VTT

Hybrid work in the human-driven industrial metaverse

Enabling people to enjoy working in the future hybrid world

Authors: Salminen Karoliina, Aromaa Susanna

beyond the obvious

Contents

1. Executive summary

The industrial metaverse could radically change the way industrial work is done. It could impact particularly hands-on work in labour-intensive domains, from manufacturing to construction, logistics and maintenance. The industrial metaverse could help resolve the labour crisis prevalent in all industrial nations with ageing populations and a lack of appeal in industrial work. It could expand autonomy, merge virtual and physical worlds, and bring place and time-independent work to all industrial/professional domains. The industrial metaverse could provide an immersive workspace for human-technology collaboration.

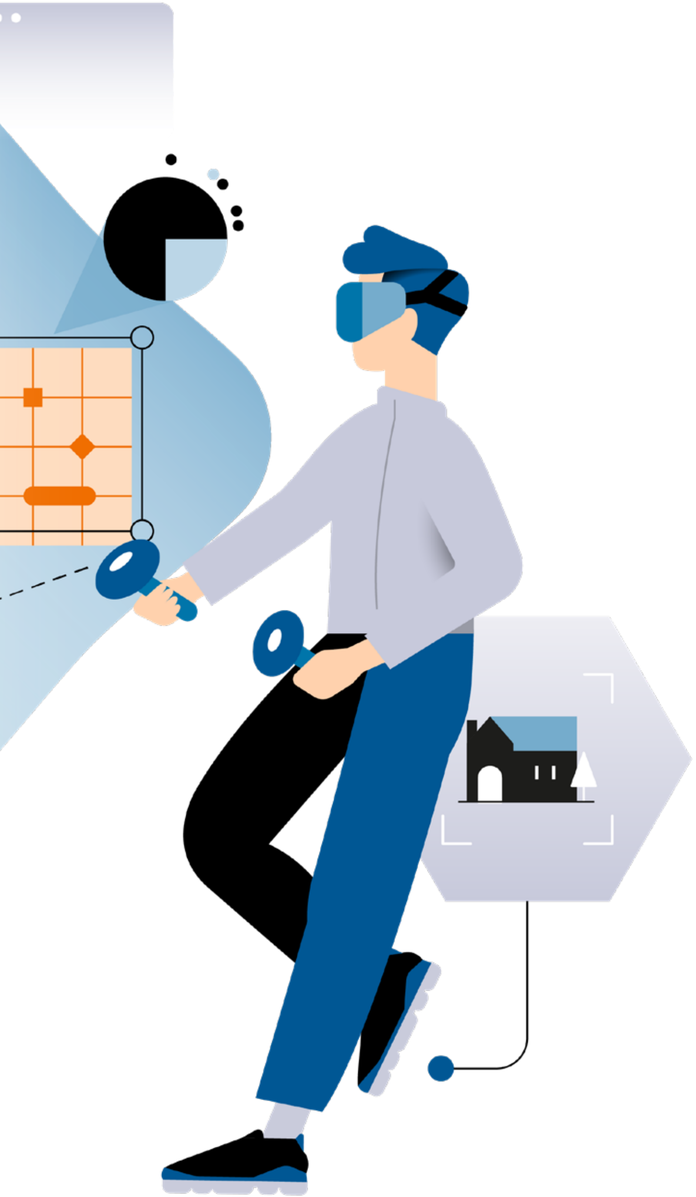
This white paper presents five examples of future hybrid work:

1. Collaborative product design and testing
2. Deployment planning and supervising in virtual collaboration space
3. Remote real-time production process monitoring
4. Shared reality in remote trouble-shooting
5. Remotely supported maintenance tasks and data collection.

All the described future work tasks can benefit the worker, team, and organisation. Novel technologies can support workers' capabilities and skills and extend inclusiveness in the workplace. New capabilities can empower workers to do their duties better (e.g. smoother, faster, or more easily). From an organisational point of view, novel technologies may increase efficiency and productivity and improve the quality and availability of expertise and knowledge.

However, many unresolved questions related to hybrid work remain. For example, how do you manage cognitive load in a hybrid world? It is important to understand the kinds of interaction tools, and work practises that could be used with diverse workers and in varying tasks. Systems will also become more complex when the work is done within and between human-technology-AI teams. This can create safety, security, and ethical challenges. The changes related to the social aspects of work need additional consideration, and the workers need to feel motivated in their work.

