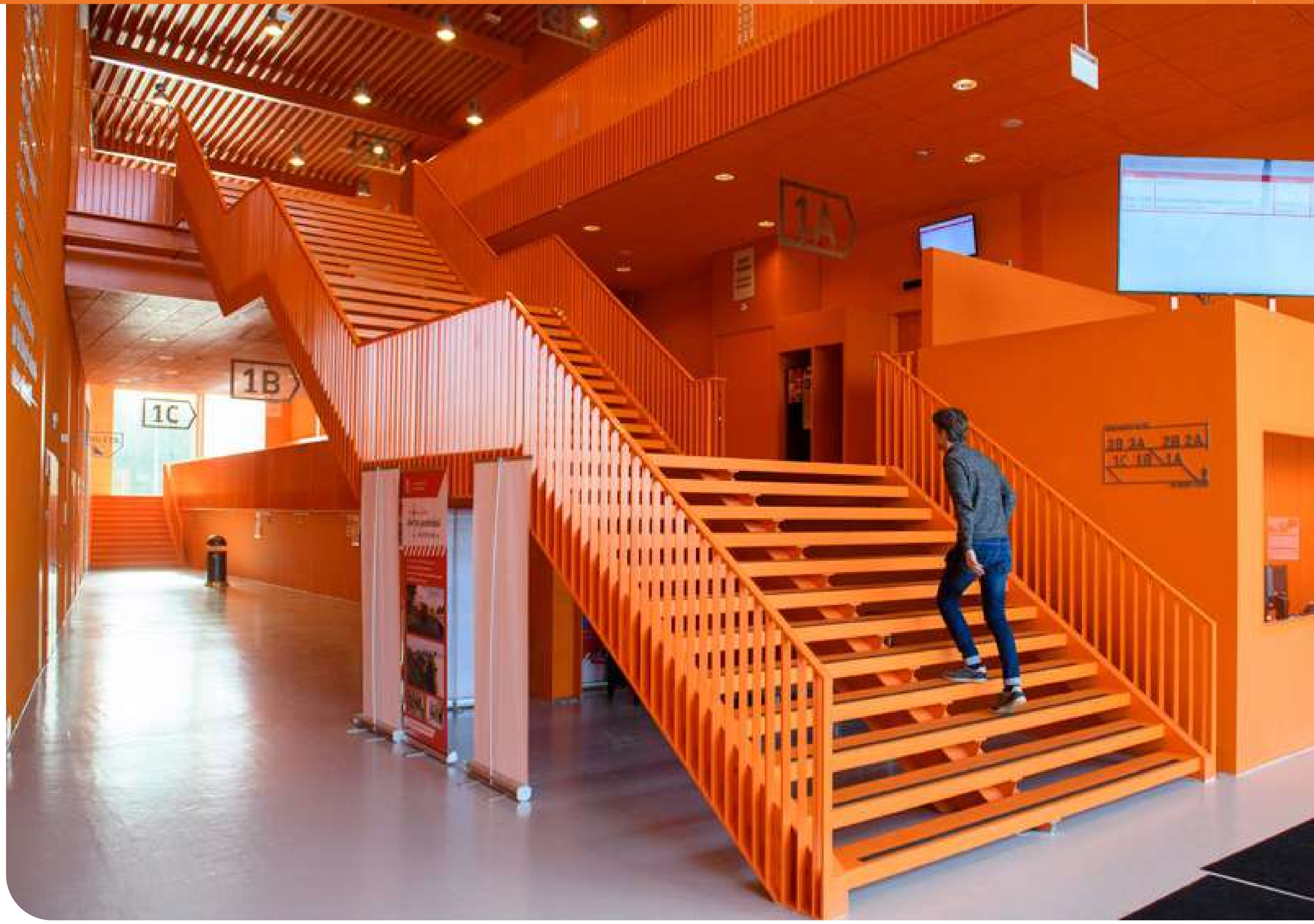
Introduction

One of SURF's objectives is to be adaptive and flexible in a complex and dynamic environment. Therefore, we see it as our task to practice futuring as a process, to help us think about the future in a structured way together with our members and stakeholders.

This trend report aims to help us understand the technological developments that are going on around us, to make sense of our observations, and to inspire. We have chosen the technology perspective to provide an overview of signals and trends, and to show some examples of how the technology is evolving.

Although SURF has published trend reports before, this is the first time we are releasing a comprehensive overview of future technology developments. In this way we lay a foundation upon which we can improve in the coming years. We will actively engage in discussions with our stakeholders to explore the implications of our predictions for education and research. We invite our partners in education and research to reach out to us and share their findings and prediction.

This report, as you can imagine, is not meant as a plan of approach or instructions. We invite you to make the translation for your own context, or reach out to us to learn what SURF is doing.



Approach

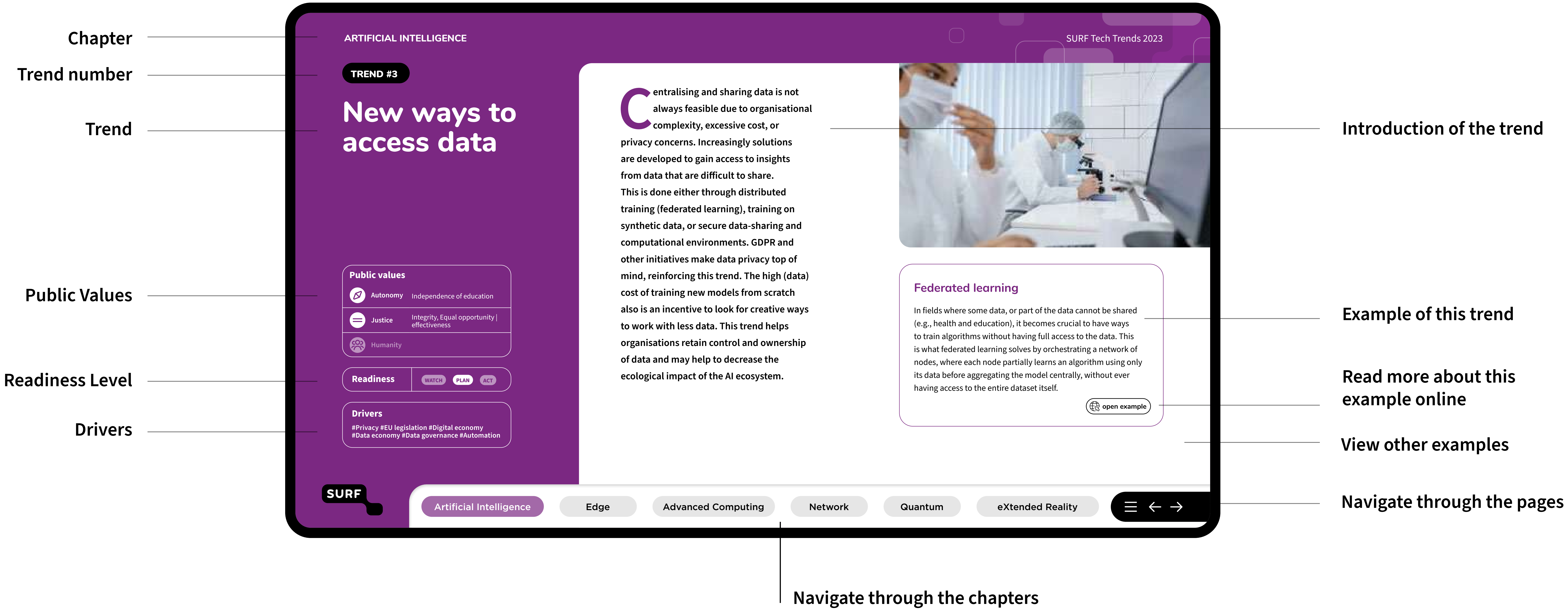
On the next pages, you can read more about our approach and about the frameworks we used to analyse the trends.

First, we scanned multiple trend reports and market intelligence services (e.g. Gartner, McKinsey, Deloitte, Future Today Institute, etc.) to identify the big technology themes. We identified some major themes: Extended Realities, Quantum, Artificial intelligence, Edge, Network, and advanced computing. We believe these themes cover the major technological developments that are relevant to research and education in the coming years.

In a second phase, we asked experts in- and outside SURF to tell us more about the technology trends that they observed, and about the relevance of these technology trends for education and research. For this part we asked Coordinating SURF contacts, Scientific Technical Council (WTR) and Kennisnet to read and think along with us. To help readers to decide how to judge a trend, we provide links to public values and the readiness level as well. We do so because public values are key to efficient education and research.

This approach is inspired by Els Dragt (how to research), Turner and Amy Webb (Future Today Institute)

Reading guide

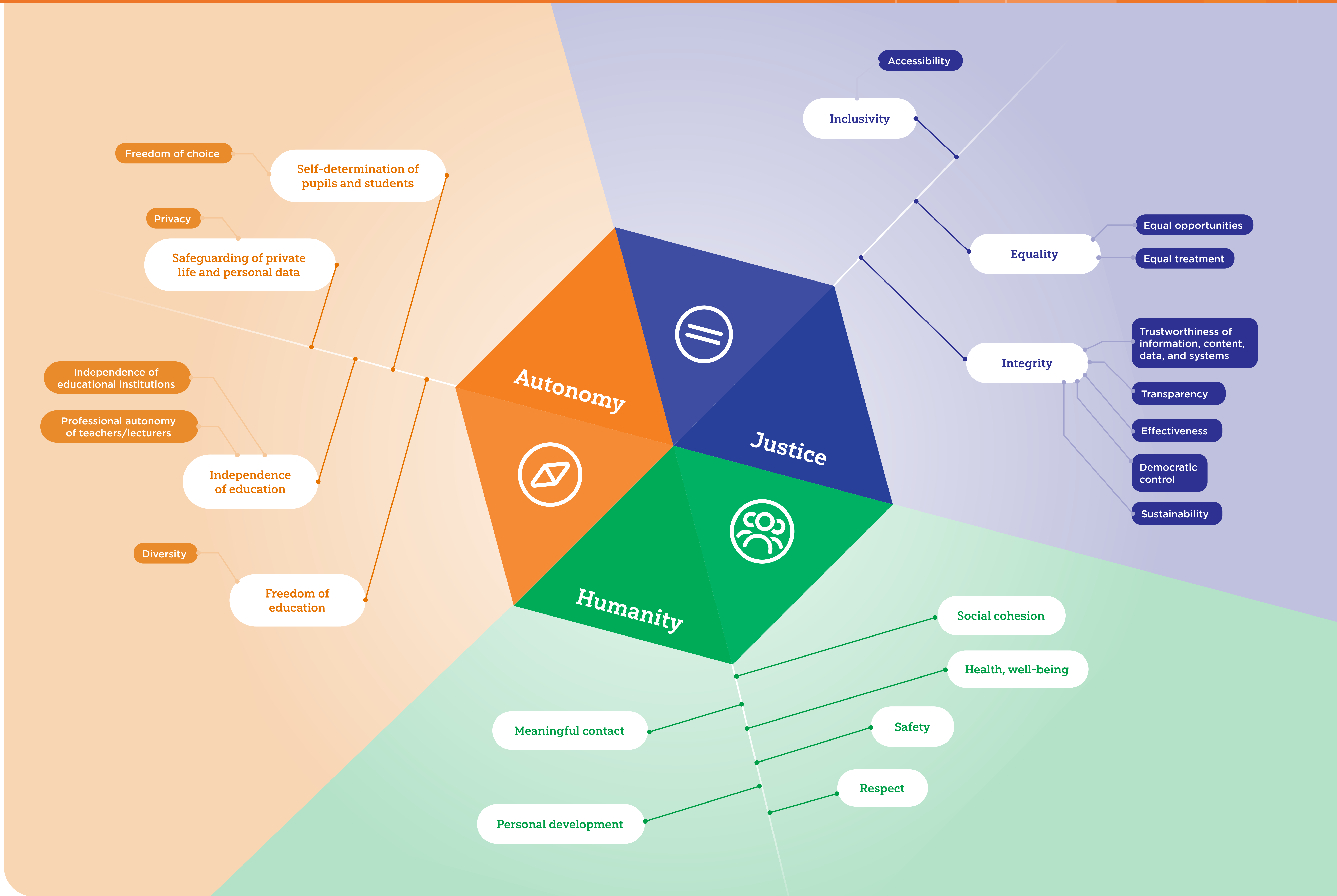


Value Compass

SURF and Kennisnet, the public IT organisations for education in the Netherlands, have developed the Value Compass to provide a common language to stimulate the dialogue about digital transformation in education and the importance of educational values.

The Value Compass provides a frame of reference for structuring digital transformation based on values.

For each trend we identified a relationship with public values. The value compass helps us to identify a value or multiple values driving the trend towards a certain direction (Dragt, 2017)



Drivers

Drivers are influential forces of change that (can) shape current developments. For a better understanding of trends, we should see them in their context: which drivers are shaping or influencing a trend? One way to analyse these drivers is by using the STEEP tool. We therefore provide a quick scan of Societal, Technological, Economical, Environmental and Political (STEEP) forces we observe in the Dutch landscape of education and research.

References:

- **WEForum**
- **2022 EDUCAUSE Horizon Report: Data and Analytics Edition**
- **2022 EDUCAUSE Horizon Report: Teaching and Learning Edition**
- **Megatrends**

Societal

- Gender balance in Science, Technology, Education, Arts & Mathematics (STEAM)
- Research environment
- Life long learning
- Digital literacy & skills
- Diversity, Equity & Inclusion (DEI)
- Internationalization

Technological

- Dataism
- Data governance
- (Cyber)security
- Connectivity
- Decentralisation
- Automation
- Open Source development
- Responsible technologies

Ecological

- Power efficiency
- Carbon footprint
- Biodiversity
- Climate change

Political

- Open Science
- Open and online education
- Right to be able to work from home
- EU legislation
- Privacy

Economical

- Digital economy
- Circular economy
- Globalisation

Artificial Intelligence

Artificial Intelligence

Artificial Intelligence (AI) and, more specifically, machine learning (ML) have taken off in recent years. This resulted in impressive achievements, such as beating the world's best Go player with AlphaGO and near-lifelike image generation by systems such as Dall-E. However, it also led to worries and discussions about the possible risks and harm caused by AI systems.

AI technology is already impacting the research and educational sectors both in content and their operation and will undoubtedly continue to do so in the future. AI is a hot field of study among researchers, and machine learning is a valuable research method. Consequently, the range of applications is growing. Within education, AI is less mature in its implementation, as can be seen in the trend manifestations presented here. However, the promise of Artificial Intelligence Educational Devices (AIEDs) is growing both in the classroom (micro level), institution (meso level), and society at large (macro level).

AI is often deployed within a complex system containing the technological infrastructure within socio-technical contexts. This development is illustrated by trends covering technical themes such as computation, data, and hosting of services. It is also reflected in trends related to ways those technological elements should be deployed in specific communities to form a trustworthy ecosystem.

TREND #1

Towards 'Franken models'

Public values

Autonomy	Independence of education
Justice	Equality | Integrity | Trustworthiness of information | Transparency | Democratic control | Sustainability | Inclusivity
Humanity	Safety

Readiness WATCH PLAN ACT

Drivers

#Dataism #Connectivity #Automation #Globalization #Open science

Early machine learning models were designed for a specific task. Recent developments show that we can now build more complex models that merge different kinds of input in a system with broader capacities. Innovations in architecture and multimodal, multi-objective training of models make this possible. Models are trained with different types of information and a diversity of tasks. Institutions with access to those models have a competitive advantage. These (Franken) models are often trained with weak labels or even unsupervised. The methodology involves using self-supervision, leading to generic capabilities. These models can be seen as a new pocketknife, unlocking new capacities and opportunities for automation, leading to value creation.

Foundation models

The term 'foundation model' has been coined by researchers at the Stanford Institute for Human-Centred Artificial Intelligence to capture the increase in large models trained at scale and adaptable to a wide range of tasks. These models all provide a platform of capacities that can later be tailored to specific applications such as BERT, GPT-3, chatGPT, DALL-E, and stable diffusion.

open example

Multimodal learning in healthcare

The multimodal approach helps researchers extract knowledge and value from an exascale dataset without requiring large labeled, annotated data. The supervision is done by using trained networks to provide labels that in turn are corrected through an active learning interface. We can combine images of tissues with their corresponding diagnostic text. A similar impact can be expected in fields where knowledge extraction relies on basic capacities from foundation models, such as combining data from sensors with multiple modalities or combining resources in a learning environment.

open example

DeepMind's Flamingo model

Flamingo is a visual language model (images + text) developed by DeepMind. It combines a visual and a language model, which means it can tackle a wide range of tasks related to those modalities. Also, Flamingo is a few-shot learning model, which means it can learn new tasks from just a few additional inputs. The next step is going from text to image to text to video applications. This technology has a big potential to help create engaging personal assistants for the education sector.

open example open example

IMPACT

These tools can unlock new capacities for both research and education: extract information from complex systems, generate new complex data, add new data modalities to existing pipelines, automate/accelerate existing tasks, and design more interactive and engaging courses. These models feature end-to-end capabilities, being able to model complex problems. As is often the case, those models are susceptible to bias, prejudice, and copyright issues. Non-uniform adoption of those tools may also increase efficiency gaps between relevant actors. Controlling the trained models will become more important to secure integrity. There is a potential risk for models to become too powerful and threaten our human values. We expect to see such generic, large, pre-trained models to be the starting point for future task design and training.

