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Introduction

Our modern society is undergoing a digital revolution. Digital areas are constantly evolving to support people's everyday lives. Revolutionary changes in the technologies becoming available to ordinary people have filtered through to everyday life, from digital payment methods to the virtual world of everyday transactions. Information is virtually present everywhere in people's environment. We see information in our natural environment, for example about animals, roads, other people, as well as in artificially created environments such as our digital devices (be it a phone, a tablet, or a desktop computer). So information is virtually everywhere, en masse.

There are many technologies available today to perform information-related activities. The collection, storage, processing, modification, refinement and transmission of information can nowadays be supported by a variety of devices and their networked systems. It cannot be argued that without these infocommunication networks, our society would have great difficulty functioning. It is no coincidence that our current information-centric society is called information society.[1] In our information society, the development and modernisation of infocommunication technologies is significant and particularly intensive; moreover, the related needs and requirements are constantly changing. In the context of information protection, the term cyberspace and related concepts are widely and well known, all of which are the result of the expansion and development of the information space. In cyberspace, there is a multitude of operational possibilities that arise from the interconnection and interaction of the real and the artificially created virtual spaces.

Nowadays, virtual spaces pervade our society and have a significant impact on our society in many ways. As it is true in real space, so it is in virtual spaces, sharing and living experiences have become a natural need in everyday life. In order to be part of a virtual community, it is required that people create a virtual entity of their own personality. Among the related technological developments, the immersive technologies stand out. In the sense of immersive technologies,

[1] "An information society is a society where the creation, distribution, use, integration and manipulation of information is a significant economic, political, and cultural activity. The aim of the information society is to gain competitive advantage internationally, through using information technology in a creative and productive way" (Definitions.net: *Information Society.* s. a.).

virtual reality, augmented reality, mixed reality and extended reality are to be discussed. All four areas are quite popular, especially virtual reality and augmented reality. Immersive technologies are of particular interest to people because they can provide experiences that real space cannot or can only partially provide to them. It is important to note that virtual environments already have and will continue to have a significant impact on people's everyday lives, and it is therefore useful to consider and interpret the technologies involved in several ways. Such multiple approaches will of course help to create a comprehensive picture of the features and capabilities of each of the technologies mentioned, thus helping the people to appropriately balance the use of these virtual spaces and the real space at the same time. In order to achieve this goal, this document will also take a number of so-called perspectives to address what is considered to be the more relevant knowledge of these technologies in question. The versatile and detailed study of immersive technologies is clearly beneficial, independently whether you are a single user of them, a developer of environments based on such technologies, or otherwise interested in this field.

Virtual reality is extremely popular and it is natural that users do not pay much attention to the deeper level of understanding of the technology beyond the experience. Following this line of thought, the next chapters will introduce virtual reality and related immersive technologies from different perspectives, with a variety of concepts and interpretations. After presenting the historical background of virtual reality, the main technological basics, the related technologies and the possible future direction will be discussed.

The economic, development and social perspectives have been selected for the study of immersive technologies. Currently, there are few documents in which one can read about the multiple perspectives on virtual reality in one place, even though the technology (virtual space) has many implications for society. In addition to the understanding of immersive technologies, it is important to note that a number of potential societal impacts can and should be considered in their application. As these are products that represent innovation, it is only natural to look at various statistical indicators and to assess their economic potential. The economic approach also involves looking at the products that are considered to be important, which is why three products from different well-known companies have been selected to provide the reader with an insight into their basic characteristics. From a developer's point of view, a deeper understanding of virtual and augmented reality as two of the most popular technologies and the design

and development testing processes and methodologies required to develop the immersive technology itself are specifically discussed. As with all development, the existence of an appropriate development environment is essential for these technologies. In addition to this, social technology assessment is also important because it is worthwhile to design and implement features that are beneficial to this area. In addition, it is also important to take a social approach because, although often unspoken, it is essential to be aware of the feelings that the human brain has about the world of reality (the natural environment). Personal behaviours in virtual environments today clearly shape people's mental states and personalities, resulting in similar behaviours in real environments. By creating feelings, colours, shapes, sounds, virtual reality helps the human brain to discover previously hidden connections in complex data sets. Users will be able to collect, store, process and transmit information faster and more flexibly. Pervasive technologies can be seen as a milestone for information services, as they enable the artificial extension and augmentation of the real space information environment and systems in our everyday lives. There is a growing interest worldwide in the potential applications of this technology, of which several examples are presented in this paper.