In the future, Finland could be known for a strong solution business cluster around industrial metaverse enablers for global markets. We could also create a significant new labour market and attract sought after talent. To reach this goal, we need to co-design and develop highly economically scalable solutions applicable to all industrial segments. It is essential to understand the needs of employees and create solutions that people trust and want to use. Likewise, developing future industrial work that people find attractive is important. The work must also provide business benefits for companies – like industrial productivity and well-being.



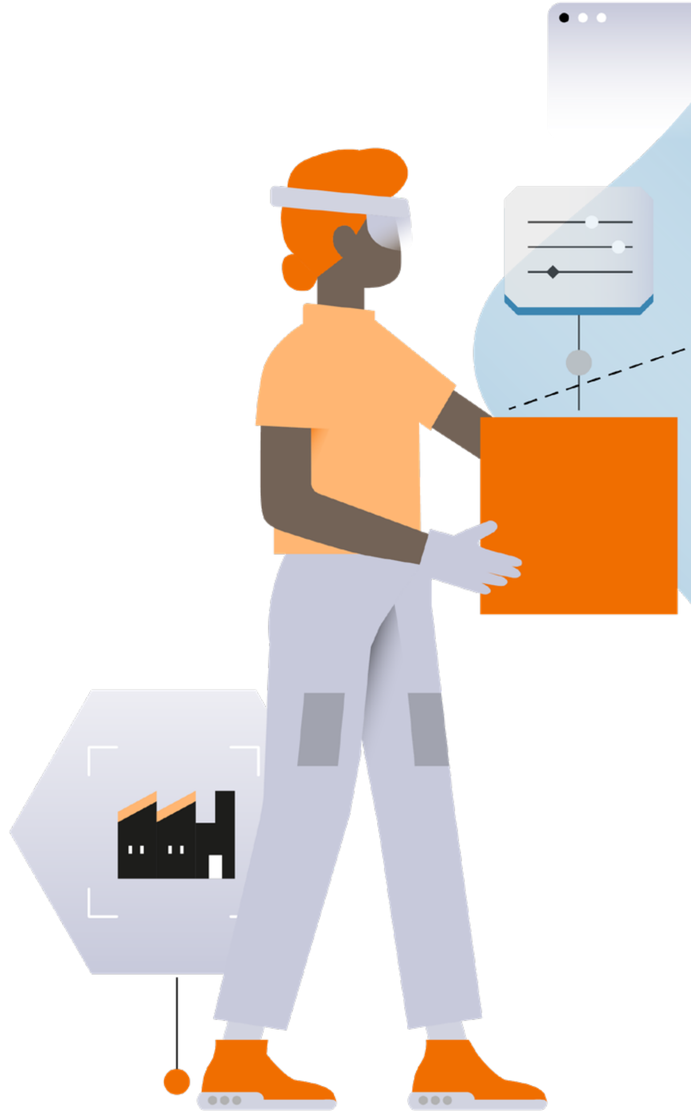
2. Introduction

The industrial metaverse combines the physical and virtual work environments. It enables the collaborative use of novel tools and shared practices between employees. However, the precondition for a metaverse – or any new technology, for that matter – to become more common is that people are willing, not forced, to adopt such solutions widely.

In October 2022, VTT launched its first Human-Driven Industrial Metaverse project to start the discussion of reforming industrial work with a select group of companies. The eleven companies represent providers of industrial work, i.e., those using the solutions and companies offering relevant solutions. The companies came from various industrial sectors with complementing technologies.

The project's objective was to identify work tasks where the metaverse would benefit both employees and organisations. The use cases identified should contribute to productivity, employee well-being, the attractiveness of work, and to achieving sustainable development goals by, for example, increasing the number of location-independent work tasks. The focus was mainly on hands-on work outside the "information worker bubble", in labour-intensive domains from manufacturing to construction, logistics and maintenance.

This white paper presents five examples of future work tasks that utilise novel technologies and hybrid work practices. These five examples are elaborated from the use cases identified by the Human-Driven Industrial Metaverse project partners and VTT experts. The main benefits for the worker and the organisation and further considerations are presented based on these five examples.