TREND #2

More efficient approaches towards AI systems

Public values

Autonomy	Independence of education
Justice	Integrity | Sustainability | Effectiveness
Humanity	

Readiness WATCH PLAN ACT

Drivers

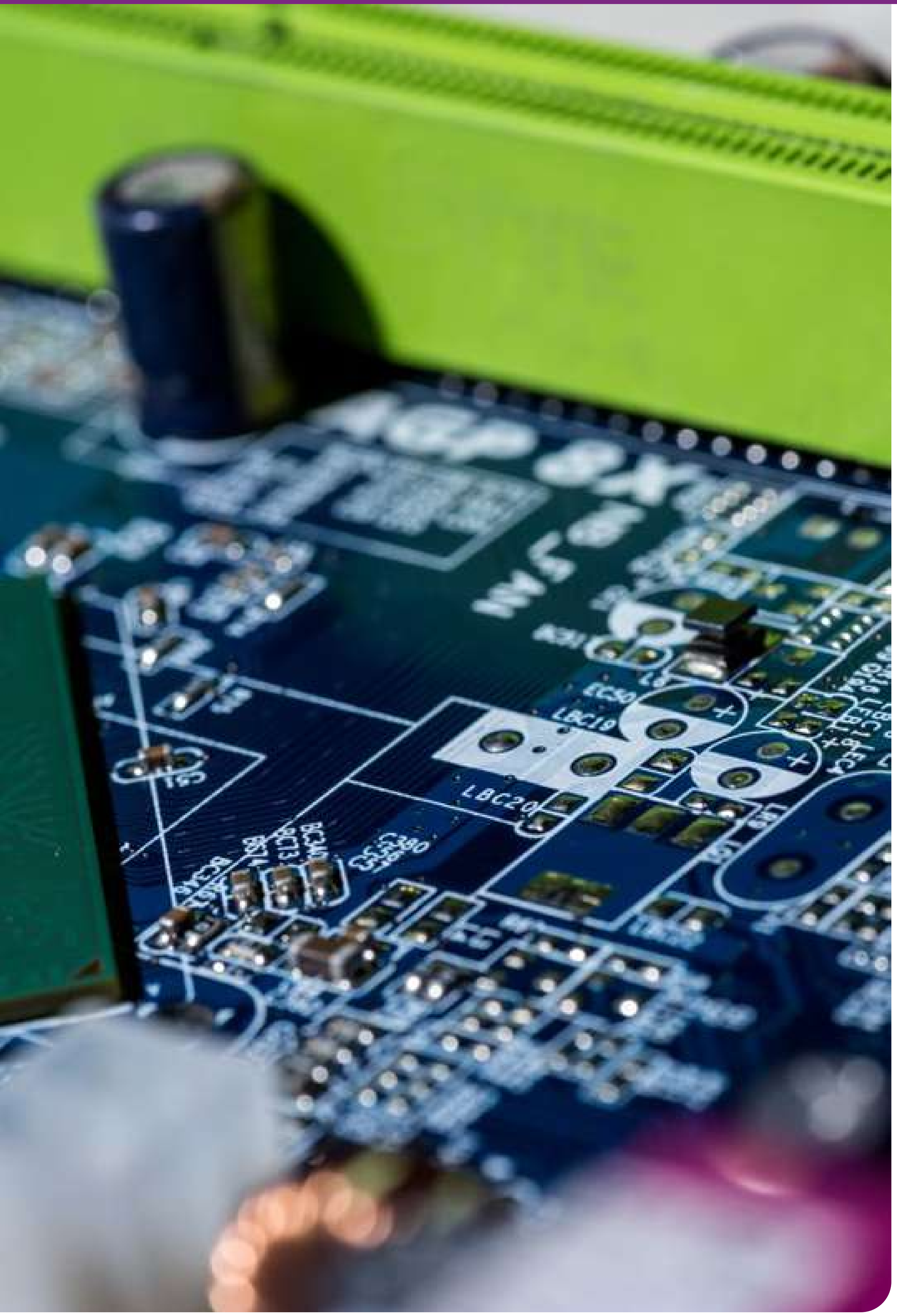
#Internationalization #Dataism
#Decentralization #Power efficiency
#Open Science #Open source development

As the use of AI systems increases, we see a trend toward ensuring the efficient training and deployment of AI systems. This trend is an effort to reduce both the data and computational cost of training and deployment of AI systems. Due to economic and environmental costs, it is not always feasible to train ever larger models. On the model level, inductive bias uses a priori knowledge of the studied system to constrain model architecture. A notable class of emerging networks is the spiking neural network, that promises to be more neuron efficient than a classical artificial neural network, i.e., achieving more complex behaviour using fewer neurons than traditional models. This is done by using biologically inspired activations. In addition to reducing the data and modeling complexity, there is also a move towards AI-specific hardware to effectively train and run models. Transitioning from CPU to GPU for certain computing tasks has led to even more specific hardware being developed.

Physics-informed neural networks

Multiple projects take physical laws into account (a form of inductive bias) when designing the simulation workflow to limit the data needs and model complexity. By doing this, the models automatically discard all possible 'non-physical' solutions to the problem, drastically reducing the number of outcomes and thus training time.

open example open example



Graph neural networks

GNNs are another example of inductive bias. These networks are particularly effective for tasks where data comes from non-Euclidian space (i.e., where the physical space is irrelevant). The most obvious example is of course social networks, but these networks can be applied in a surprisingly broad range of domains (e.g., natural language processing, chemistry).

open example

Towards AI-specific hardware

With the rise of AI there have also been new opportunities for alternative computational and data architectures to take advantage of the specific operations required by deep learning algorithms. From the early TPU from Google, many companies are now developing innovative solutions to train and deploy algorithms efficiently (e.g., Graphcore, Cerebras, Habana, Rain Neuromorphics).

open example open example

IMPACT

More effective AI systems will increase AI adoption by making them more accessible to a wider range of users. Inductive bias is likely to significantly impact research into AI and with AI. Moreover, the development of AI-specific hardware will give yet another boost to AI system capabilities and these capabilities will create demand for new infrastructures. The key driver here is to get the most out of limited resources. However, this requires highly specialised hardware and skills.

TREND #3

New ways to access data

Public values

Autonomy	Independence of education
Justice	Integrity, Equal opportunity | effectiveness
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Privacy #EU legislation #Digital economy #Data economy #Data governance #Automation

Centralising and sharing data is not always feasible due to organisational complexity, excessive cost, or privacy concerns. Increasingly solutions are developed to gain access to insights from data that are difficult to share. This is done either through distributed training (federated learning), training on synthetic data, or secure data-sharing and computational environments. GDPR and other initiatives make data privacy top of mind, reinforcing this trend. The high (data) cost of training new models from scratch also is an incentive to look for creative ways to work with less data. This trend helps organisations retain control and ownership of data and may help to decrease the ecological impact of the AI ecosystem.

Federated learning

In fields where some data, or part of the data cannot be shared (e.g., health and education), it becomes crucial to have ways to train algorithms without having full access to the data. This is what federated learning solves by orchestrating a network of nodes, where each node partially learns an algorithm using only its data before aggregating the model centrally, without ever having access to the entire dataset itself.

open example

Synthetic data

Another approach to this issue is to generate a set of synthetic data based on a model of the true distribution and share that dataset instead. While powerful, this works only if a powerful base model to generate synthetic data can be trained in the first place. If a synthetic dataset can be used, this allows downstream applications to work on an equivalent dataset but without privacy issues. With state-of-the-art algorithms, such as the foundation models presented in the first trend, we expect a rapid development of synthetic data use in research and education.

open example

ODISSEI Secure Supercomputer

Through a secure supercomputing environment highly privacy-sensitive data of Statistics Netherlands (CBS) is made accessible for researchers in a safe and secure manner. This democratises access to population data and accelerates research within the social sciences.

open example open example

IMPACT

This trend is particularly helpful to provide AI capabilities to fields that until now have not been able to make full use of AI because of the difficulty to access data (e.g., health, education). By making it easier to share and access data, new research insights can be gained which will lead to new capabilities. However, the privacy risks linked to the synthetic data approach should not be underestimated. Once the appropriate infrastructure and protocols have been developed, synthetic data can both help maintain privacy and allow models to be trained on larger datasets. This will also create further possibilities for international research collaborations. Synthetic data also gives more control to data owners.

TREND #4

Towards trustworthy AI

AI models' increased uptake and performance have led to more significant societal questions of responsibility, trust, and transparency. This is evidenced by the European Commission's focus on Trustworthy AI and upcoming AI legislation. Within trustworthy AI, several societal and technological developments come together to address these societal questions. Frameworks and legislation provide a baseline for the requirements AI should meet. A stronger focus on reliability, standards, and interoperability in development leads to more robust and transparent AI systems. Democratisation of AI leads to more resources to learn and more standards to follow, which also helps newcomers get started.

AI ethics guidelines

Within a growing discourse on the responsible use of AI, academics, NGOs and companies are discussing the impact of AI and its ethical implications. These discussions include topics like challenges of trust, transparency, fairness, and accountability. Many resources have emerged, but one of the most important is the ethical guidelines issued by the European Commission's High-Level Expert Group on AI.

open example

Public values

Autonomy	Independence of education | Safeguarding of private life and personal data
Justice	Equality | Transparency | Democratic control
Humanity	Respect | Safety

Readiness WATCH PLAN ACT

Drivers

#EU legislation #Responsible technologies #Privacy #Carbon footprint #Globalization #Digital economy #Data governance #Diversity #Inclusion #Equity #Digital literacy #Gender balance

Algorithm registers

To provide transparency in the use of algorithms, multiple municipalities and governmental institutions have started using algorithm registers to provide the public insight into their use. In the future this is likely to become mandatory for all governmental organizations. Publicly sharing where, when, and how algorithms are used helps being transparent and accountable to relevant stakeholders such as citizens, users of applications, the media, and the relevant authorities.

open example

Standardisation and professionalisation

From data acquisition and curation to training and deployment, the typical engineering workflow is complex. As with software engineering best practices and tools, there is a trend in AI led by major companies and research groups to facilitate such workflows through, for example, MLOps. Standardization of operations and deployment leads to more mature, professional environments. This is crucial for interoperability but also helps with transparency to promote trust and avoid biases.

open example

Community-led initiatives

Large AI models are often only accessible to large research labs and corporations. Community-led efforts such as BLOOM aim to democratise AI models by making them available for researchers in smaller labs with fewer resources. These efforts also involve more parties in the training phase to insure better transparency and more robust models. BLOOM is a collaboration of 1000+ researchers from 70+ countries, which trained a large language model for 46 natural languages and 13 programming languages.

open example

IMPACT

Trustworthy AI is a critical driver that impacts all parties working on AI, either in research or education. Formalising good practices and standards helps professionalize the community and provides resources for responsible use and fast, practical tools. Sufficient attention to trustworthy AI can prevent that (1) damage is done to communities through irresponsible use of AI, and (2) communities are split with different standards on how to work with AI methods.

TREND #5

More accessible computing and models

AI methods are becoming a scientific instrument that can be used as a readily available tool, the same way as a microscope. As a 'new tool' among others, AI must be accessible as a commodity at a low cost to provide easy access to non-experts. As most deployments take place in cloud environments, AI is increasingly accessible in the public domain. The use of abstraction layers (such as autoML or MLaaS approaches) helps to provide direct access to complex computational abilities for non-technical expert stakeholders. However, this leads to a trade-off between ease of access and the risk of vendor lock-in and privacy concerns when using these applications in commercial cloud infrastructure.

Low-code/no-code

With more advanced software layers on top of computing infrastructure, there is a low/no code movement. Several service applications enable complex computational tasks with little or no programming. While traditional HPC centres still have an edge for advanced intensive research, low/no code makes computing more accessible to new groups of stakeholders.

open example

Public values

Autonomy	Freedom of research and education
Justice	Equality | Inclusivity
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Research environment #Digital literacy #Dataism #Decentralization #Automation #Connectivity #Digital economy #Globalization

Toward machine learning as a service (MLaaS)

Related to the previous example, the growth of platforms to share datasets, pre-trained models and easily build on them is a good example of the ongoing democratization of AI methods and the lower entry costs. These platforms also help with transparency and standardization of methods.

open example

Facilitating model design with autoML

An important part of the current data scientist workflow is to experiment with model architecture for a given problem and to tune the training procedure to obtain the best results. This is very time-consuming and highly dependent on the practitioner's experience. Instead, autoML proposes to automate this part of the workflow and leave more added-value tasks to the user. Examples are how to frame the problem of interest, what metric is relevant and how to interpret results in a responsible way.

open example

IMPACT

This trend is a double-edged sword: it democratizes access to computing resources and AI methods but at the expense of potential vendor lock-in, privacy issues, and irresponsible use of those algorithms due to a lack of in-depth knowledge. Research and educational institutions will need to learn and follow guidelines for the responsible use of AI and understand the implicit trade-offs when choosing different computing platforms. The democratization of AI methods should help progress in fields that were left out until now.

More about Artificial Intelligence

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Continue reading

more info   communities

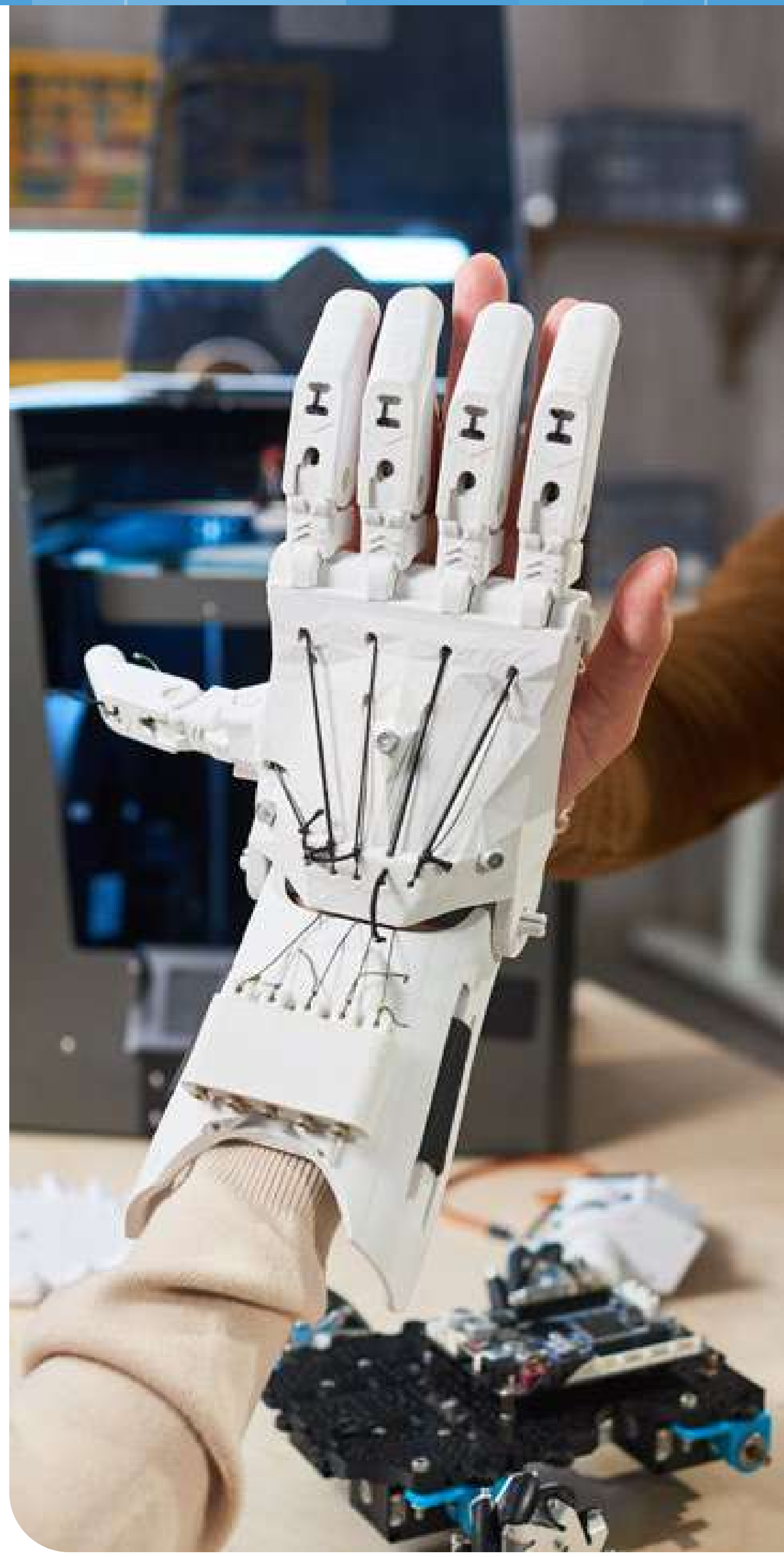
Edge

- → Cloud-Edge Continuum
- → Digital Twins
- → Actual real-time data streams
- → Run code anywhere
- → Robotic Automation

Edge-oriented Technologies

Edge computing covers a broad spectrum of technologies from internet of things (IoT) sensors to robots and extended reality (XR) devices. It is not surprising that there are many interesting trends happening across these technologies. To put it simply, edge computing refers to all networked technology outside centralised data centres as part of the so called edge-to-cloud continuum or digital continuum. In recent decades, and even today, there is a shift from on-premises computing, such as local data centres and self-owned infrastructure, to computing in the public clouds of Amazon, Google and Microsoft. On the other hand there is also an increasing push against big-tech and hence in favour of self-owned infra. In this sense, we could say that conventional edge computing is in decline. As generic computation and IT services move to the cloud, more specialized computational and technical solutions shift towards the edge. Indeed, the two developments are not actually opposed, as most of the edge-oriented trends depend on an integration with cloud services. Moreover, the boundaries between cloud and edge are not as clear in practice. Cloud computing refers to on-demand access to compute resources, such as virtual machines, storage and applications, over the internet. In this sense "cloud"is a delivery model for compute services.