In addition to the civilian applications, it is important to highlight the potential military applications of these technologies, which are dealt with separately in this document. Military operations are also surrounded by a vast amount of information and, of course, a very large number of information communication tools and systems. Military developments are clearly intense in our society today, particularly in the quest for continuous modernisation and innovation. The second half of this study therefore focuses on potential military applications in the context of the use of immersive technologies. After a brief introduction, related development areas of specific interest to military capabilities are examined, as well as different military sectors and units with specific ideas to share with the reader.

By studying virtual reality and with it, immersive technologies for civilian and military purposes, the aim is clearly to provide the reader with a comprehensive picture. As a final result, what follows is a great starting point for those interested in the field of immersive technologies, in terms of multiple approaches. Therefore, as described below, the document can be taken both as a guide with conclusions and as a technology overview.

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Historical overview of virtual reality

The historical overview of virtual reality can be linked to the need and process of virtualisation; therefore, it is worth saying a few words about the emergence of the needs and conceptual interpretation of the field. It is a technology that is now quite popular and its everyday use has become natural. But let us stop here for a question: What does virtualisation actually mean? It seems natural, yet the more people you ask, the more answers you get. Virtualisation is defined as follows: "Virtualization is the creation of a virtual – rather than actual – version of something, such as an operating system (OS), a server, a storage device or network resources."[2] Virtualisation is an activity that does not take place in physical space, it is not a tangible process. Many people think of it as an extension of physical space, an approach that comes quite close to lumping the needs of virtualisation together in this thinking. In order to make virtualisation as a whole easier to understand (from its inception to the emergence of today's modern technologies), it is useful to look at the main aspects of virtualisation, starting with the needs, which can be divided into two main areas:

- the need for virtualisation of computing resources
- the need to create virtual reality, virtual space

With the development of electronic components, computers with ever-increasing computing power have come onto the market. Components became smaller and smaller and at the same time, more and more capable. The evolution of data collection, storage, processing and transmission functions has led to an increasing variety of needs. Pushing the limits of computers' capabilities, there is a need for more efficient use of resources, which is now a well-known virtual solution. To make efficient use of computing power, seven main components can be virtualised: desktop, server, storage, network, application, hardware and the operation system.

Desktop virtualisation allows multiple virtual machines to run desktops on the same physical and virtual server. Server virtualisation allows management in a cloud. It creates a virtual server in a physical computer. Storage virtualisation reducing costs associated with space in a centre. The network virtualisation uses physical and virtual components at the same time to create a hybrid network and

[2] Visible Stars: *Virtualization*. s. a.

make efficient administration of the network (through software switches). The application virtualisation helps to create a virtual instance of the applications (needed for business) to keep app software off from the local operating system. Finally, the hardware virtualisation aims to make and run different operating systems (creation of virtual machines) on the same hardware. It allows to use the processor simultaneously by more than one user. In addition to all this, a special type of virtualisation is the operation system virtualisation, that can run multiple operation systems instead of having a dedicated server for each system. Virtual environments and virtual spaces are becoming more and more natural for the efficient use of resources, especially for operational tasks. The efficiency of virtually shared resources has certainly contributed to the evolution of the way of thinking about virtual space. The development of virtual services has been accompanied, so to speak, by an examination of the dimensional potential of virtual space. Clarifying the functional needs of virtual space and exploring possible platforms for it are essential measures for the development of the technology. Virtual space, and with it virtual reality, is currently considered a cutting-edge technology, but the history of its development goes back much further than many people realise. It is important to note that the two main trends in the development of virtual solutions is to make computing resources more efficient, and the development of virtual reality are parallel to each other. In the following, detailed main historical events of virtual reality are described.