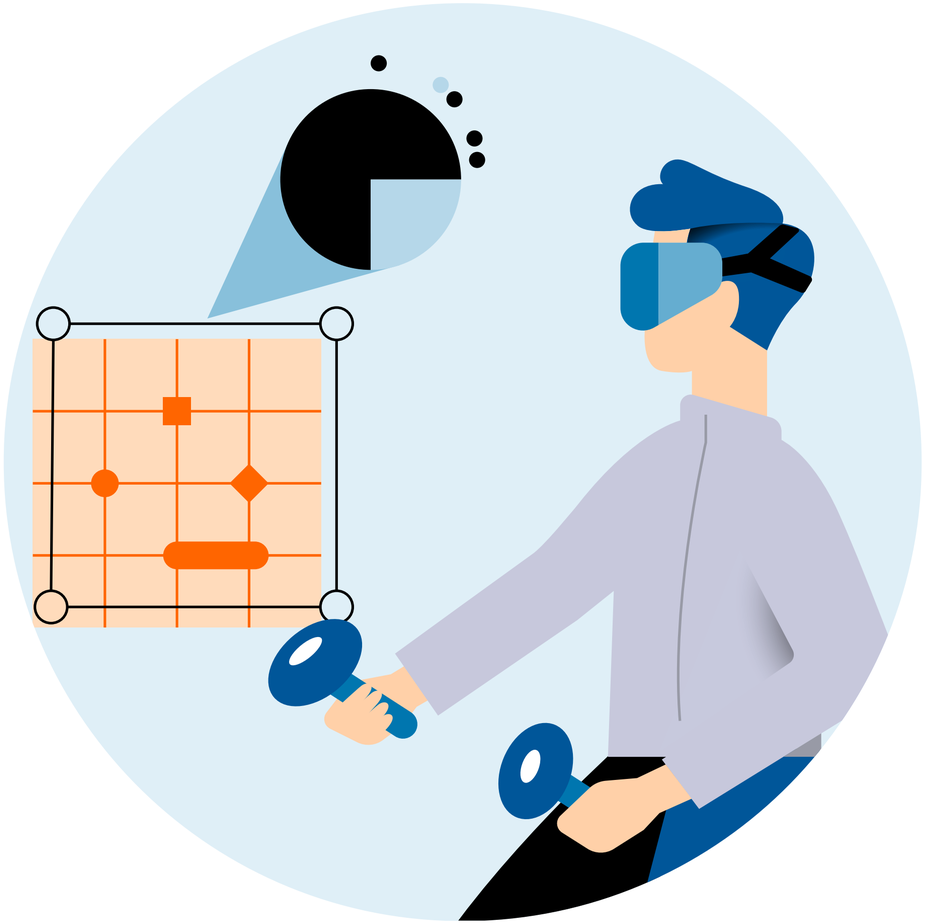
3. Human-driven industrial metaverse

Due to the fourth industrial revolution (Industry 4.0), novel technologies are emerging in workplaces. There is also a pursuit towards social, environmental, and societal considerations instead of a pure profit-driven approach (Industry 5.0). These changes create new demands for the workforce, such as managing task complexity and cognitive load at work. Simultaneously, the change provides opportunities to enrich the work and better support workers' performance. For example, hybrid work practices or ensuring effortless decision-making with the help of artificial intelligence (AI) can create more flexibility.

The industrial metaverse is a new and emerging trend in various industries. It can enrich the work and support hybrid ways of working. The metaverse can be seen as a collaborative, social and immersive environment that blends the physical and virtual realms to the point that data exchange and interactions become fluid and affect each other.

The industrial metaverse combines real world elements with contextualised and meaningful data. Its purpose is to keep workers informed and ensure that processes operate efficiently. It seamlessly integrates the physical and virtual and allows employees to work in a purely virtual environment or a combination of virtual and physical environments. Users may access the industrial metaverse using extended reality (XR) technologies or more traditional user interfaces.

In the human-driven industrial metaverse, human-technology-AI teams work smoothly in hybrid work environments. Employees feel empowered and engaged, and their well-being is ensured. The design and development of new solutions and ways of working are based on a systemic approach that considers all physical and virtual actors in human-technology teams.



4. Five examples of future hybrid work

In the future, industrial employees could collaborate with an increasingly versatile group of people and use continuously developing technologies. This section describes five examples of what future hybrid work could look like. The work tasks are:

1. Collaborative product design and testing
2. Deployment planning and supervising in virtual collaboration space
3. Remote real-time production process monitoring
4. Shared reality in remote troubleshooting
5. Remotely supported maintenance tasks and data collection

1. Collaborative product design and testing

Easily accessible visual information helps understand the context better. It leads to new innovations and better solutions. Real-time information in all design phases improves efficiency and quality.