In this section we see definite evidence of a growth in edge computing. Drivers of these developments are better wireless networking, such as 5G and in the near future 6G, and specialized and/or cheaper hardware. Crucially some, if not all, of the trends listed in this section include a cloud component. This is because the progress in edge computing is made possible by advancements in cloud services. Finally, please note that while technically XR technology is also a big part of edge technology, we have dedicated a separate section to this topic because XR is such a large field with many exciting developments.



TREND #1

Cloud-Edge Continuum

Public values

Autonomy	Privacy
Justice	Transparency | Sustainability | Trustworthiness of information, content, data and systems
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Connectivity #Decentralization #Privacy #Power efficiency

More computation will take place on the edge because edge computing can provide extra security and privacy, increase service availability, reduce network latency and save energy. Although it could also pose an extra security risk if not properly implemented. As computational processes shift away from centralized clouds to mobile devices and sensors, a new paradigm emerges in which workloads will be scheduled on a continuum from the cloud to the edge-based solutions, depending on their requirements. This paradigm requires a new infrastructure that connects edge users with each other and with various cloud providers, making it easy to integrate services independent of their location.

See also: Computing Continuum

How IoT is helping to create smart university campuses

There are many ways IoT can be used to improve both student services and the sustainability and security of the campus. Examples are a 3D holographic model to teach architecture, an interactive method of teaching Mandarin with the use of robots, and interactive information booths.

open example

Utilisation of mobile edge computing on the Internet of Medical Things: A survey

The internet of medical things requires the streaming of large amounts of data that need to be analyzed in real-time. These requirements are expected to be satisfied by mobile edge devices with 5G capabilities.

open example

Why autonomous vehicles will rely on edge computing and not the cloud

In situations where data needs to be analysed as quickly as possible, such as with driving cars, the computation occurs on the edge. When you are in a moving vehicle, and this vehicle relies on computing for its essential functions, you need to have your compute as close to the data as possible, which is what edge computing is about.

open example

Want a connected home without a cloud? Get smarter sensors

Privacy conscious people are starting to use edge devices to create smart homes without relying on the public cloud. By putting machine learning on a sensor, engineers can build devices that don't need an internet connection for basic tasks.

open example

IMPACT

On the campus, in the classroom and in labs, more edge devices will be encountered. Privacy considerations in both education and research will require certain processes to run on edge devices instead of the cloud, for example in smart surveillance systems and in health research.

Researchers will rely on a combination of edge computation and cloud services to reach their goals. One of the challenges in future research will be to determine where on the edge-cloud continuum a certain computation should take place.

TREND #2

Digital Twins

Public values

Autonomy	Privacy
Justice	Transparency | Trustworthiness of information, content, data and systems
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Connectivity #DigitalEconomy

A digital twin is a real-time virtual model of something in the real world, like a spacecraft or a supply chain process. A digital twin of a critical infrastructure could be a virtual representation of a power plant, for example , that includes data from sensors, simulations, and historical performance data. With information from sensors and systems, a digital twin receives constant feedback from its physical twin. Digital twins allow us to study a real-life object or process through simulations or tests that would otherwise be physically impossible or too costly. Another advantage is that each physical object or process can have its own digital twin. Therefore, the digital twin can account for different contexts and developments. This trend builds upon the growth in edge computing and real-time data streams.

Simulia living heart

Simulia is a digital twin of a living heart that can be used to study heart defects and diseases, as well as test the efficacy of medical devices. The model comprises, among other features, a dynamic, electro-mechanical simulation, a blood flow model and a complete characterisation of cardiac tissues.

open example

Destination Earth

Destination Earth is an initiative by the European Union to create digital twins of the earth combining various data sources, artificial intelligence and high performance computing. The digital twins will be used to study the effects of climate change as well as strategies for mitigating and adapting to it.

open example

Digital Tomato Twins

Researchers in Wageningen are using digital twins to study the impact of sustainability measures on tomato crops. The 'Virtual Tomato Crops' receive feedback from actual tomatoes growing in a greenhouse.

open example

Digital twin: Empowering power systems with real-time training and predictive simulation

In the energy sector, digital twins are used for training and simulations of power systems that would be too risky and costly in the real world. Digital twin technology allows for effortless collaboration and the application of real-time insights, helping to streamline diagnostics and troubleshooting.

open example

IMPACT

Digital twins are a useful approach for researchers to study real world phenomena, especially when it is difficult or costly to study these systems or processes otherwise. Using this approach will require training in digital twin technologies.

In education, digital twins can be used to simulate job scenarios that an intern would normally not get access to, for example operating a power plant or making management decisions. In fact, some universities may turn themselves into digital twins in the metaverse, so-called 'metaversities'.

TREND #3

Actual real-time data streams

Public values

Autonomy	Privacy | Freedom of choice	
Justice	Transparency | Trustworthiness of information, content, data and systems	
Humanity	Health, well-being	

Readiness WATCH PLAN ACT

Drivers
#Smart living #Connectivity

Three technological advancements are providing the ideal conditions for real-time data streams: 1) better and smarter networking due to 5G/6G connectivity, high-frequency, optical wireless and AI network orchestration; 2) the integration of various data sources both from the edge and traditional IT systems; 3) cloud services specialising in data streaming. These real-time data streams can be used in real-time analytics to yield better insights into what is happening in the present. Industry is using real-time analytics in its supply chains, manufacturing processes and finance to make better decisions. Soon, real-time data will become a part of education and research too.

What can real-time data analytics do for higher education?

Universities are starting to use real-time data analytics to track student progress and design curricula. Real-time data collection tools have huge implications for higher education, from campus network management and fast-action security protocols to student safety and academic success.

open example

Real-time attention span tracking in online education

Researchers are using image processing and machine learning to track the attention of students in real-time during online education. This allows for real-time feedback for both students and organisation, which may in the end increase the overall performance of students as well as the teaching standards of the lecturers.

open example

Demand for real-time data visibility in the logistics sector will boom

In logistics, real-time data streams help businesses to make better predictions and decisions with regards to their supply chain. With live logistics data, smart factories can plan just-in-sequence supply chains, warehouses can improve productivity, and retailers will be able to provision shelves better.

open example

IMPACT

Real-time data can be used to keep track of the educational progress and mental health of students. If a student is predicted to be at risk, a teacher can intervene directly. In the classroom, real-time data analytics can give educators instant feedback on their teaching methods. One potential risk of this trend is that the autonomy of students and staff is compromised.

Researchers can make use of real-time data streams for many research purposes. For example, AI/ML models can be trained and assessed on a constant flow of data and remain up-to-date for longer periods.

TREND #4

Run code anywhere

Public values

Autonomy

Justice — Accessibility | Equal opportunities

Humanity

Readiness WATCH PLAN ACT

Drivers

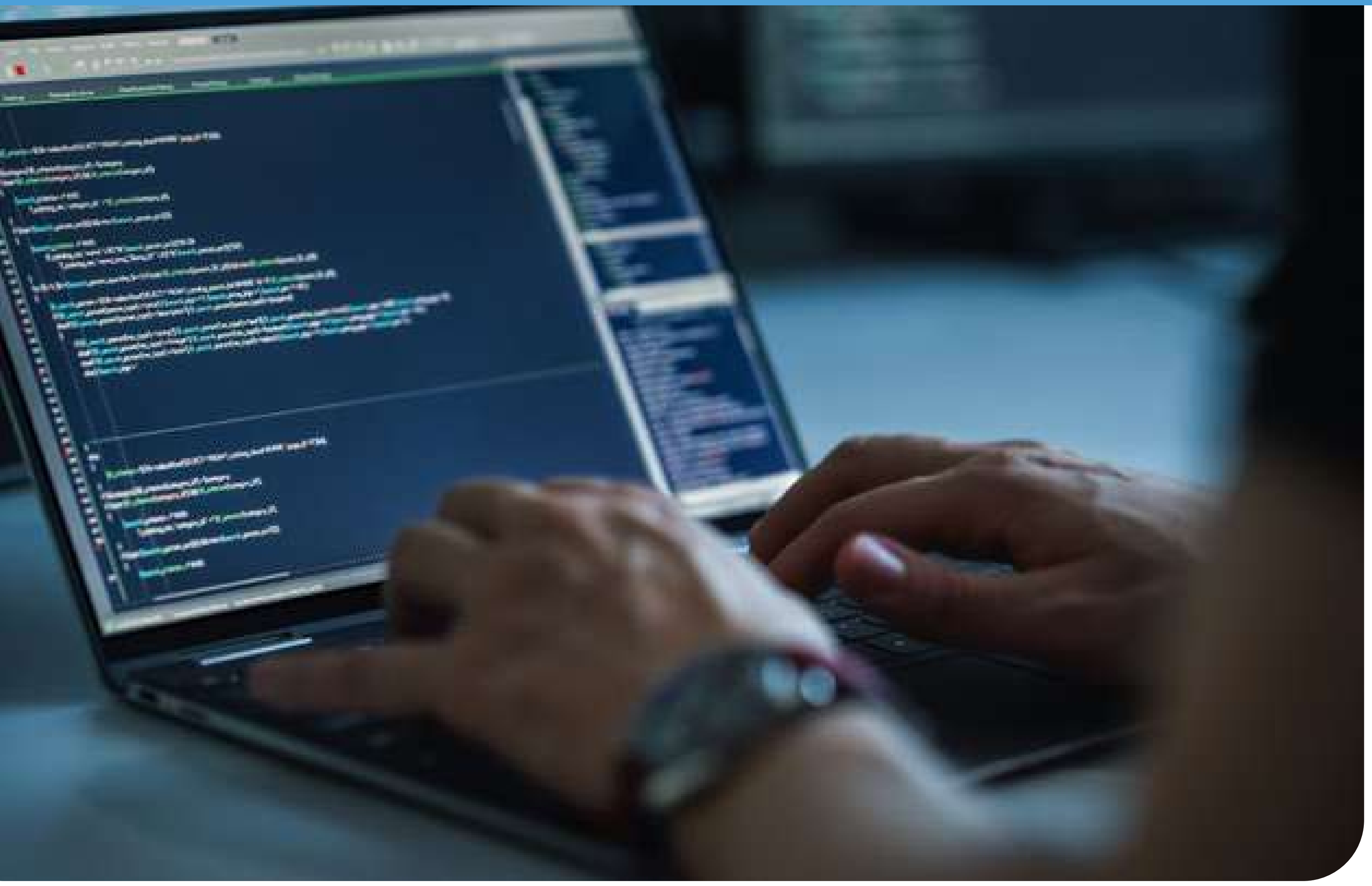
#Decentralization #Automation #Gender balance in STEAM #Open science

In the fields of software development and IT operations, developers are finding solutions for running the same code reliably in different environments. Starting with virtual machines and continuing with containerised applications and serverless functions, this trend moves towards separating code from the infrastructure it runs on. As this trend progresses, the number of devices and cloud platforms that can run the same code will increase significantly. At the same time, the technology will gradually operate independent of the underlying infrastructure and allow for smarter scheduling decisions on the cloud-edge continuum.

CNCF reports record Kubernetes and container adoption

In companies, the use of containerized application and container orchestrators, such as Kubernetes, are quickly becoming standard practice. Gartner predicts that 70% of organizations will run containerized applications by 2023.

open example



Leveraging containers for reproducible psychological research

Researchers are becoming aware of the benefits of containers for reproducible research and open science. In psychology, the use of containers may be an important step to solve the replication crisis.

open example

Singularity (Apptainer) containers improve reproducibility and ease of use in computational image analysis workflows

In high performance computing, Singularity (Apptainer) containers, as opposed to Docker containers, are used for easier and reproducible workflow. Singularity containers do not need root access to the host system to run and are therefore widely adopted on HPC clusters.

open example

Using containers to enable AI at the edge

Containers are also used to deploy AI models, even on edge devices. This innovation exemplifies two converging trends: proliferating AI use cases at the edge of the network and increasingly heterogeneous infrastructures that include hybrid cloud platforms powered by containers and Kubernetes.

open example

IMPACT

This trend will mainly impact the way researchers do their work. They can reliably run the same algorithms and models on their laptop, on a supercomputer, in the cloud or on the edge, wherever the need and/or resources are present. These technologies also increase the reproducibility and shareability of their research and will benefit the open science movement. To take advantage of this trend, however, researchers will need to become familiar with DevOps processes and technologies or rely on IT departments and new platforms to facilitate adoption.

TREND #5

Robotic Automation

Robotic automation takes place on a hardware and software level. Physical robots have been a part of manufacturing for a while and single-purpose robots for private use, such as lawnmowers, are also becoming more common. Still, robots are not as omnipresent as we would have expected a decade ago. This will change with general-purpose robots that can operate in various contexts and with the rise of robots-as-a-service companies. On the software side, robotic automation is also steadily progressing. For instance, robotic process automation is taking over repetitive desktop work and chatbots are used to automate customer service.

Public values

Autonomy		
Justice	Equal treatment | Transparency | Democratic control	
Humanity	Safety | Personal development	

Readiness WATCH PLAN ACT

Drivers

#Automation #Gender balance in STEAM

Cloud labs: where robots do the research

Companies are creating remote labs where robots conduct experiments for researchers. The benefits of ‘cloud labs’ are that lab research becomes more affordable, reliable and reproducible.

open example

Cobots

Cobots, short for collaborative robots, are designed to be programmable and work safely alongside humans. Safety is provided by sensors, that make a cobot go into safety mode when interrupted.

open example

Are the robots coming for white-collar jobs?

Robotic processes are automating the work of white-collar workers like physical robots are disrupting manufacturing. The question is how this will change future jobs. Jobs that may be (partly) replaced by robotic automation include lawyers, legal secretaries, accountants, translators, marketing managers and real estate agents.

open example

The rise of robots-as-a-service

Robots-as-a-service companies are making it easier for businesses to get started with robotic automation without prohibitive capital expenses. This change to the robotics business model may radically transform markets and the future of work.

open example

IMPACT

In both education and research, people will need to learn how to work with both physical and virtual robotic automation. In certain fields, students will need courses on working with robots in their future jobs. On the administrative side, robotic process automation is likely to be used for routine tasks, so staff can focus on the creative and strategic aspects of their job instead. In laboratories, certain tasks and experiments can be delegated to a collaborative robot onsite or a robot in a cloud lab. Besides automation of processes, we will see a growing interaction with robots in the daily life of a student, teacher, researcher, etc.