The first related device was certainly the stereoscopic dissipative (also called mirror stereoscope), invented by Sir Charles Wheatstone in 1838, which can be considered the predecessor of head mounted displays. The invention as you can see in Figure 1 allowed users to see a separate image in each eye (see E and F marks on the picture) creating a wider, three-dimensional image.

Many years later, in the early 1900s, the advent of aeroplanes would see further claims close to the technology. The ancestor of educational flight simulators was made a reality by Edwin Link. The simulator provided cockpit exposure and pneumatic pumps that gave an artificially created sense of the flight environment, a realistic experience for pilots. Training systems can support skills development, practice and maintenance in an efficient way (location, time, equipment, running costs) by complementing the traditional training tools.

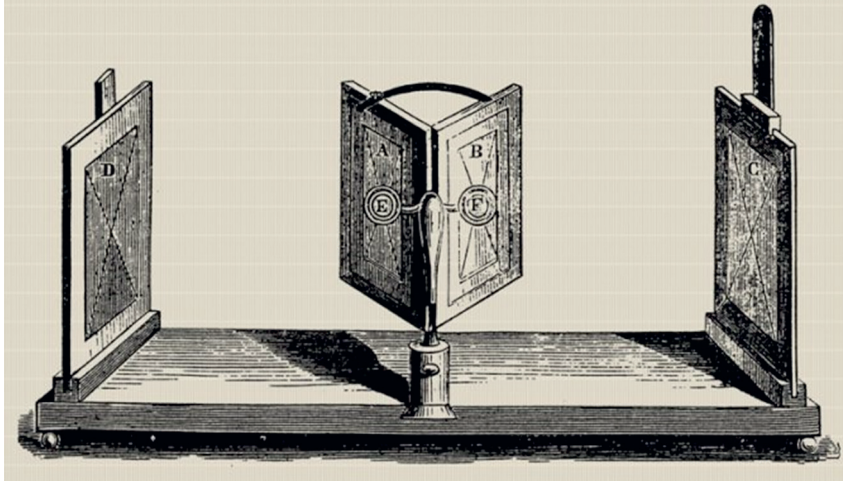

Figure 1: The stereoscopic dissipative
Source: Duncan (2019): op. cit.

This has proved to be beneficial, as pilots have been able to develop their skills without actually using an aircraft. It is therefore important to stress that the military application of this technology has also begun to be intensively applied. "In 1929 Edward Link created the "Link trainer" (patented 1931) probably the first example of a commercial flight simulator, which was entirely electromechanical. It was controlled by motors that linked to the rudder and steering column to modify the pitch and roll. A small motor-driven device mimicked turbulence and disturbances. Such was the need for safer ways to train pilots that the US military bought six of these devices for $3500."[3] As a point of interest, in 1930 Stanley Grauman Weinbaum presented a science fiction story linked to technology, Pygmalion's Spectacles. In the story, the author imagined a pair of spectacles that would allow virtual experiences of sight, touch, smell and taste. It is important to emphasise, after the initial focus on vision as a perception, the focus has increasingly shifted to the study of the other human senses. The initial testing of the senses in an artificial environment has led to further technological developments.

[3] Virtual Reality Society: *History of Virtual Reality.* s. a.

The 1950s was a very important period for the capabilities (creative ideas and initial implementations) of immersive technologies as we know them today. One example in civilian applications is the theatre cabinet Sensorama, which was designed by Morton Heilig. The aim was to immerse the user completely in the film, using stereo speakers, a stereoscopic 3D display, odour generators, fans and a vibration chair, among other things. The Sensorama in Figure 2 was called the cinema of the future. The product was accompanied by short films such as Belly Dancer, Motorcycle, Dune Buggy.

Figure 2: The theatre cabinet, Sensorama
Source: Jeremy Norman's HistoryofInformation.com (s. a.): op. cit.