Different design phases, such as ideation, concepting, prototyping, testing, and validation, are carried out in a collaboative virtual design space. At the beginning of the design process, the design space has all the requirements visualised so that the designers see the requirement type, source, priority, and other relevant information. Stakeholders from different physical locations can access the design space and co-develop different concepts together in real time. 3D models and additional information are collected in the same space, and ready-made 3D models can be bought from a virtual store.

Designers can now try different options hands-on using extended reality (XR) and haptics technologies early in the design process. Haptic technology allows users to feel the shape, material, and other characteristics with their hands. With XR technology, the designers can see and feel the product with more senses. Simulations of different features or environments allow people to see how well the alternative design options fulfil the requirements.

Feedback from end users is collected in the ideation and testing phases. End users can access the design options using different devices, for example, augmented reality (AR) glasses and see how the design would work in the final location. End users give feedback directly in the design space, and the designers can see them in real time. Final test results and validation proofs are added to the system and connected to the correct requirements. Validation and verification documents are automatically generated.

2. Deployment planning and supervising in a virtual collaborative space

Up-to-date visual information supports collaborative planning and decision making. In addition, real-time information improves efficiency of complex and changing deployment processes and supports sustainable ways of working.

Planning a major deployment project typically requires cooperation between multiple stakeholders from all around the world. The project manager, product owner, site manager and many other stakeholders come together in the same virtual collaboration space. They can see each other as avatars around a virtual table. Those who access the virtual space using a virtual reality (VR) headset and a full body tracking system can walk around and interact freely. Others who have used a mobile phone to join the meeting have more restricted abilities to move their avatars but can still move around.

In the virtual collaboration space, stakeholders access any real-time data needed in the planning. For example, they can inspect digital twins of the deployment site and the machines to be installed. They can check the status of the process or fast forward with the help of simulations. Different data collection means provide real-time data on the current deployment progress on site. For example, mobile robots and drones can continuously scan the environment.

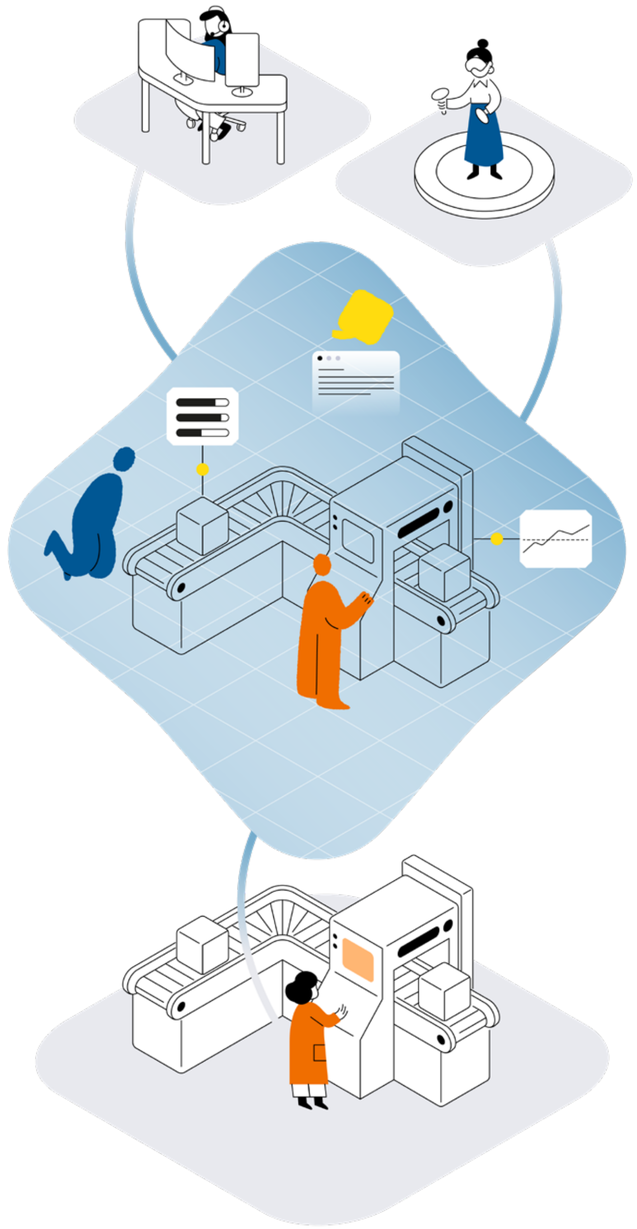
Due to the immersive and visual collaboration space, building a shared understanding of the plans and progress of the deployment is straightforward. In addition, it helps with discussions and optimisation of deployment plans.