More about Edge

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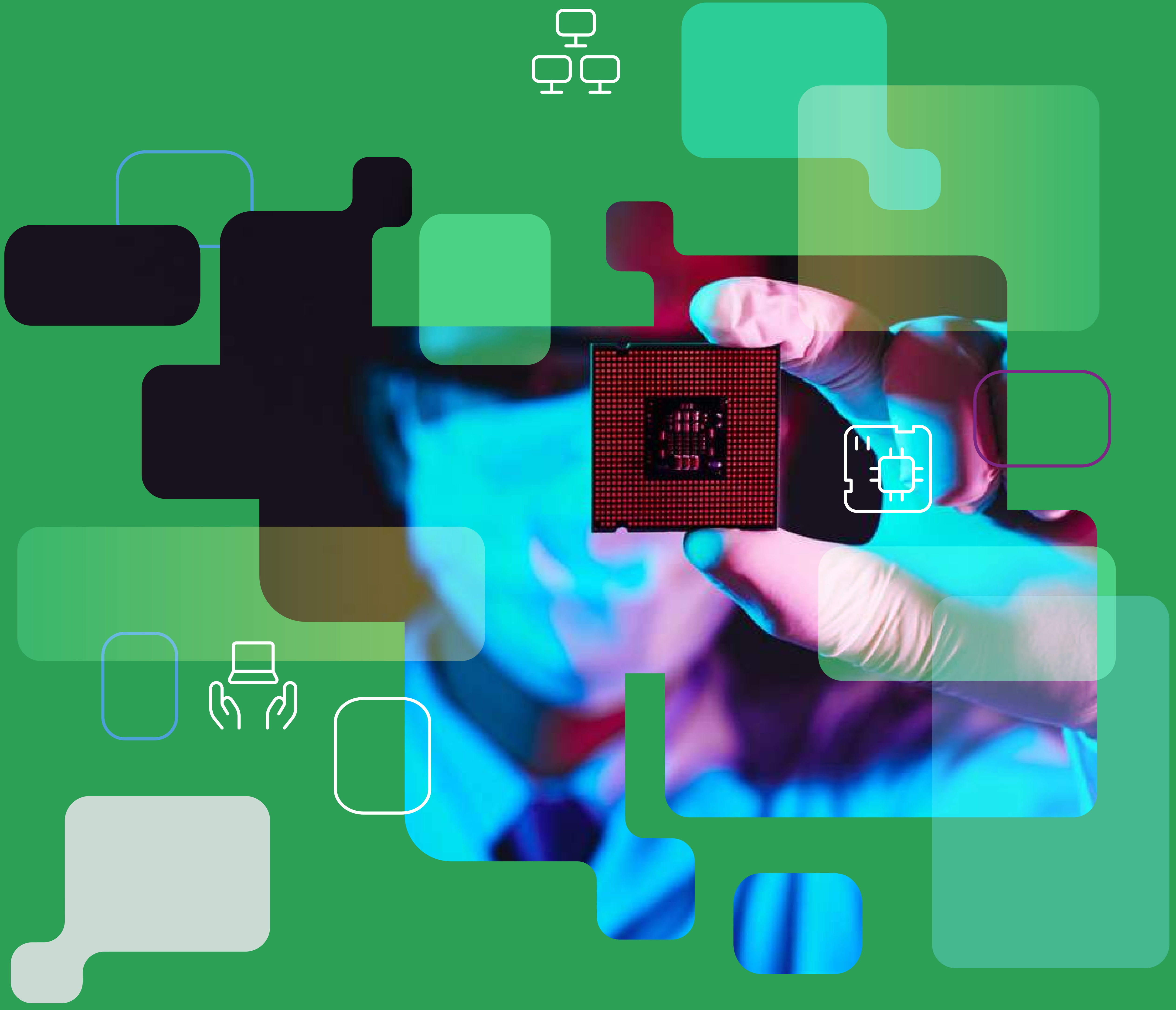
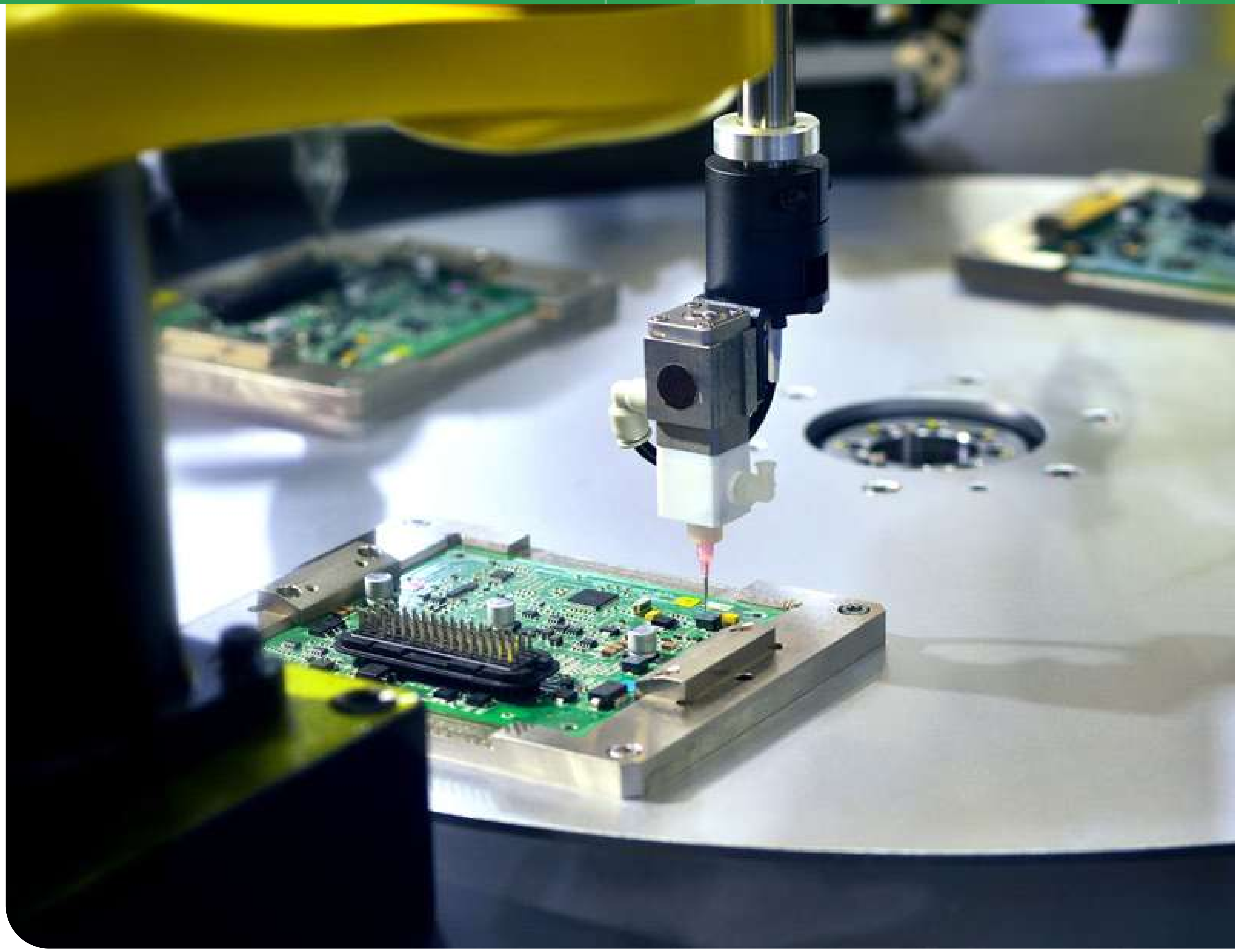
communities

Advanced Computing



- → Computing continuum
- → Energy sustainability in digital infrastructures
- → Protect sovereignty in digital infrastructure
- → Unconventional paradigms for computing
- → High-end computing in qualitative research fields

Advanced (Research) Computing



Solving societal challenges with digital research infrastructure on a global scale requires a unique combination of computing, storage, and networking technologies. We face a future full of complex emerging scientific questions, a growing energy demand and a growing number of bottlenecks in the semiconductor supply chain, but also a growth in opportunities offered by technology. In the last 50 years Moore's law enabled transistor size to shrink by half every few years; this in turn has led to a doubling of performance and functionality within the same chip area. But transistor size soon reaches fundamental physical limits, and the growth trajectory is expected to flatten out.

This will challenge the development of digital ecosystems, including technologies for research computing. (see CompSys NL Manifesto) These challenges include addressing increasing energy demands while at the same time increasing productivity, avoiding technology monopoly, protecting sovereignty and encouraging diversification in the field of computational science, as illustrated by the trends below.

For the future of science and humanity, digital transformation is going to play a pivotal role. Therefore, its exploration should include cultural values, expertise development, knowledge creation and most importantly understanding market developments. Some maturing trends mentioned here are further described in other chapters.

TREND #1

Computing continuum

Public values

Autonomy

Justice Integrity

Humanity Safety

Readiness WATCH PLAN ACT

Drivers

#Dataism #Globalization #Carbon footprint
#Climate change #Power efficiency
#Decentralization

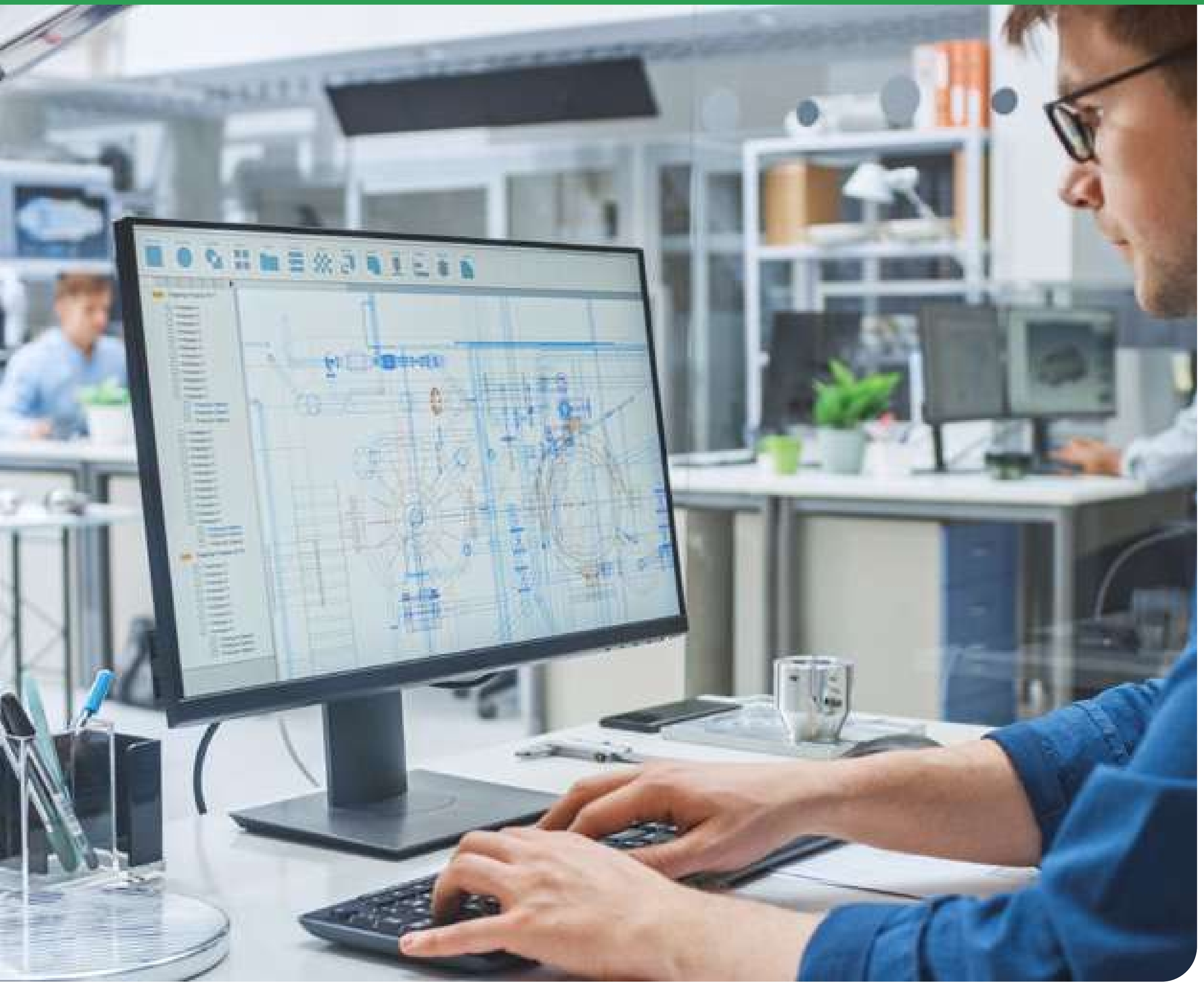
Applications like climate and earth observations, digital twins, drug discovery, protein folding, policy scenario analysis, high-energy physics et cetera require a large number of computing technologies and data infrastructures to work together. The need for high orders of magnitude of detailed modelling and simulation and also scaling data and meta-data, demands hyper-connected infrastructures with smooth accessibility and usage. It also requires efficient middlewares, programming models and research software leading to challenges for efficient usage and wider impact.

See also: Edge-Cloud Continuum

Orders of magnitude higher resolution

e.g. 1KM resolution for global Climate modelling, 10 times more data processing e.g. earth observation

open example



Real-time sensing and data ingestion

(Edge / IOT / Wired and wireless networks)

open example open example open example

Urgent computing

Disaster prevention, Hazard modelling

open example

Federated solution (Cloud continuum)

Federated cloud-based infrastructure for science and research

open example open example open example

Data visualisation for extreme scale modelling and simulation

Need of accelerated computing and I/O for in-situ visualization, digital twinning

open example

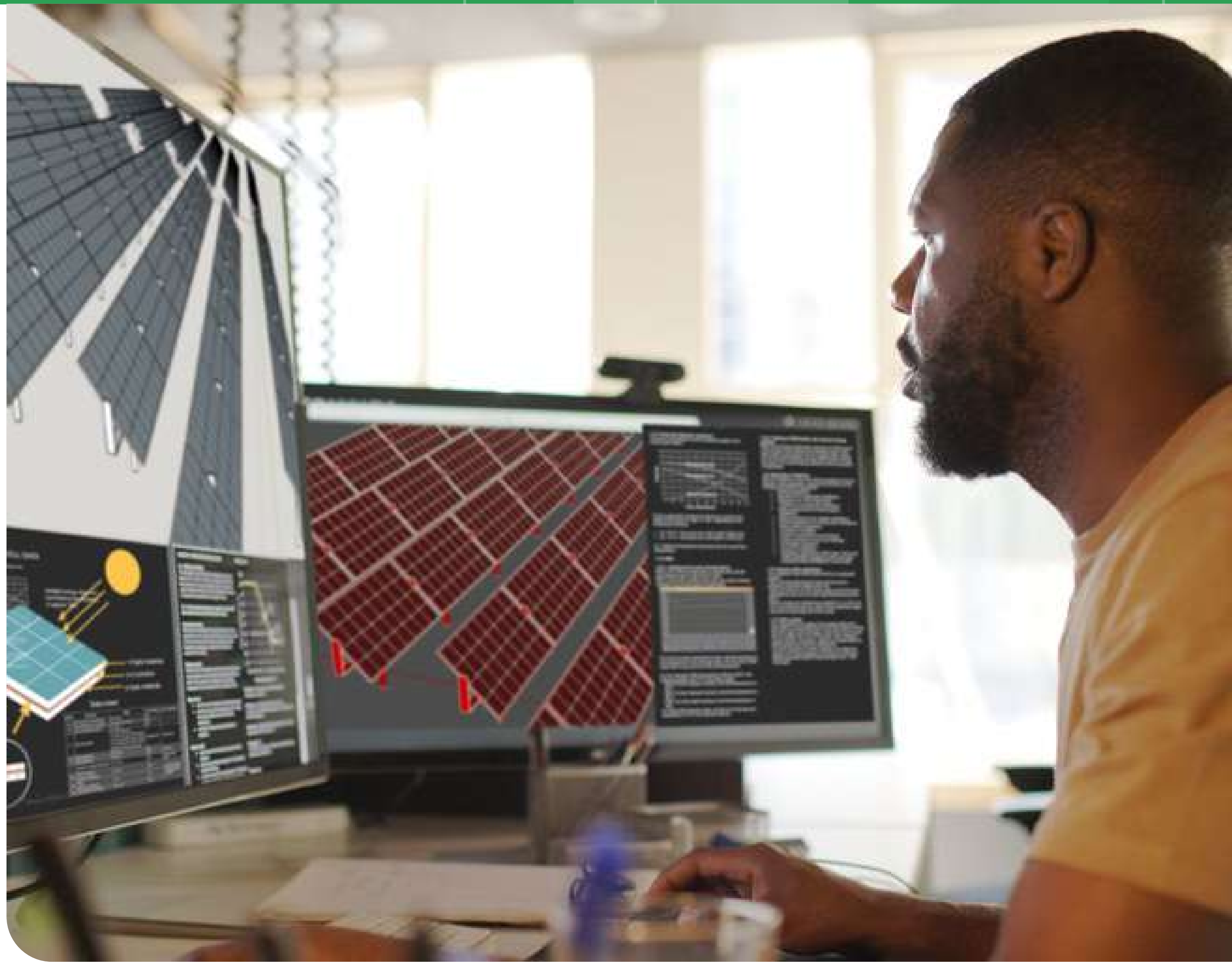
IMPACT

This trend affects the collective ability of the research community to tackle complex scientific challenges using distributed computing ecosystems. Furthermore, the trend helps this community to accommodate a wide range of scientific applications and workflows in the future. Future education and training could use networked XR or edge computing systems to understand digital twins or to demonstrate art and culture prototypes for different geographical locations. Working towards a federated infrastructure in the Netherlands offers NL-based researchers opportunities to access various computing and data infrastructures for research.

TREND #2

Energy sustainability in digital infrastructures

The surge in demand for advanced computing also leads to an exponential increase in our energy footprint. We should strive to reduce energy waste, improve efficiency and energy awareness for the entire value chain, from manufacturing to operations to decommissioning systems, while considering computing demands. We also need to involve community stakeholders in these efforts and communicate the results to all involved.



Public values

Autonomy

Justice — Integrity

Humanity — Personal development

Readiness WATCH PLAN ACT

Drivers

#Power efficiency #Biodiversity #Climate change #Circular economy

Push for energy efficient systems

Climate change, Green deal, Operational Cost, Energy / carbon accounting

open example

Digital and green transition picking up in Netherlands / Europe

Disaster prevention, Hazard modelling

open example open example

Electricity consumption for computing space expected to reach ~5-10% of global electricity consumption

open example open example open example

IMPACT

Due to the substantial amounts of electricity required by digital facilities, rising energy costs and energy budgeting are no longer distant prospects. These are already impeding improvements in advanced computing solutions. Advanced computing facilities must therefore be planned with energy as a design principle. Improvements in energy use can be found across the spectrum. Funding agencies will need to prioritise energy awareness, optimization and develop innovative policies to minimise negative impact on publicly funded research infrastructure. This trend also underlines the necessity for more engagement and interaction about energy with the user community. Also, energy as a topic for computing should become part of academic training, curricula and courses.

TREND #3

Protect sovereignty in digital infrastructure

Geopolitical tensions, global pandemics, growing dependence on global supply chains and emergence of private cloud providers have forced governments to formulate policies and introduce legal frameworks and laws to tackle technology sovereignty. The challenge is to strive for autonomy, effective investment of public money for research and avoid monopolisation of technological development by a small number of companies in the ecosystem.

Public values

Autonomy — Freedom of choice | Independence of education

Justice

Humanity

Readiness WATCH PLAN ACT

Drivers

#Data governance #EU legislation #Privacy #Decentralization

More research universities adopting cloud providers for their computing needs and operations

open example

open example

Chips are designed and owned by Big Tech

open example

Connected Digital facility

open example

Geographical chips act

open example open example open example

IMPACT

The need for data and infrastructure sovereignty is probably higher than ever before, given the proliferation in data and processing techniques in recent years. However, the challenges to achieve this sovereignty are non-trivial and multifaceted.

Firstly, there is the impact of Big Tech, with significant amounts of data being concentrated in the cloud storage of these major providers. Secondly, large cloud providers also provide easy-to-use tools to the research ecosystem for conducting data analysis. However, this also poses risks regarding data confidentiality and data lock-in. Thirdly, there is the issue of semiconductor manufacturing, which is now concentrated in three large companies. To address these risks a multi-level, hybrid ecosystem could be considered. In such a system, data with higher degrees of confidentiality would be processed using systems and techniques that grant sovereignty, whereas the bulk of data could be processed with ‘easy-to-use’ cloud tools.