In the 1960s, the development of technology began to intensify, based on earlier ideas. The real breakthrough for virtual reality products was Morton Heilig's patented invention of the Telesphere Mask in 1960, the world's first head-mounted

display. The invention had three-dimensional, widescreen images and stereo sound (stereoscopic technology), which gave rise to many new ideas for many people interested in technology. It is important to note here that virtual reality and augmented reality, two popular development trends today, are presumably based on the later idea of both the abovementioned, and have started to develop for both civil and military applications. "The history of VR has often been influenced by the defense industry. One of the first VR projects was developed in the 1960s for a US military combat system. Virtual reality has always played a significant role in the military and was adopted by all services: army, navy, and air force. It is mostly used for army training purposes, but there are other use cases where VR is a powerful tool."[4] At this time, the analysis of user experience needs and the mapping of related technological capabilities were already going on in parallel and intensively.

Among the developments of the 1960s, it is important to highlight the appearance of the first motion tracking system, which was implemented in 1961 as the "Headsight" product developed by the Philco Corporation. The product was not developed to create virtual reality, but it allowed for getting realistic experience, particularly military operations. The two main components of the product were a video screen for both eyes and a magnetic motion tracking system linked to a camera. Later, in 1965 computer scientist Ivan Sutherland presented his vision of the Ultimate Display. The concept aims to reproduce reality so that the user cannot distinguish between the actual reality and the virtual reality created. It is important to note that this interaction between man and machine has become a key factor in the development of technology. Around the world, documentation written at this time is seen as the basic blueprint for virtual reality. In 1969, Myron Krueger (considered the computer artist of virtual reality) described his experiences with projects such as Glowflow, Metaplay and Psychic Space, Videoplace, which were major advances, particularly in the development of the so-called "Videoplace" technology.

In the 1970s, aircraft simulators continued to evolve. In 1972 General Electric started to produce a computer flight simulator. The Videoplace project shown in Figure 3 led by Myron Krueger, opened up further and quite new possibilities for human–machine interaction. Research during this period can be seen as an artistic exploration of visual experiences. As you can read about the project: "Videoplace consists of two rooms that could be in the same building or on

[4] Sandrine Laserre: *4 Use Cases for Virtual Reality in the Military and Defense Industry.* 2021.

the other side of the planet. When a participant enters they immediately see themselves projected on a screen in front of them, as well as the projection of anyone in the other room. Both of the participants see the same image. The participant can move their image around on the screen by moving themselves and can interact with the other participants image as well. Either participants image could be resized, rotated, have the color changed, and they could also interact with objects that were completely virtual."[5]

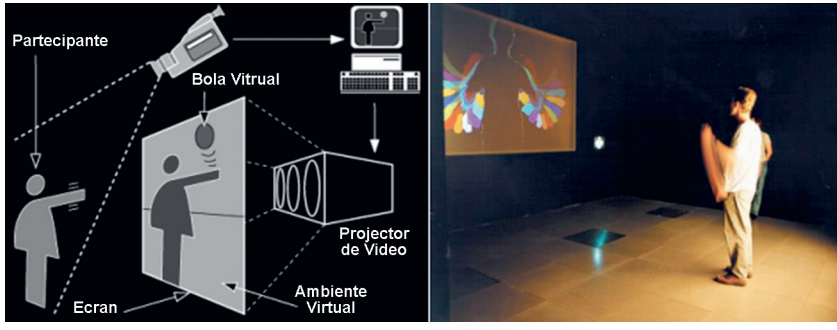

Figure 3: The Videoplace project
Source: Lee–Lee (2014): op. cit. 433.

In 1977, a program was created that allowed users to roam around a city, Aspen (USA, Colorado), by taking photographs of the city. The program was called Aspen Movie Map, which is similar to the now well-known Google Street View. It was the first human–machine interactivity that made it clear that virtual reality could take users to other places. Meanwhile, in terms of military applications, in 1979, the McDonnell-Douglas Corporation integrated virtual reality for military use into a head-mounted display, called the "Vital" helmet. The head tracker of the device already tracked the pilot's eye movements, interacting with computer-generated images.