3. Remote real-time production process monitoring

Artificial intelligence supports workers based on their skill levels and personal preferences. Human-AI collaboration improves efficiency and productivity due to proactive way of working.

A remote operator can monitor many production processes around the world simultaneously. Managing production processes requires access to real-time data and active collaboration with remote and on-site workers. Artificial intelligence (AI) and other systems support the operator when intervention in the process is needed. For example, AI notices from the real-time production process data that certain changes in the parameters can lead to a machine break down. AI asks the operator to check the situation and suggests the needed repair actions and helps order a correct spare part.

The operator can monitor and get involved with the process in an immersive 3D virtual space that visualises the digital twins of the production sites. They can see the critical parameters of each machine, pipeline, and sub-processes in the corresponding digital twins. They can also see live camera footage of the production site from various locations provided by fixed cameras or mobile service robots. The operator can use the virtual space to share information and discuss with the people on site when attention is required.



4. Shared reality in remote troubleshooting

Increased immersion with more senses creates a more natural way to collaborate. Flexible work and global pool of experts increases the availability of needed workforce.

When faced with an issue, experts can troubleshoot it in close collaboration, even in different locations. A meeting is scheduled in a virtual collaboration space when a problem occurs. Meeting participants will ask an AI solution to capture the relevant data from various systems and people. The digital assistant imposes the data on the 3D digital twins visualised in the collaboration space. The meeting participants are working in shared reality (SR). They share realistic experiences: visual, sound, touch, emotions, and maybe even smell or taste. Novel devices that capture, analyse, and share more diverse data enable these realistic experiences.

Visualised data and an immersive way of working are used to find the root causes and discuss actions to solve the problem. When specific expertise is needed, the person in charge checks their availability from a global expert database. The assigned expert can either guide a worker on-site or execute the operations by remotely controlling robots or other devices.

Remote helpers can provide additional information to the technician's AR glasses while discussing with them. Remote workers see the environment via VR headsets or PCs. They monitor the progress from the point-of-view of the technician's helmet camera or using the data collected by sensors.

During the maintenance process, different experts can collaborate remotely. The experts can virtually teleport themselves on-site, assess the situation and run simulations to make corrective responses.

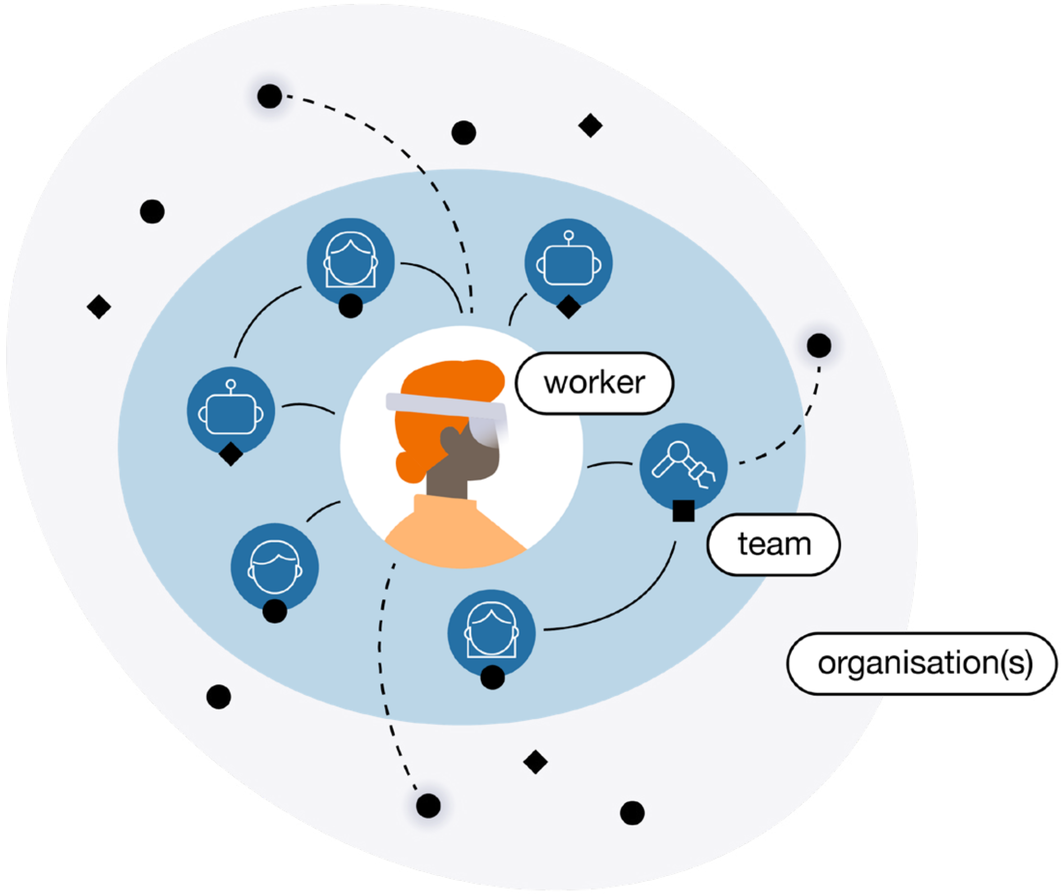
5. Remotely supported maintenance and data collection