Developing thought leadership on these topics and collaborating with the political establishment will help to improve legal framework and policies for the future and to deal with the sovereignty of computing research infrastructure in the long term. At the same time, the future needs and requirements of research and education communities need to be supported.

TREND #4

Unconventional paradigms for computing

In the next two decades, our demand for computing is expected to increase exponentially. This increase implies new modelling techniques, generating new science and an unprecedented need for moving, storing, and processing data at different scales. This trend also implies breaking current technological limitations and exploring solutions beyond the standard roadmaps. A positive development is the rapid influx of public/private large-scale funding, for instance for topics like AI+HPC, quantum, photonics, et cetera. It is important to understand that these are not replacement technologies, but complement existing technologies or even help us explore new untapped science. Exploring emerging technology, e.g non-von Neumann architectures, dataflow to accelerator-driven computing, quantum and neuromorphic paradigms, tools and specialisations offers an alternative way to break current barriers and increase efficiency with limited resources. It also involves redesigning scientific applications to match with future infrastructure and hardware.

Public values

Autonomy	Independence of education
Justice	Integrity
Humanity	Personal development

Readiness WATCH PLAN ACT

Drivers

#Internationalization #Connectivity
#Automation #Digital literacy and skills

Semiconductor technology reaching 2nm transistor lengths

Emergence of Chiplet for semiconductor chip design

open example open example

Hybrid /mixed precision algorithms

open example open example

Quantum-HPC integration with supercomputers

open example open example

Machine learning enhanced scientific computing

open example

open example open example open example

Rise of brain inspired computing; In-memory

Neuromorphic computing

open example open example

Unconventional computing chips

e.g. FPGA for data processing in the networks

open example open example open example

IMPACT

Our ability to understand and experiment with unconventional paradigms, technologies and methodologies will help us explore opportunities together and develop expertise and competences to prepare for the use of new technologies. This ability also help us to support operational teams in choosing design, architecture, and hardware technologies in the next generation research computing systems. Finally, we can also make best use of public funds when future requirements, technology roadmaps and emerging applications are taken into account.

TREND #5

High-end computing in qualitative research fields

A growing number of new communities in for instance social sciences, humanities, art, history, digital health, sports, and medicine have started using computing services for enhancing research and insights development. They regularly need expertise and support to map their research questions onto computing systems. This is mainly because the data they have at their disposal today is much larger than 5 years ago (a laptop is not enough). Furthermore, the statistical analysis and modelling tools they use have transformed into ML/Big Data workflows, and these require large computing power.

Public values

Autonomy	Freedom of education | Privacy
Justice	Inclusivity | Equality
Humanity	

Readiness WATCH PLAN ACT

Drivers
#Dataism #Internationalization #Digital economy #Research environment #Privacy

Increased use of computing resources in social sciences, arts and humanities

open example open example open example

Provisioning funding for software research engineers

open example

open example

Community specific project calls

e.g., for Humanities and social science, Linguistics, Health, Education, Science

open example

IMPACT

Nurturing and supporting the compute requirements of these new emerging communities will in the long term lead to diversified usage of research infrastructure and sustainable business models. Strategically this will lead to the inclusion of talent and people from various backgrounds, ethnicities and cultures. Overall, designing solutions for these communities will ensure that computing becomes an accessible digital research infrastructure suitable for researchers from all domains.

More about Advanced Computing

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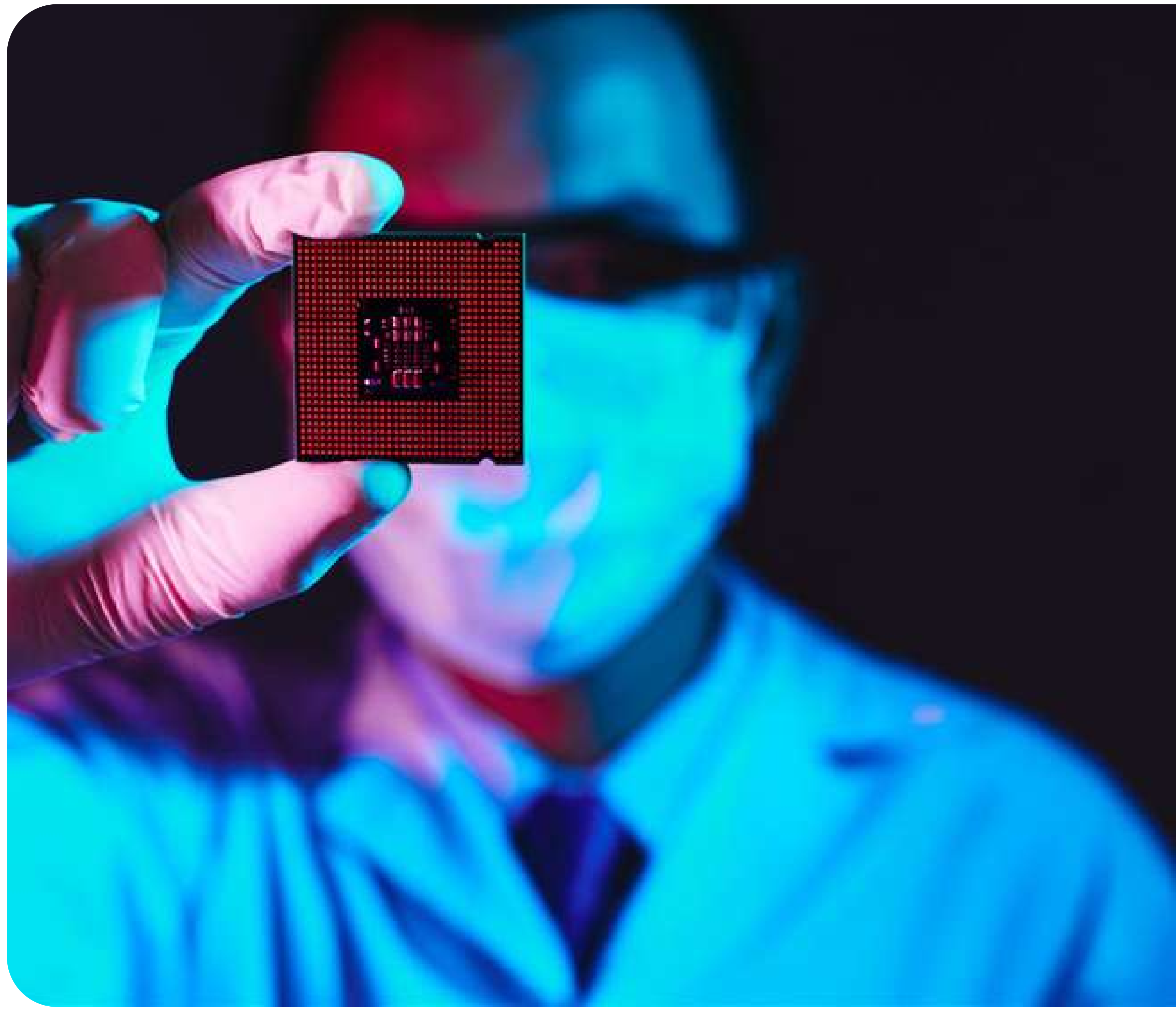


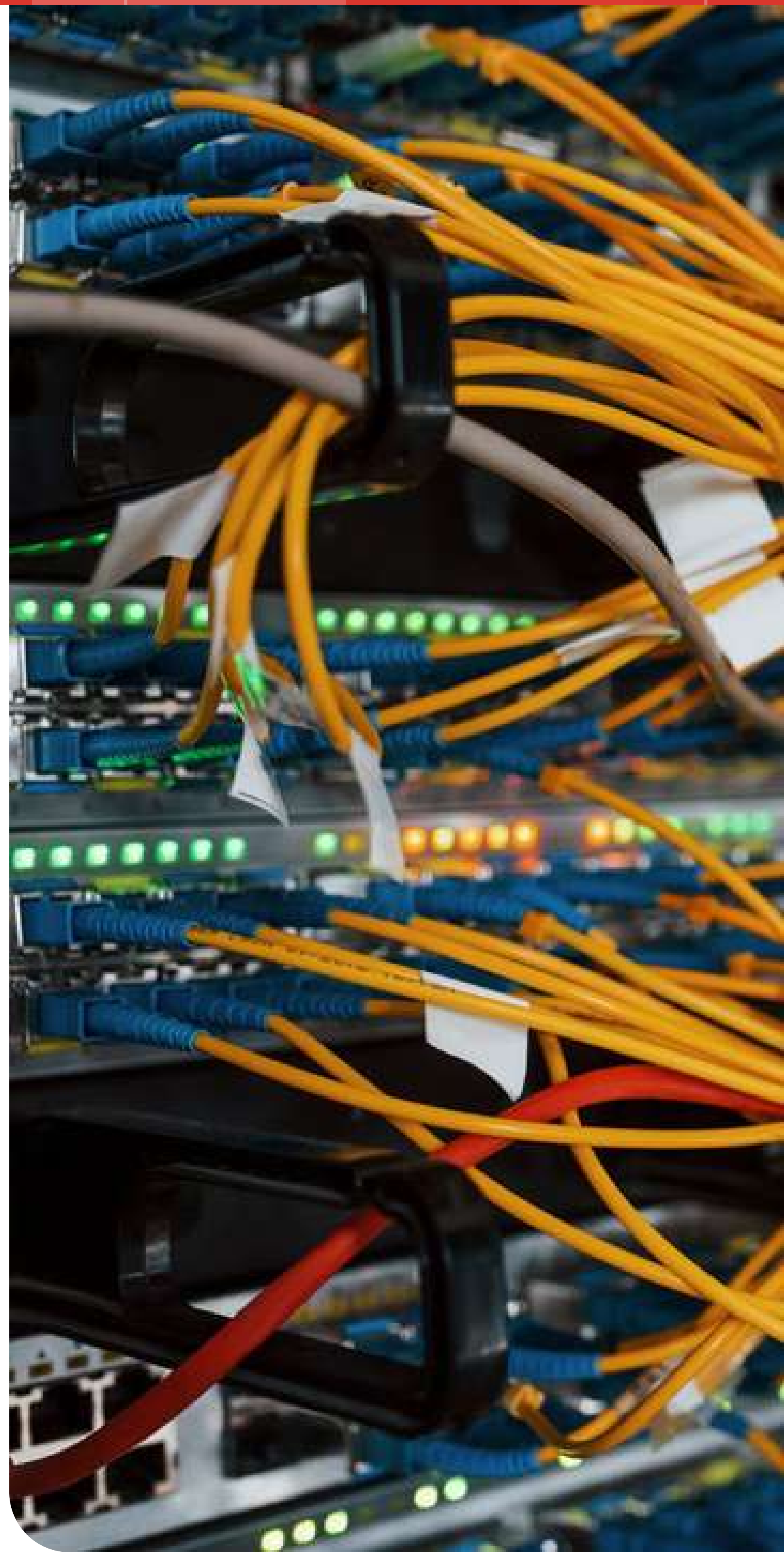
Network

Network technology

Fixed communication networks are essential for the digitalisation of society in the Netherlands. Networks also integrate compute and storage more and more. Cellular, Internet and data centre worlds are overlapping more and more. Together, these networks form the foundation for internet applications, (research) services and cloud. Without a suitable network these applications, services and clouds would not function properly. National Research and Education Networks (NRENs) provide appropriate connectivity allowing students, teachers and academics to collaborate without boundaries.

Communication networks are essential for research and education in the Netherlands and for increasing global collaboration. These networks not only facilitate digital communication for many students and researchers, but also enable innovation in all areas of expertise, from climate science to health science to radio astronomy. In addition, fixed communication networks are essential for addressing major societal challenges, for example in the field of sustainability and safety. The landscape of an NREN is changing continuously to facilitate new and improved applications and technologies, such as campus integration, XR, edge computing, quantum, etc. Some trends offer opportunities, while others represent risks and challenges. This chapter describes the trends that we see in the fixed network landscape.

Network technologies can be viewed from different angles. In this chapter we focus on fixed networks; the other perspectives, such as wireless (LoRa, WiFi, etc.) and non-traditional use of network infrastructures (quantum, etc.) are out of scope.



TREND #1

Big Tech and networking

Public values

Autonomy	Freedom of choice | Self determination | Independence of education | Safeguarding of private life and personal data
Justice	Integrity
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Open science #EU legislation #Privacy #Data governance #Open-source development #Globalization

Big Tech companies and cloud providers are expanding their worldwide dominance by acquiring ever more physical infrastructure and introducing innovative techniques focusing on operating and facilitating their services even better. While these companies already own content and data on the internet, these strategies allow them to own the physical network infrastructure and services as well. Due to Big Tech's monopoly and the lack of feasible and ubiquitous alternatives, innovation initiatives by other parties to improve security, stability and transparency of the internet are less likely to succeed. Broad collaboration is required to change course and safeguard our digital sovereignty.

Strengthening digital sovereignty makes Europe less vulnerable, both politically and economically

TNO provides options and ideas to strengthen digital sovereignty, taking into account European initiatives. Those options include new legislation and the development of European alternatives, through state-supported investments and collaboration.

open example

Big Tech's next act will be to evolve into networks

Big Tech companies are teaming up to deliver networking capabilities. Facebook and Google announced they were funding two trans-Pacific cables connecting the US West Coast to Singapore and Indonesia.

open example

2STiC: security, stability and transparency in inter-network communication

A joint research program in the field of trusted and resilient internet infrastructures helps putting the Dutch and European networking communities in a leading position to enhance the security, stability and transparency of internet communications.

open example

Big tech conquers internet infrastructure

Big Tech companies (Meta, Microsoft, Amazon Alphabet) are expected to become the largest shareholders in the submarine cable market in the next three years.

open example

IMPACT

Big Tech companies and cloud providers are able to deliver high quality services due to their level of integration. Researchers, students, IT managers, teachers, etc. find this level of service convenient and place ever more trust in one provider. Ultimately this poses a risk as users become dependent on one or a small number of parties. Free and open science, access to data and unrestricted usage of the internet, may become less self-evident.

TREND #2

Intelligent networks

With the emergence of ever more service-orientated architectures in software, we see that the operation of networks is evolving as well. Networks need to be more flexible, open and programmable; moreover, they need to be defined around a service that the provider is delivering to a customer. To enable this, network provisioning is evolving from manual and/or device specific provisioning to service provisioning through APIs, across multiple network components with different functionalities. This allows the network to be integrated with other infrastructure like compute and storage. Intelligence can be added to the network by leveraging telemetry, artificial intelligence and machine learning algorithms. These additions can modify the network through the defined services to fix anomalies, optimise service delivery and improve security. These additions can modify the network through the defined services to fix anomalies, optimise service delivery and improve security. Network developments are also relevant and needed to support the further development of AI/ML.

Public values

Autonomy	Freedom of choice | Self determination | Independence of education | Safeguarding of private life and personal data
Justice	Integrity
Humanity	

Readiness	WATCH	PLAN	ACT

Drivers

#Data governance #Automation #Cybersecurity

Creating a Smarter Network

Several NREN networks enable on-demand data feeds between researchers and scientists. Scientists are able to schedule large data transfers via multi-domain, high-bandwidth virtual circuits that guarantee end-to-end network performance.

open example

Cloudflare outage - Cloudflare

Outages at Cloudflare affected 19 data centers, which handle a significant proportion of global traffic.

open example

IMPACT

Intelligent networks provide users, such as students, scientists and operational staff, with network functionality that matches their needs. This allows users to make better use of network resources due to integration of services (e.g. compute, storage, …) or automatic recovery in case of incidents. Service provisioning is guaranteed to be fast and secure as human error is eliminated.

The introduction of data plane programming makes it possible to research and design protocols and APIs to increase our insight in the network and utilise resources more efficiently. However, with the emergence of this trend operators run the risk that running networks becomes even more complex. By introducing intertwined architectures and high levels of automation and orchestration, the network layer and application layer become highly interdependent and therefore increasingly impact each other. Programmability can facilitate the integration of automation tools.

TREND #3

Edge and campus architecture

Campus network operators are experiencing a brain drain of employees who are willing and able to run networks. SURF and their members can help universities to select a network architecture that scales well, is very robust and secure by design. At the same time, the services that need to be delivered at the network edge or on campus are getting increasingly complex. As a result, various technologies are increasingly being applied to campus and edge networks to ensure service delivery. Examples of these technologies are: NFV, SD-WAN, 5G/hybrid cloud infrastructure and EVPN-VXLAN.

Public values

Autonomy — Independence of education

Justice

Humanity

Readiness WATCH PLAN ACT

Drivers

#Automation #Connectivity

CNaaS - SUNET, SIKT, Nordunet

Development of a concept and toolkit for an NREN to provide a 24/7 secure and highly reliable campus network service for campus networks.

open example

As 5G, Edge computing and hybrid multiclouds converge, industries will be transformed

The emergence of edge computing and the telecommunications network as a hybrid multi-cloud platform. The combination of 5G, edge computing and hybrid multi-cloud represents a new computing model capable of transforming a wide range of industries.

open example

The AI driven campus architecture

Network architects are redesigning their networks to accommodate modern business requirements of cloud-ready applications for data, voice, and video, using open standards and software-driven management platforms to reduce operational costs. The ultimate goal is to leverage simpler automation, telemetry, and AI capabilities to expand the network of the next decade.

open example

IMPACT

This trend allows campus operators to focus more on end-user services and less on the underlying technology. The underlying edge and campus technology can be highly standardised and integrated with other infrastructures and applications. This combination allows small operational campus teams to run networks that serve a variety of end-users. In addition, this integration ensures innovation and new opportunities may arise in due course. Edge and campus networking includes many components and potentially a lot of third-party suppliers. This operational model and architecture require well defined SLA's, agreements and trusted parties.