In the 1980s, the production and sale of head-mounted displays and associated gloves with sensors, among other things, became a prominent feature. In 1985, Jaron Lanier and Thomas Zimmerman founded VPL Research, the first company to deal specifically with these products from a financial, business perspective. Concerning Jaron Lanier, it is worth noting that he both coined and popularised

[5] Myron Krueger: *Videoplace.* 1975.

the term “virtual reality”. The gloves were linked to a computer system and used optical sensors to detect finger movements. These gloves were the forerunners of the so-called “data gloves” today. The previously invented finger-tracking glove “Sayre” (the first wired data glove), shown in Figure 4, was developed by Richard Sayre, Daniel Sandin and Thomas DeFanti.

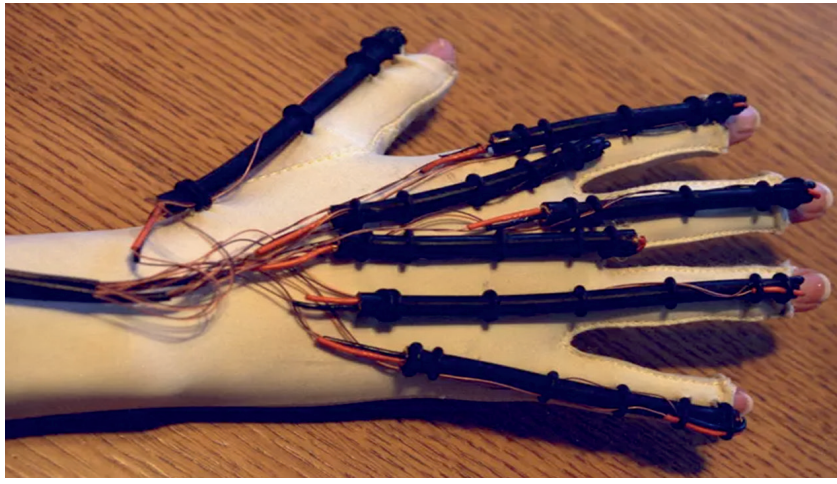

Figure 4: The Sayre finger-tracking glove
Source: Electronic Visualization Laboratory (1977): op. cit.

From a military perspective, a flight simulator called “Super Cockpit” was developed between 1986 and 1989, which used computer-generated three-dimensional maps in the cockpit, as well as infrared and radar images. The helmet had a tracking system with sensors that allowed the pilot to control the aircraft by speech, gestures and even eye movements. The pilot could see and hear everything in real time. In 1987, British Aerospace developed a virtual cockpit with speech recognition. It is important to point out that in 1989 NASA also took notice of virtual reality technology and created the so-called “View” project. As Figure 5 shows, the project aims to use the product for astronaut training. “The Virtual Interface Environment Workstation (VIEW) is a head-mounted stereoscopic display system in which the display may be an artificial computer-generated environment or a real environment relayed from remote video cameras. Operator can ‘step into’ this environment and interact with it. The DataGlove has a series

of fiber optic cables and sensors that detect any movement of the user's fingers and transmit the information to a host computer; a computer generated image of the hand will move exactly as the operator is moving his gloved hand. With appropriate software, the operator can use the glove to interact with the computer scene by grasping an object. The DataSuit is a sensor equipped full body garment that greatly increases the sphere of performance for virtual reality simulations by reporting to the computer the motions, bends, gestures and spatial orientation of the wearer. VPL[6] created its own version, the eye display in NASA's helmet system, the EyePhone, a head-mounted stereo display."[7]

Figure 5: NASA's VIEW project
Source: Rosson (1990): op. cit.

Developments in the 1990s were also significant, as in the past. Products have increasingly become available for public viewing and purchase. It should be noted that Jonathan Waldern exhibited Virtuality (a line of virtual reality gaming machines, that were produced by Virtuality Group), a virtual reality gaming machine, in London. So virtual reality was present in video arcade games. These

[6] Visual Programming Language (VPL) Research Inc., the company that worked with NASA on the project.