The use of different technologies (e.g., AI, AR) assist maintenance technicians with their tasks. Automatically collected data from the site supports many departments related to the product's life cycle.

Real-time digital twins can pinpoint the exact time when a maintenance technician should go on-site and ensure they have the fitting spare parts and tools. A real-time digital twin of the machine or site is connected to a global spare part database, which shows the spare parts availability and expected delivery times. An AI solution analyses the availability depending on the urgency and other factors and orders the spare parts at the right time to minimise inventory.

Some spare parts can be automatically manufactured on-site or in nearby spare part hubs using additive manufacturing. When the site is ready, a maintenance technician is called, and the spare parts and tools are available. While doing the work on-site, the technician gets instructions and help from remote colleagues, experts and AI through his AR glasses.

Sensors continuously collect information during the maintenance visit. The information can be used by other departments, such as R&D, when redesigning products and monitoring their quality. Once maintenance is ready, the changes can be simulated and tested in a digital environment before restarting the production.



5. Benefits and opportunities of future work

New ways of working can benefit the worker and the organisation. Novel technologies can support workers' capabilities and skills and provide inclusiveness in the workplace. New capabilities can empower workers to do the same task smoother, faster, or with greater ease.

Combining these capabilities and placing them in specific operational contexts unlock new possibilities and create unique value for performing work tasks. For example, these capabilities can help understand complex information using digital twins, plan easily with simulations, use more detailed information in hands-on work, collaborate more efficiently, work remotely with hands-on tasks, and get support from digital assistants. In addition, new employment models may emerge.

From an organisational point of view, novel technologies may increase efficiency and productivity and improve quality. The needed expertise and knowledge can be easier to access and use. New ways of working can also enhance employee engagement and attract skilled and diverse employees. In addition, new business models can emerge. Values, such as sustainability, can be closely adhered to.

This chapter describes the benefits of the previously presented five work examples from worker and organisation points of view. Similar benefits were identified across different tasks and environments. Therefore, the presented solutions have a great potential to scale across different industrial domain areas.

Worker benefits

Inclusiveness

- More visual data and digital assistance make collaborating easier despite the workers' nationality, level of expertise, and background.
- A more diverse group can participate in the work when multiple ways exist to access the information.
- Technical solutions can augment workers' skills and capabilities based on individual needs and preferences.

Collaboration

- The amount of visual information makes communicating and understanding the context easier.
- Easy access to a virtual collaboration space simplifies tacit knowledge sharing between project group members.
- Increased immersiveness creates more natural ways to collaborate.
- Digital collaboration tools increase the availability of peer support, even between maintenance experts working in different locations.

Performance

- Technicians on-site get better assistance to perform their tasks. Easy communication and clear visual guidance help them implement the tasks and prevents errors.
- Up-to-date visual information supports discussions and helps make plans and decisions based on real-time data.
- Using more senses can give new ideas, leading to innovations and better solutions.
- There are no useless site visits or waiting for spare parts when everyone has real-time information about the situation.