TREND #4

Next generation networks

Numerous examples show that the amount of data being transported is increasing every year. Vendors of network hardware are focusing on these increasing demands in their hardware design. National research and education networks (NRENs) must be able to support all types of traffic on their network. Examples are regular internet and campus traffic, latency sensitive flows, data intensive flows and other research traffic. This is usually not the case for normal network providers, therefore technology that an NREN requires may not be incorporated in future chipsets.

SKA: network requirements

Next generation network requirements for the Square Kilometre Array project. Multiple redundant large networking pipes are expected to be needed to and from various locations worldwide from the start of the project. NRENs need to collaborate to provide the required connectivity.

open example

Public values

Autonomy	Independence | Freedom of education and research
Justice	Integrity
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Connectivity #Datagovernance #Cybersecurity

ITER: network requirements

Next generation network requirements for ITER; one of the most ambitious energy projects in the world. Multiple 100Gbps connections are expected in the first years of operations.

open example

Global internet bandwidth - the era of networking measured in petabits

Over the past few years the internet traffic has increased with an annual growth rate of 29%.

open example

ITU-T Technical Report - Use Case: Huge Scientific Data Applications (HSD)

Towards the year of 2030 and beyond, many novel applications are expected to emerge as others mature, leading to increasingly intertwined human and machine communications. New applications often trigger new services and introduce challenging requirements that demand the continuous evolution of networking technologies. Thus, the inherent capabilities of interconnected networks and the running principles therein need to be enhanced, or even replaced, as requirements unfold.

open example

HL-LHC: Network Requirements and Associated Issues

The Large Hadron Collider in Geneva demands next generation network requirements. The amount of data that needs to be transported is expected to increase tenfold in the next five years.

open example

IMPACT

Large-scale research projects enable the development of next generation networks, not only by facilitating bandwidth requirements, but also by enabling new network applications, protocols and architectures. This will accelerate the commoditisation of new integrated services, increase sustainability and trigger vendors to build suitable hardware.

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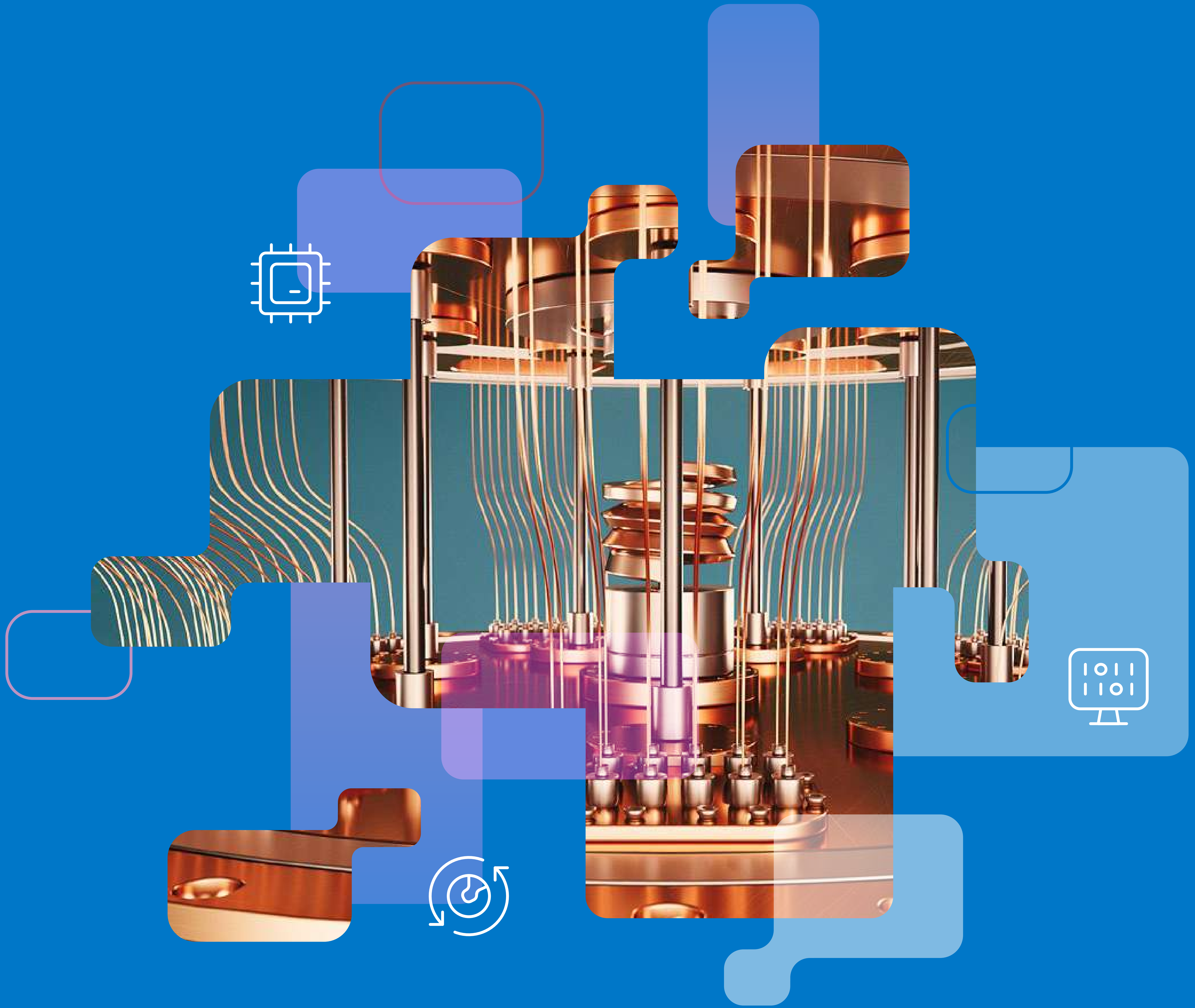
Quantum



→ Quantum Key Distribution (QKD) gaining momentum

→ Quantum Computing in the Cloud

→ Hybrid quantum/classical computing

→ Error correction techniques

→ Quantum curiosity

Quantum Information Science and Technology (QIST)

There are three main subfields under the umbrella of Quantum Information Science and Technology (QIST): quantum computing and simulation, quantum sensing and metrology, and quantum communication. In the Netherlands, these fields are reflected in the Quantum Delta NL catalyst programs. In this section we elaborate on these fields.

1. Quantum Computing

Quantum computers are devices that process information by taking advantage of the quantum-mechanical properties (superposition, entanglement and interference) of their building blocks, the qubits. These qubits harness work in a powerful and efficient way and perform certain operations with an exponential speed. Currently available quantum computers are known as 'noisy intermediate scale quantum' (NISQ) devices. They contain small numbers of qubits and suffer from decoherence, meaning that information is altered by the system's interaction with its environment. NISQ devices can be used to execute quantum algorithms that do not require deep and fully coherent quantum circuits. Generally, these algorithms are executed in a hybrid way: classical and quantum resources are combined to make use of their complementary strengths and features. This results in a more robust and flexible approach than using NISQ devices alone (hybrid quantum/classical computing). Quantum computing dramatically alters the way we solve problems at a fundamental level. To take advantage of quantum computing, it's not enough to further develop the hardware, we also need to rethink the way we normally approach problems. We have to create and redesign algorithms from the ground up and identify the applications that can benefit from quantum computing.

2. Quantum Sensing

Quantum sensors can measure different physical properties with extreme precision. These properties include temperature, pressure, rotation, and electric and magnetic fields. Their precision stems from the sensitivity of quantum states to minor changes in the environment. Some quantum sensors can measure much smaller quantities than current sensors, while others provide better resolution when images are captured. Due to their high sensitivity, areas such as renewable energy, nuclear energy, and geothermal energy have been adopting quantum sensors for their applications. In the future, quantum sensors could be placed in a quantum network with quantum processors, allowing sensor data to be correlated in the quantum information plane.

3. Quantum Communication

Quantum communication services, such as the delivery of entangled qubit pairs, allow quantum processors, sensors, and computers to exchange quantum information using quantum protocols. Entangled qubit pairs have the quantum mechanical property that a change in properties of one qubit results in a direct change in properties on the other qubit, irrespective of the distance between the qubits. The transmission of quantum information and eventually the communication between quantum computers is also the foundation for a quantum internet (QI): a quantum network with features like the internet we have currently.

A first quantum communication service, that can be implemented today, provides an alternative to conventional encryption of sensitive data. Sensitive data, once encrypted, is sent across fibre-optic network cables and other channels together with digitally computed semi-random keys needed to decode the information. The data and the keys are sent as classical bits—a stream of electrical or optical pulses representing 1s and 0s. That makes them vulnerable, as quantum computers can potentially reverse the algorithm used to compute these keys. Quantum key distribution (QKD, one aspect of quantum communication) allows classical information to be encrypted using truly random key material that cannot be decrypted using classic or quantum computation techniques.

TREND #1

Quantum Key Distribution (QKD) gaining momentum

Public values

Autonomy Privacy

Justice Trustworthiness of information

Humanity

Readiness WATCH PLAN ACT

Drivers

#Cyber security #Digital economy #Privacy #Research environment

QKD is a secure communication method that enables two parties to produce a shared random secret key known only to them, which can then be used to encrypt and decrypt messages. As opposed to classical key distribution, QKD allows users to know when a third party is attempting to gain knowledge of their key. QKD is not new, some companies have already taken advantage of it. But it is only recently that QKD equipment is becoming commercially available; currently seven companies worldwide are offering commercial QKD systems. Additionally, integration is becoming easier: European and International standardization bodies (ETSI and ITU) have standardized interfaces allowing connections between QKD equipment and other equipment and software packages.

Quantum Key Distribution: The Future Of Secure Communication

The European Commission has launched several calls to implement a quantum communication infrastructure with tooling for full funding when co-funded nationally.

open example

Quantum Cryptography Market

Market research shows us that the global quantum cryptography market is growing at a compelling rate. In 2031, the market is expected to be eight times larger than today.

open example

A market of $2 billion by 2027

According to the Insight Partners report titled ‘Quantum Cryptography Market To 2027,’ the Global QKD market is expected to grow towards $2 billion by 2027 with a compound annual growth rate (CAGR) of 39.2%.

open example

ID Quantique: Quantum-safe security white paper

QKD networks will soon become a reality. QKD is therefore set to become an integral part of a global security framework. In this framework both computational methods and physical methods are used to ensure data security. In particular, it will provide quantum-safe security against the threat of a quantum computer.

open example

IMPACT

QKD is still expensive to implement for any large-scale educational service/purpose. First use-cases will be in high-security scenario’s, such as transport of medical data The technology will probably not be used in education, but it will trigger the need to develop - through establishing curricula - competence for operating and building equipment. The technology will have an indirect impact on research. With the use of QKD, research data can be encrypted on different layers in the network. In addition, QKD will create active research in finding and implementing more robust protocols and in the technology needed to make these protocols work over ever greater distances. This impacts research on how to connect quantum and classical IT, as well as connecting future quantum devices These results are essential for new quantum communication related use cases.

TREND #2

Quantum Computing in the Cloud

Public values

Autonomy	Freedom of choice
Justice	Accesibility | Integrity
Humanity	Personal development

Readiness WATCH PLAN ACT

Drivers

#Connectivity #Digital literacy and skills #Research environment

In the last years we have seen the rise of quantum computing. Not only is hardware rapidly developing (we now have computers with up to 433 qubits and many different technologies), but the whole software stack and platforms that give access to quantum computing are rapidly evolving as well. Researchers and students can now access quantum computers through the internet. Access can be granted directly by the quantum computing provider, as is the case in IBM and Quantum Inspire, or via public cloud providers like AWS and Azure. Furthermore, quantum computing providers show increasing interest to engage with end-users to explore use cases that can prove quantum advantage. The quantum computing providers are constantly expanding their portfolio, both on the back-end side (quantum computers available) and on the software/platform side (modules, tutorials, tools for analysis, abstraction layers, etc) to help the onboarding of users and the development of new applications.

Tools and tutorials for quantum computing

Microsoft developed a course for educators to support the development of a quantum-ready workforce. Also, IBM Research developed Qiskit, an open-source software development kit for working with the most widely used programming tool in quantum computing. Qiskit has a very robust set of tutorials, videos and examples available for everyone.

open example open example

Quantum Delta NL action line 3

Quantum technology is still in an early, pre-paradigm phase. In this phase, it is extremely important to focus on talent. In this action line, Quantum Delta NL will focus on educating, training and attracting top talent for strengthening the Dutch innovation capacity that incorporates all the affiliated quantum research institutes.

open example

Quantum.Amsterdam workshops and training

To educate and prepare professionals, Quantum Amsterdam organises workshops and masterclasses on quantum computing. These workshops and masterclasses are aimed at senior management, entrepreneurs and IT staff. For more extensive training on bachelor's and master's level, university courses are available.

open example

Quantum engineering course in the making

All five quantum hubs in the Netherlands are developing University Master programs on quantum information science and technology. This initiative lies by the University of Delft, the University of Leiden, the Eindhoven University of Technology, the University of Amsterdam, and TU Twente. Moreover, the four Applied Science Schools Fontys, HvA, Saxion and HHS, are jointly setting up Talent and Learning Centers and their own Master quantum technology program.

open example

IMPACT

With more quantum computers, information, tutorials, tools and abstraction layers available, there will be a faster adoption of quantum computers. As the adoption of quantum computer grows, so will the need to develop expertise in the field, through establishing curricula. Easy access to quantum computers will enhance the overall understanding of students by providing the possibility for practical experiments. In research, the access to quantum computers will speed up the development of applications and use cases. Access to different technologies will also allow for a better characterization of quantum computers and therefore accelerate knowledge in quantum computing itself. Comparison, testing and benchmarking studies for different algorithms and applications will also increase.

TREND #3

Hybrid quantum/ classical computing

Public values

Autonomy

Justice — Accessibility | Integrity

Humanity

Readiness WATCH PLAN ACT

Drivers

#Digital literacy and skills #Dataism
#Connectivity #Digital economy

Hybrid algorithms are currently the only way to exploit NISQ devices and have been proposed for most applications envisioned for quantum computers. However, a hybrid approach is not exclusive to the execution of hybrid algorithms. Every quantum algorithm requires the support of classical resources. Furthermore, in most cases, quantum algorithms will not be executed as isolated instances but as part of larger workflows that combine classical and quantum resources. For complex problems, classical resources will most likely be provided by high performance computing (HPC) centers.

To enable the development of quantum applications, quantum computing providers, and in particular QaaS, are now also including classical resources to their platform to ensure users can execute a wider range of experiments. HPC centers are becoming the earliest adaptors of quantum computers and/or simulators and working together with quantum providers to integrate quantum and classical resources.

NVIDIA Announces Hybrid Quantum-Classical Computing Platform

The hybrid quantum-classical capabilities provide an efficient way to program quantum and classical resources in a consolidated environment. This enables HPC developers to accelerate their applications, in chemistry, the development of new medicines, materials science and other disciplines. The integration with quantum computing allows for new discoveries as quantum advantages emerge.

open example

European investment on <HPC | QS > infrastructure

<HPC | QS > seeks to integrate and couple two quantum simulators, each capable of controlling more than 100 qubits, with two existing European Tier-0 supercomputers, and to deploy an open European federated hybrid HPC-QS infrastructure that will provide non-commercial cloud access to public and private European users.

open example

Accelerate hybrid quantum-classical algorithms on Amazon Braket

Research into hybrid quantum/classical algorithms is an important paradigm in the NISQ era of quantum computing. The performance-optimised software-based simulators from PennyLane, powered by NVIDIA, allow researchers to push the boundaries of research on hybrid quantum/classical algorithms.

open example   open example

IMPACT

Several research fields (for example chemistry, machine learning, financial modelling, logistic optimisation, climate simulations, etc.) can migrate parts of their current HPC applications to quantum computers. This migration could speed up the experiments and hence the research in these areas exponentially.

Hosting of quantum computers

The European High Performance Computing Joint Undertaking (EuroHPC JU) has selected six sites across the European Union (EU) to host and operate the first EuroHPC quantum computers: Czech Republic, Germany, Spain, France, Italy, and Poland.

open example

High performance computing centers early adopters of quantum computing

Several HPC centers have already acquired and integrated quantum simulators and quantum computers into their resources.

open example   open example   open example

Forbes: The quantum revolution is here, its name is hybrid

Classical and quantum computers will work together to tackle difficult problems. Hybrid computing will give non-quantum users access to quantum capability, primarily through the cloud. The classical computer will never go away, and without them quantum computers are never going to realise their full potential either.

open example

TREND #4

Error correction techniques

Public values

Autonomy

Justice Integrity

Humanity

Readiness WATCH PLAN ACT

Drivers

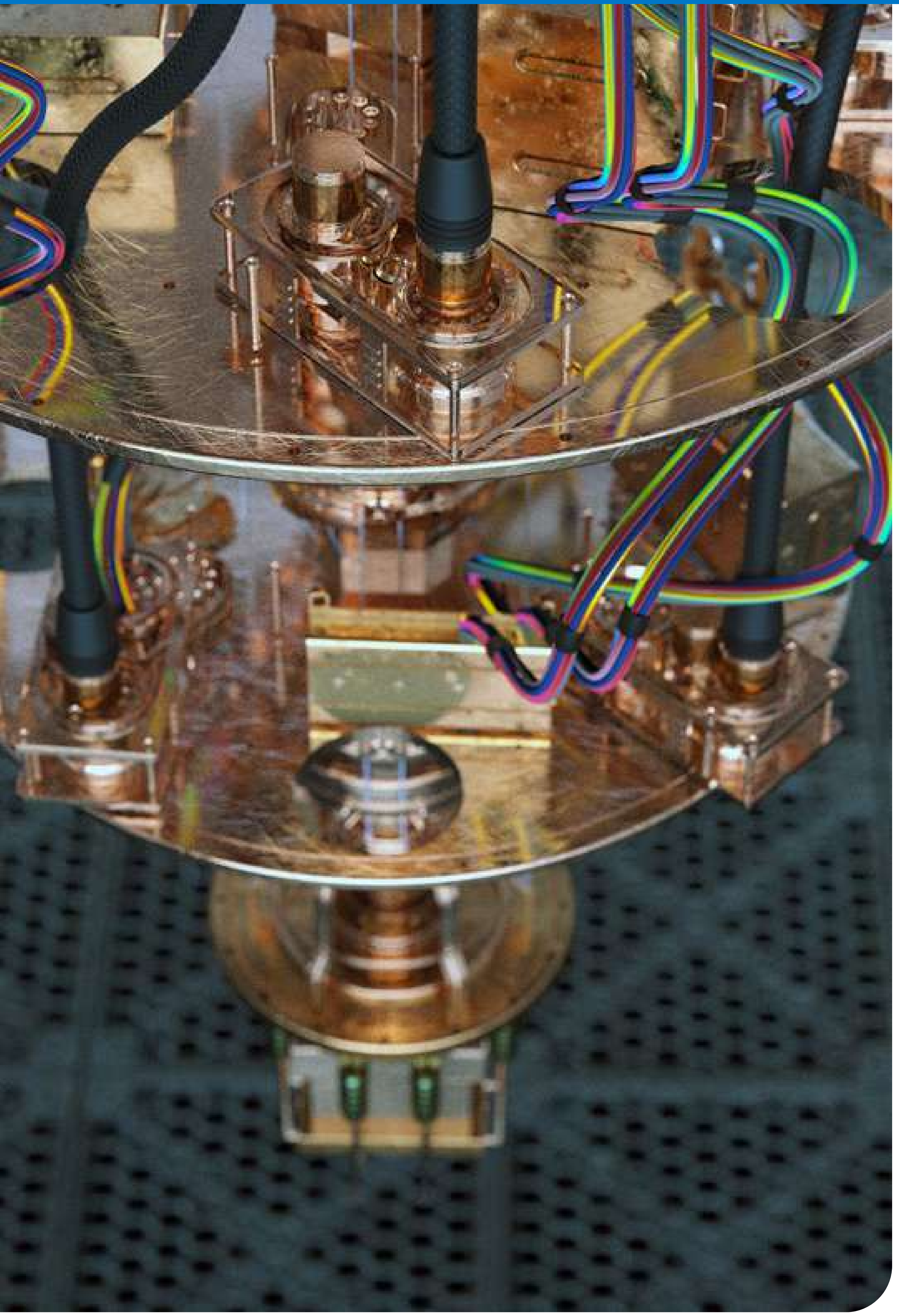
#Connectivity #Data governance

Qubits are delicate, unstable and prone to errors that can quickly lead to faulty computations. Decoding these errors on even a ‘small’ quantum computer requires real time identification and correction of billions of errors per microsecond. In order to be able to use quantum computers, we need error correction. In quantum error correction, quantum information is distributed among many qubits, so that the dominant noise processes affect quantum information in a reversible manner. This means that an error reversal procedure is employed to detect and correct the errors. There are currently many efforts in the development of advanced error correction techniques. Quantum error correction is a critical technique for transitioning from noisy intermediate-scale quantum devices to universal quantum computers. The surface code, which has a high threshold error rate, is the leading quantum error correction code for two-dimensional grid architecture.” [Youwei Zhao et al. Phys. Rev. Lett. 129, 030501 (2022)]

The big impact of quantum error correction

To do complex calculations, we must drastically scale up the number of high-quality qubits. Without error correction, a quantum computer’s answers could be nonsense. To make quantum computers useful, we need to reduce the impact of errors in our computations. There are different ways and levels of handling errors. For example, IBM currently looks at quantum error management through the lens of three methods: error suppression, error mitigation, and error correction However, the ultimate goal: fault-tolerant quantum computations requires the development of quantum error correction techniques.

open example open example



How IBM Quantum is advancing quantum error correction with hardware experiments

This article demonstrates the importance of performing real experiments in implementing our error correcting codes onto quantum hardware. Not only can they help to advance theory, but they can also tell us what kinds of coding and decoding schemes work best for the hardware that we're constructing and show us what kinds of errors to expect in the real world. These experiments even provide new ideas that theory may not have anticipated.

open example

The path to useful quantum computers with error correction

During the IEEE Quantum Week in September 2022, a variety of workshops and keynotes highlighted the emerging engineering challenges for getting quantum computing 'to scale'. We also learned more about the burgeoning ecosystem focusing on error-corrected machines.

open example

IMPACT

Most quantum algorithms require billions of gates, and hence require extensive error correction. Once mature fault-tolerant computers exist, end-users can operate them much more similar to a conventional computer, as they simply execute the logical instructions without worrying about mistakes.

TREND #5

Quantum curiosity

Quantum technologies are becoming sufficiently mature to be commercialised and a growing number of people are curious to explore possibilities and opportunities. Research institutions and private enterprises are increasingly teaming up to patent developments. Venture capitalist and governments are investing large amounts of money. Big companies are also investing in start-ups to increase their capabilities. Companies are investing and exploring quantum out of fear of missing out.

Public values

- Autonomy
- Justice — Equality
- Humanity

Readiness WATCH PLAN ACT

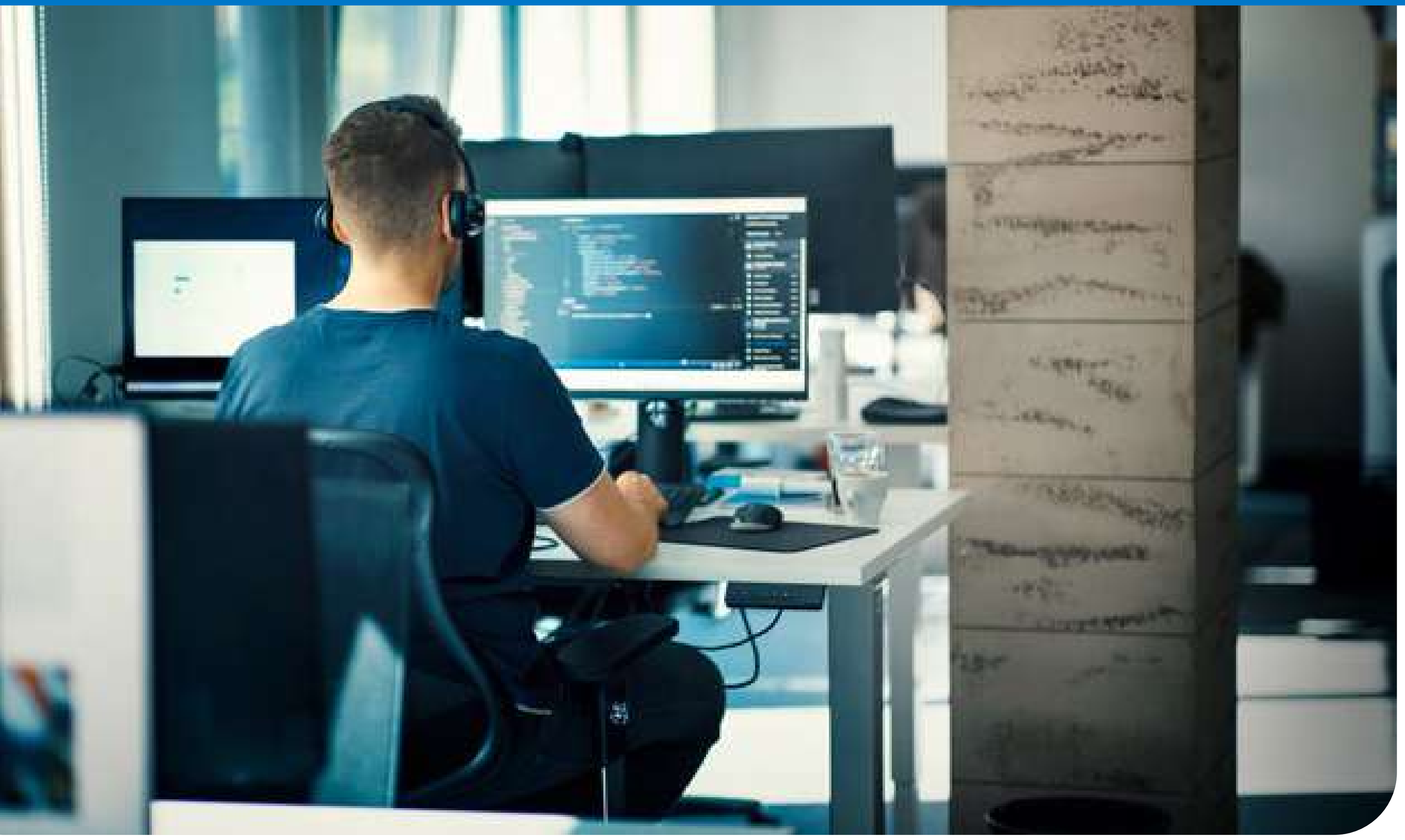
Drivers

#Dataism #Cyber security #Research environment

QDNL calls SME's for applications

SMEs can submit projects as individual companies or in a public-private partnership consortium from EUR 500,000 to EUR 2 million per project. Quantum SME aims to fund annually recurring calls of EUR 5 million per year for the further development of quantum technology.

open example



Quantum Delta NL launches two million euro micro fund for quantum startups

Quantum Delta NL launched a EUR 2 million micro fund called 'LightSpeed Fund 1'. The fund will support early stage quantum start-ups. If a start-up fails, it does not have to repay a EUR 50,000 pre-seed ticket.

open example

IMPACT

More jobs and opportunities for students with quantum technology knowledge. More collaborations with private sector and funding opportunities.

Capgemini launches a dedicated quantum lab

Capgemini has signed an agreement with IBM to become an IBM Quantum Hub. This hub will provide Capgemini's clients access to IBM's quantum computing systems, including IBM's recently announced 127 qubit processor 'Eagle'. The hub will also give access to IBM's quantum expertise and to Qiskit, IBM's open-source quantum information software development kit. By working with IBM, Capgemini joins more than 170 IBM Quantum Network members, all working to advance quantum computing and explore practical applications.

open example

Quantum Applications Lab

QAL will fullfill the much-needed connection between scientific developments of quantum hardware and software and demand-driven solutions for e.g. optimisation, simulation, and machine learning. Embedded in the Quantum Delta NL (QDNL) ecosystem, QAL will accelerate the construction of a social and economic innovation infrastructure for quantum computing and the knowledge, capabilities, and competencies required for this. QAL will do this by identifying promising domains for quantum computing applications and executing projects together with scientific, industrial, and/or private sector partners.

open example

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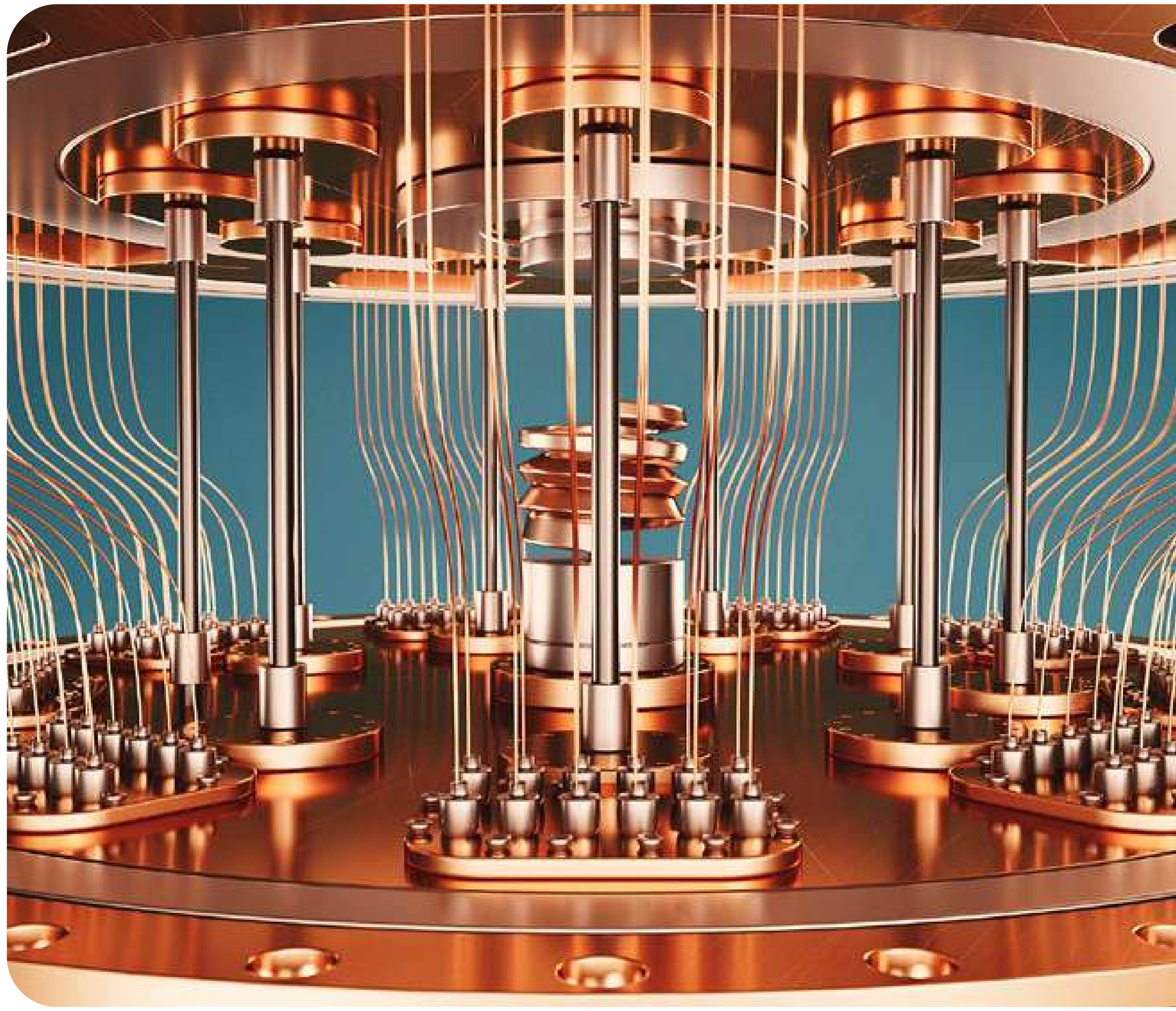


eXtended Reality

XR Technology

XR, or 'eXtended Reality' is both a technology in its own right as well as a term used for a combination of other reality altering technologies; combinations of virtual reality, augmented reality and mixed reality could all constitute XR. XR continues to be a developing technology in a variety of fields. Education, research, medical training, military, health care and even tourism embrace the technology in different and innovative ways. Whether XR is used to take a classroom of children to a national monument for a virtual field trip or to train practicing nurses how to dissect a virtual human body; XR continues to find new uses in a variety of learning spaces.

The XR technologies are commonly being used to immerse users in a physical-virtual world, now more commonly referred to as a 'Metaverse'. This immersive 3D internet experience has largely grown out of funding from major technology companies who see the future of the internet as something you are always 'in' and not necessarily something you are separated from. In this way, the metaverse does not compete with the internet, but builds on its very foundations. Web3 also represents a possible answer to the question how a new market can emerge within these simulated environments. The concept of Web3 is envisioned as a blockchain-based web including (hyped) products such as cryptocurrency and NFT's.

Of course, large technology firms are increasingly investing in XR devices and platforms and their presence grows as gaming, social communities and educational institutions bring in new headsets or equipment. Engaging with a metaverse or simulations in these domains will create new impact on the social and cultural norms of these institutions. Social norms regarding how professional communities are developing within these digital spaces, how people work together, and what is socially acceptable in these spaces, continue to evolve.

Educational spaces have begun to experiment with XR technologies for learning in new ways, including time-machine effects of learning new cultures, immersion in learning material, and even virtual rehearsal scenes for presentation skills. Researchers may find new opportunities in fully remote XR research, where a comprehensive experiment framework is yet to be established. Skills and competencies in new learning environments such as lab spaces, equipment protocols and virtual field trips can be effectively applied with promising results. Students and workers that are learning to work with new tools, equipment, medical facilities or laboratories are allowed to break things and make mistakes. They have a safer perspective thanks to a virtual environment before they enter the real one; this opens new doors to virtual places in both work and leisure.

TREND #1

Enriching XR by combining technologies

Public values

Autonomy

Justice

Humanity — Social cohesion | Safety | Health and well-being

Readiness WATCH PLAN ACT

Drivers

#Digital economy #Open and online education #Connectivity #Automation

Several modes of XR are often combined to create a more in-depth experience or layered on top of one another to combine different capabilities. New XR innovations take advantage of combining both digital interfaces and your body, both input and sense of self. Technologies in a variety of industries are being used in combination with XR to create innovative ways of changing a user's experience. Technologies like computing and AI are key enablers for the immersion of XR technology.