Skills

- AI can collect relevant data from different sources, which helps and saves employees' time in decision-making.
- Increased immersion provides a new way to dive deep into different subprocesses, machines and other objects to see detailed information.
- Workers are supported in managing multiple complex systems with different kinds of tools.

Employment

- Workers can offer expertise through a global database as a freelancer.

Organisation benefits

Efficiency and productivity

- Real-time information improves efficiency and reduces problems and delays in deployment and similar projects.
- Better situational awareness enables the efficient use of resources, and there are no unnecessary delays.
- The data collected from the field visits can be used across the company to improve efficiency in many processes (e.g., R&D, sales, marketing).
- Problems are identified faster when all relevant data and people are managed together.

Employee availability and expertise

- A global expert database increases the availability of the needed workforce.
- Better knowledge management as tacit knowledge is readily available from the experts and the maintenance site.
- Flexible ways of working, which consider workers' capabilities, skills and preferences (e.g., hybrid ways of working, different kinds of interfaces), could increase the attractiveness of work.

Quality

- Enhanced use of simulations simplifies the proactive management of possible challenges.
- Product and process requirements are easily accessible and always visible, which helps make correct choices.
- Final design, product acceptance, and compliance reports, including a digital thread, can be generated automatically.
- Product users can be included in earlier design phases to offer their complete experience, which enhances the final product adoption and acceptance.
- Stakeholders can overview processes more easily and efficiently. They can help solve problems before they are realised on the site.

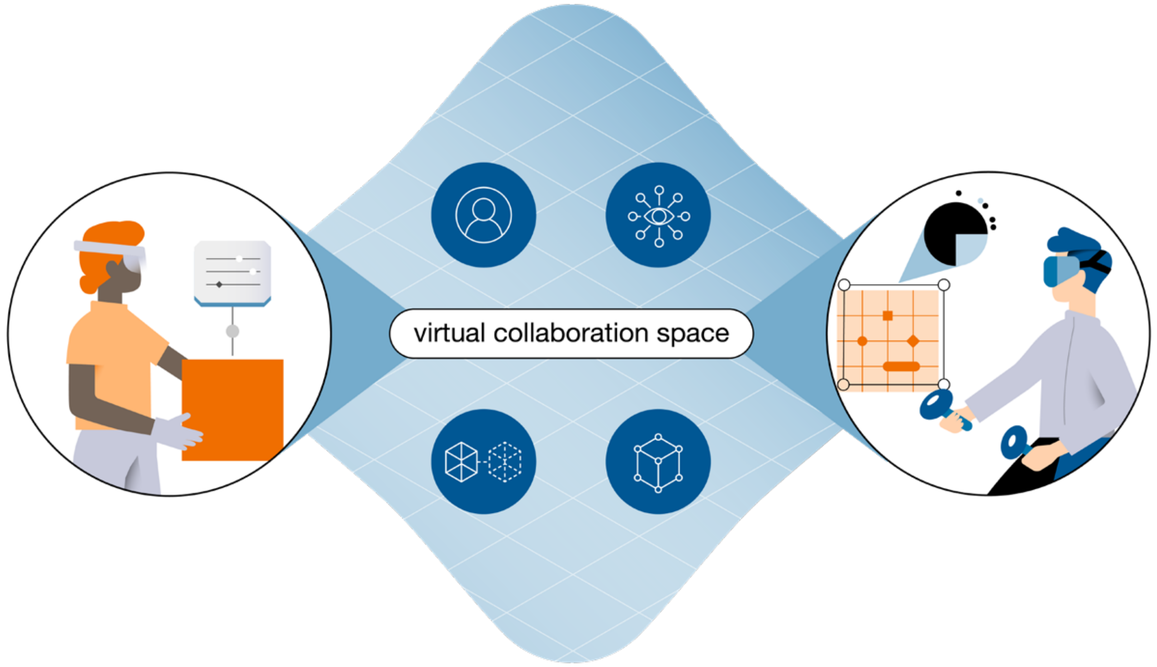
Sustainability

- Simulations, data collected from the site, and AI help optimise a total benefit (e.g., a combination of time, cost and sustainability).
- The way of working could support sustainability (e.g., less travelling, intelligent use of resources and fluent material flows). Enhanced situational awareness decreases unnecessary work tasks and the movement of people, goods, and data.