Meta's Codec Avatars 2.0 becoming very realistic

At Meta Connect 2022, Meta showed the current state of their Codec Avatars 2.0. These offer very realistic person-like avatars, including realistic facial movement (e.g. when laughing). The avatars are built with the use of advanced machine learning techniques and take a lot of processing power and time to generate.

open example

Generative AI for possible digital world creation

By combining XR and generative AI models, XR content may be automatically generated in the near future. Point-E, created by OpenAI is an example case, creating easy, text-generated 3D models that may find purpose in simulated worlds.

open example

Remote rendering to enhance digital fidelity and realism

With 'remote rendering' the 3D imagery is rendered in a powerful cloud-based server, with only the visuals streamed to the XR headset. Currently there are some solutions for remote rendering on devices, but there is a lack of network capabilities to make this scalable.

open example open example open example

IMPACT

With more layering of devices for an XR experience, our digital selves and digital impact become entrenched deeper in both our research and education. With new connectivity and immersion, educators can find more opportunities to take students on virtual field trips, such as new and more adventurous places in our universe. Research could create opportunities through better hardware with more rendering power needed for richer virtual environments. Social cohesion may benefit with more powerful renders with students having more enhanced learning environments and learning materials.

TREND #2

Virtual social interactions are getting more advanced

Public values

Autonomy	
Justice	Inclusivity
Humanity	Meaningful contact

Readiness WATCH PLAN ACT

Drivers

#Right to be able to work from home
#Open and online education #Connectivity
#Internationalization #DEI
#Research environment

XR is providing users access to virtual digital spaces, where people can meet, interact and collaborate. These new spaces allow people to play, work and train together in the same virtual space. Users can 'travel' around the world, without losing the time needed for travel; they may even visit a space station through teleportation at a click of a button. This new way of connecting offers a variety of opportunities, but it may have negative effects as well. For instance how will it affect the way in which we are working now?

Virtual campuses are opening

Ten universities have opened their virtual doors to university students, with some registering as many as 45,000 online-only students. Meta has sent many of these students headsets free of charge and currently doesn't charge colleges involved in the partnership with them.

open example

2 billion dollars to build a Metaverse for children

Epic Games collected investment money to create a Metaverse for children in cooperation with the LEGO Group. The developers will take the privacy, safety and well-being of children into account.

open example

IMPACT

Technologies that mediate our daily practices are changing behaviour, social norms and values. Students and educators find themselves in front of a screen more often and in forms that were not available before. New international collaborations become possible for educators, students and researchers; these virtual interactions create new educational opportunities. Inclusivity is affected as more people have access to virtual educational materials and places, and work in multidisciplinary teams.

How the Metaverse could change our daily work

The emergence of the Metaverse has already changed the workplace. Accenture, for example, is using 60,000 Meta Quest 2 headsets to support on-boarding, while Microsoft is collaborating with Meta to integrate Microsoft Teams and Microsoft365 with the Meta hardware.

open example

Virtual spaces can and will be used for dating

Many people find VR world dating much more inviting and safer than going out to a bar. VRChat alone has 30,000 monthly users that interact in a variety of ways, including dating and working. Users that live in small communities can still date outside their physical boundaries.

open example

TREND #3

New gear for new realities

Special gear is needed to gain access to new digital realities. Therefore, XR technology is pushing the development of new hardware by different tech companies. The list of XR devices is currently growing, and wearables like smart eyewear, head mounted display (HMD) and smart glasses are being developed to grant (new) users access. Devices for other modalities, such as touch and smell, are also under development and/or are available as products.

Meta vision of the Metaverse shows futuristic headset design

In June 2022 Meta released a video that shows the new futuristic headset design and fingertip input device. The device is slimmer than the Oculus Quest and probably will be used in combination with haptic gloves or EMG wristbands.

open example

Public values

Autonomy	Freedom of education
Justice	Inclusivity
Humanity	Personal development | Safety | Health & well-being

Readiness WATCH PLAN ACT

Drivers

#Connectivity #Digital economy #Globalization #Dataism

Feeling virtual objects with gloves that provide feedback

Meta microfluidic gloves now provide high-fidelity haptic feedback, which makes for a more immersive and real experience. The gloves can let you feel resistance, texture and shape of objects in XR.

open example

Build your XR training scenario with Interhaptics

Unity has developed Interhaptics, which can be used to create large and complex scenarios. One interaction can trigger several events, depending on the rules the developer applies to it.

open example

Virtual kisses with ultrasonic transducers

A kiss can now be simulated in VR with an off-the-shelf virtuality headset. This headset can recreate the sense of touch, without hardware that is touching the user's face.

open example

IMPACT

As XR devices continue to become lighter and user friendly, their use will change. Users will wear their headsets for a longer period of time. Currently, XR is making improvements in training procedural knowledge regarding decision making, though not for motor skills. Haptic gloves and other designs offer more realistic learning possibilities for motor skills. Medical and police communities have found particular interest and effective use cases for XR training simulations. These developments will lead to new research in eye tracking and data collection of whole body movement. New hardware will also increase pressure on interoperability and price as the market becomes saturated with different headsets.

TREND #4

An increasing number of ethical concerns

Like most mobile devices, XR allows providers and suppliers to collect data. However, with XR more advanced and personal user data can be tracked, both physically and digitally. For instance, the technology allows not only tracking of body movement, but also of eye movements and pupil dilation. These developments raise ethical concerns, in terms of both privacy and data management. What user data is collected, how it is collected, who has access, how is it processed? Perhaps most importantly, for which purposes can that data be used?

Public values

Autonomy	Safeguarding of private life and personal data
Justice	Equality | Integrity
Humanity	Safety

Readiness WATCH PLAN ACT

Drivers

#Cyber security #EU legislation #Privacy #Digital literacy & skills #Research environment

Watching your eyes means understanding your desires, and much more...

Tracking a user's eyes using cameras can improve user experience in XR, by allowing one to naturally focus on virtual content by simply looking at it. Eye tracking data can be used to make interpretations about what a person wants or desires.

open example

Our bodies could be the new data source for surveillance technology in the Metaverse

XR headsets, hand controls, cameras and microphones allow for a drastic increase in the recording of biometric information. There are as yet few restrictions in place to protect us from unrestricted data gathering.

open example

The ethics of a brain-computer interface in VR - Digital Bodies

A brain-computer interface (BCI) gives lots of opportunities, like allowing a person with a prosthetic hand to grasp a glass of water with their thoughts. However, brain-computer interface solutions raise profound ethical challenges – and not just in virtual reality.

open example

The future of advertising in AR/VR

New ways of selling (virtual) merchandise to users of XR technologies are emerging. New experiments focus on keeping the user within the XR experience as much as possible, including Interactive Advertising Bureau (IAB,) which is guiding digital advertising standards and terminology to allow disparate systems and platforms to work together.

open example

IMPACT

Ethics, regulations and standards will continue to develop as XR technologies challenge current data collecting and usage norms. These new XR technologies also open up new opportunities for security. For instance, eye tracking can be used to identify individuals, allowing it to be used as an authentication mechanism or even as a password. Collecting marketing data and tracking individuals across digital worlds and spaces will likely lead to massive changes in privacy laws. The risks and amount of data that will be collected by XR devices will need to be communicated to stakeholders differently, especially in education, where students and educators lack basic knowledge of new XR capabilities to record nearly every movement and sound.

TREND #5

A fragmented ecosystem

Public values

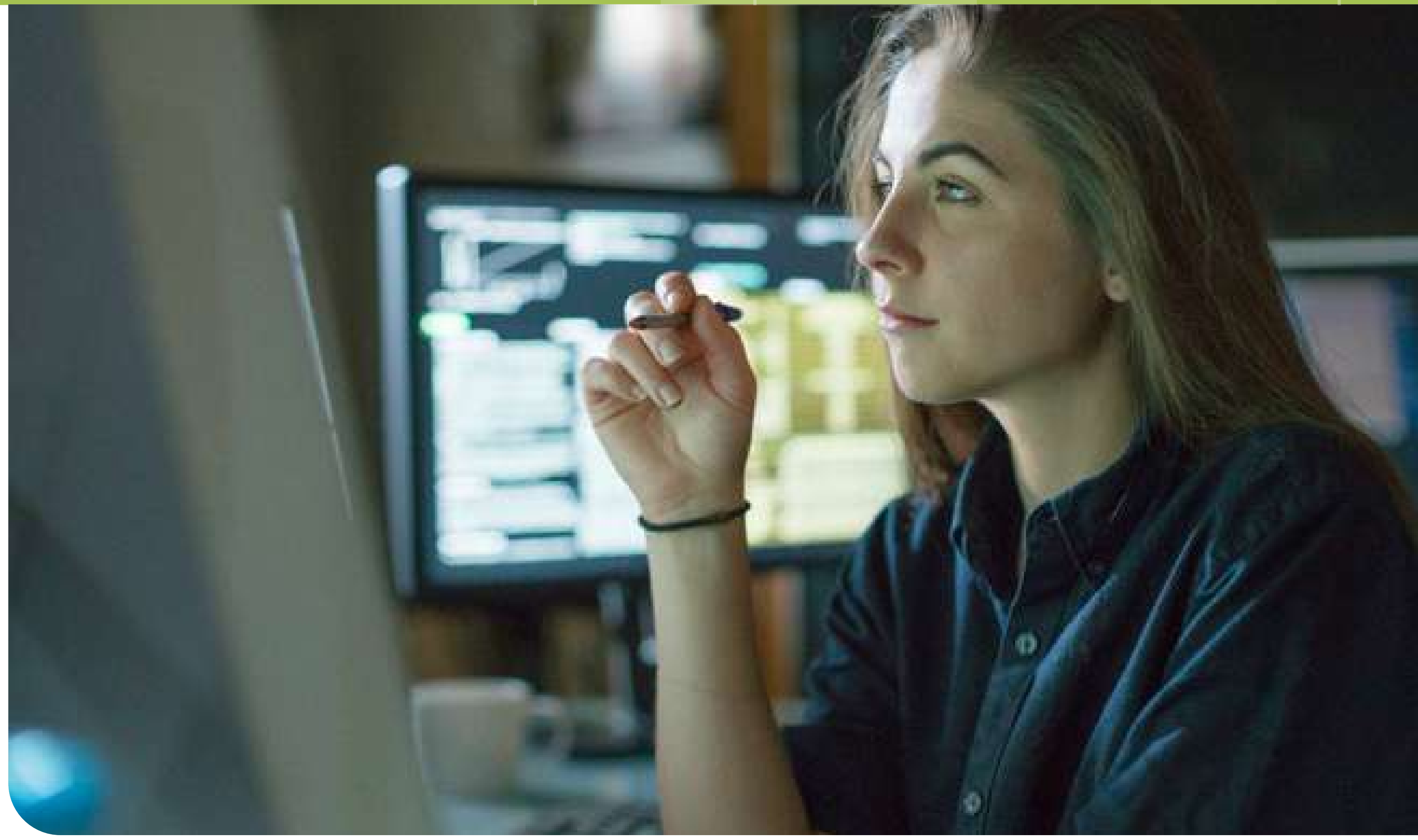
Autonomy	Independence of education | Freedom of education
Justice	Integrity
Humanity	

Readiness WATCH PLAN ACT

Drivers

#Open source development #EU legislation #Decentralisation #Digital economy

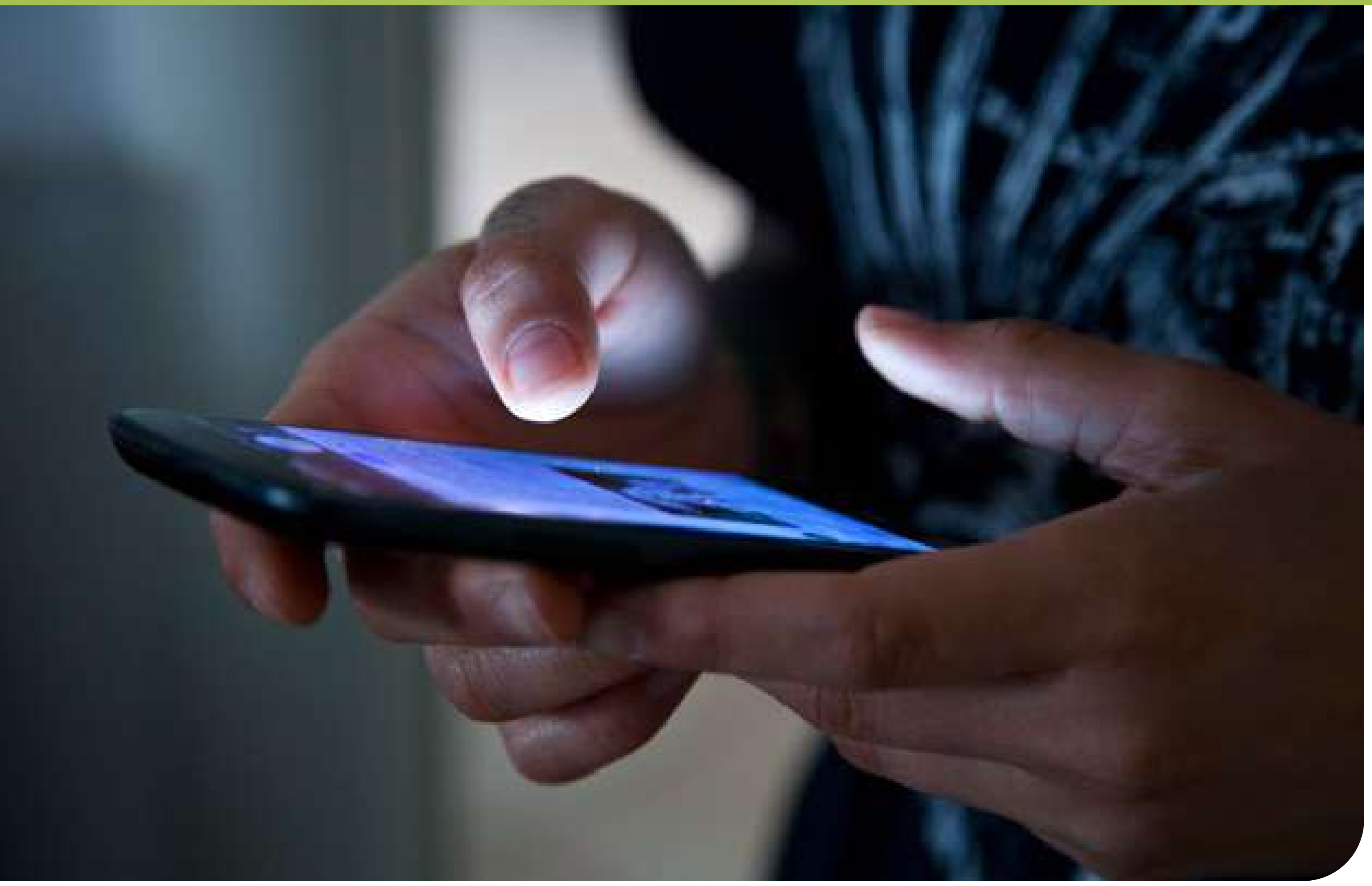
Recently there has been a proliferation of XR devices, platforms, and software tools. Due to a lack of industry-wide standards for many of these virtual realities, capabilities are not yet scalable and interoperable. The technologies and its underlying platforms are not open source, but are controlled by the platform providers. This includes standards for data tracking & collection, storage or standard protocols for linking different platforms. A question for the near future is whether this fragmentation will be a short-term trend, followed by some form of convergence, or whether market forces will perpetuate barriers, effectively leading to multiple 'metaverses'.



Metaverse Standard Forum

The Metaverse Standard Forum brings together companies and standard developing organisations to provide interoperability within the open Metaverse. This includes a substantial number of standard developing organisations that will be collaborating and cooperating, which is an important step in regulating formats.

open example



Meta sparks anger by charging for VR apps

Developers of content for XR devices are frustrated that Meta insists on a charging model for the applications. Charging will diminish the open source character of platforms that VR developers strive for.

open example

Rapid growth in technologies accelerate development of Metaverse

To provide an immersive experience, higher requirements on infrastructure should be met. The 5G technology can meet these higher requirements and provide more throughput on the network infrastructure.

open example

The XR4ALL Revised Landscape Report 2020

Included in this report are images produced by The Venture Reality Fund, which summarise hundreds of companies of active AR and VR market parties. Providing "… an analysis of the landscape of immersive interactive XR technologies … in the time period July 2019 until November 2020".

open example

IMPACT

A rapid pace of development makes it very hard to plan for the longer term, and thus requires more flexibility. Users have to accept that the current XR ecosystem is not stable. Educational and research institutions struggle with these continual changes; this has implications for proper procurement, scaling up experiments and thus understanding XR usability in education and research. The unstable ecosystem can lead to adoption stagnation. Solutions usually have some form of downside in terms of technical capability, price, openness or compatibility. One option for education and research is to accept the current state of the XR ecosystem. Thereby accepting constant changes in the ecosystem and focusing more on developing standards in both respective fields. A good awareness of requirements is crucial to make the right choice.

More about eXtended Realities

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more info communities

Surf Cooperative

Driving innovation together

SURF is the cooperative association in which Dutch research universities, universities of applied sciences, vocational schools, university medical centres, and research institutions work together to provide the best IT for education and research. We develop and provide reliable, state-of-the-art IT services, or purchase them centrally on favourable conditions. We collaborate on new, innovative applications of IT in education and research. And we come together to exchange knowledge, ideas and expertise. This keeps Dutch education and research at the top of the world.

Colophon

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