6. Further research needed before adopting future hybrid work

There are still many unresolved questions related to hybrid work in industry. Hybrid work has become common in office work, but how it could change hands-on industrial tasks and ways of working remains to be discovered. Some tasks may disappear, and new ways of working will emerge.

To enable work in virtual and hybrid environments, there are still topics to solve related to physical and cognitive ergonomics. For example, what interaction tools are used, and how will they be available for workers? We identified that novel technologies could support inclusiveness in workplaces. However, this can be a challenge, too. The technologies need to be designed and implemented to support workforce diversity, or they can create inequality among employees.



Also, the systems will become more complex when the work is done in physical and virtual environments and within and between human-technology-AI teams. This can create challenges related to safety, security, and ethics. The change associated with the social aspects of work needs to be considered. It is essential that the workers feel part of the work community. In addition, the workers need to feel motivated and that their work is meaningful. In general, their work-life needs to be in balance.

Things to consider in future hydrid work:

Working in a virtual environment

- Physical and cognitive ergonomics (e.g., simulator sickness, comfort, physical and mental load)
- Tools and means of manipulation for a diverse group of users

Hybrid work

- Smooth transfer between virtual and physical tasks and spending time in both
- Ensuring a proper balance between physical and virtual work, from the perspectives of human well-being and the ability to learn

Complex systems

- Managing human-technology-AI teams working together in hybrid environments
- Lack of deep expertise when sharing issues with a large and varying group. Some crucial details may be diluted, and some relevant information missed
- Data transfer, integrations, computing, etc. capacity, infrastructure and needed skills

Safety, security and ethics

- Safe workways and privacy, also when monitoring and part of the work are happening remotely
- Inclusiveness
- Data security and privacy issues when collecting, managing, and sharing data

Motivation and feeling of meaningfulness

- Working based on employees' values
- Work-life balance
- Willingness to share your expertise and tacit knowledge
- The balance between making your own decisions and receiving guidance

Social aspects at work

- Being part of the work community if the work mainly consists of, for example, remote process monitoring
- Social interactions during workdays

Employment models and organisational aspects

- Sharing responsibilities in, e.g. accidents or giving tasks
- Regulations on hybrid work
- Contract models, if work can be offered through the metaverse
- Rules and responsibilities between different locations
- Ensuring the level of expertise, needed certificates, etc.
- Risk of losing jobs and unemployment

7. Could Finland set an example as a leading country in the future of work

Transformation of industrial work is inevitable. Global trends drive towards social, environmental, and societal considerations instead of purely profit-driven approaches. Trends like global knowledge scarcity, the interconnected and digital world, the ageing population and generational change, and the transformation of work pave the way for new working methods. Systematic actions and cooperation are needed to start the transformation and first implementations.

This white paper is based on research done in Finland. Based on this research, we now have a better and deeper understanding of how new trends, such as the industrial metaverse, could change the way of working in Finnish companies. However, several considerations must be tackled in cooperation with companies and research before wider adoption is possible. In other countries, the approach can be slightly different due to different technological maturity and industrial structure.

It is vital to develop the enablers of different solutions and to ensure that the adopters who will use these solutions are also considered. Finland is well known for its expertise in several technological fields at the core of the industrial metaverse, such as wireless networks, artificial intelligence, microelectronics and photonics. Finland is also known for people with excellent digital skills, low hierarchy, and good adoption of new technologies. This provides a sound basis for being a leading country in transforming industrial work. Finland could be known as having a strong solution business cluster around industrial metaverse enablers for global markets. We could create a significant new labour market in Finland and for Finnish companies abroad, attracting talents to work in new hybrid tasks with global customers.

The way forward is to co-design and develop highly economically scalable solutions applicable to all industrial segments. It is important to understand the needs of employees and create solutions that people can trust and want to use. The goal is to develop future industrial work tasks that people find attractive and provide benefits for companies regarding industrial productivity and well-being.

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VTT has a lengthy research background in several critical enablers, such as XR software and hardware, spatial computing, robotics, human factors, human AI and human sensing, safety and cybersecurity, sensors, connectivity, critical systems, foresight, and ethics. This gives a unique combination of the needed technical and non-technical foundations for transforming work in different industrial domains.

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For more information

To learn more about the human-driven industrial metaverse, please contact

Karoliina Salminen
karoliina.salminen@vtt.fi

Susanna Aromaa
susanna.aromaa@vtt.fi

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