[7] Lois Rosson: *The Virtual Interface Environment Workstation (VIEW).* 1990.

were the first arcade machines to feature virtual reality technology, allowing players to play in a three-dimensional gaming world, and the first mass-produced virtual reality entertainment system. The machines were already networkable for multiplayer games (for example a popular game was Pac-Man). In 1991, the work of Antonio Medina (then a NASA engineer) led to the development of a virtual reality system that allowed a Mars rover to be driven (the time delay was taken into account). This solution was called "Computer Simulated Teleoperation". It was also during this period that several companies in the entertainment industry started to focus intensively on technology. The popular SEGA company introduced its own virtual reality headset in 1993, developed for the SEGA Genesis console. Unfortunately, technical development difficulties meant that the device remained forever in the prototype phase (although four games were developed for the product). Later, in 1994, the company released the SEGA VR-1, a motion simulator arcade machine. In 1995, the Nintendo company also got involved with the technology, launching the Virtual Boy console, a 3D monochrome video game player. The Virtual Boy shown in Figure 6 was the first portable device to display 3D graphics.

Figure 6: Virtual Boy, the pioneer of the 3D display
Source: TheGeek (2020): op. cit.

Unfortunately, the product's development was halted after a year due to the lack of colour graphics and software support, as well as the inconvenience of using it. It is important to note that in the meantime, virtual reality headsets for using at home have already appeared, for example Virtual IO has released its I-Glasses product shown in Figure 7.

Figure 7: Virtual IO I-Glass
Source: V-Rtifacts (1995): op. cit.

A particular use of the technology has also attracted attention, with the virtual reality product being promoted as a treatment for trauma. In 1997, Georgia Tech and Emory University used the technology to help war veterans treat PTSD (post-traumatic stress disorder) by controlling the factors that trigger trauma. Virtual reality has become useful for therapists to know what patients are seeing and experiencing. It was called Virtual Vietnam at the time. "Virtual reality exposure therapy (VRET) is patterned after real-world exposure therapy techniques used to treat common phobias such as fear of heights. By creating a virtual environment where the level of stimuli (such as helicopter flights and gunfire sound) can be carefully controlled by a trained therapist, VRET allows clinicians to apply exposure therapy techniques in a virtual setting."[8] It is important to mention the virtual reality-related film The Matrix, released in 1999. The characters in the film live in a fully simulated world, which is difficult to separate from the real world (a key motif). As Figure 8 symbolically illustrates, The Matrix has a significant cultural impact on virtual reality, which has encouraged further thinking about the technology.

[8] David Gotz: *Virtual Vietnam Virtual Reality Exposure Therapy for PTSD.* s. a.

Figure 8: The protagonist (Neo) is in virtual space, in the matrix
Source: Van Meeuwen (2012): op. cit.

In the 2000s, further, already noticeably intensive development took place. An important event to be mentioned is the development in 2001 of the SAS Cube, the first computer-controlled cube room, based on the ideas of Maurice Benayoun and David Nahon. The aim was to enable the user to visualise the artificially generated virtual environment in the cube, in all spatial directions. A few years later, in 2007, the well-known and famous Google LLC also introduced the technology. The company expanded its existing two-dimensional map service with 360-degree street images (Street View). The pictures were taken by cars specially upgraded for this purpose (which has since been continued worldwide), using a unique camera system. In 2010, Palmer Luckey (American entrepreneur; founder), then just 18 years old, led the development of the first prototype of the Oculus Rift headset, which offered a 90-degree field of view. The product relied on the specific processing power of the computer to produce the images. In the same year, Google announced that the Street View service would also include a 3D mode, which was being developed for the Oculus Rift headset. In 2012, Palmer Luckey launched a Kickstarter campaign to develop the Oculus Rift, raising nearly $2.5 million. It is important to note that from this moment on, the demand for the development of virtual reality products (despite initial failures, see SEGA) has skyrocketed, a virtual reality revolution has been started. Facebook, founded in 2004 under Mark Zuckerberg, acquired the aforementioned

Oculus in 2014. As a result, the social media and virtual reality fields began to converge for development.

Meanwhile, Sony announced that it had started to develop a virtual reality add-on for its very popular PlayStation 4 console. By 2015, the technological opportunities had become widely popular with potential users. For example, *The Wall Street Journal* launched a virtual reality-based rollercoaster that followed the ups and downs. "This year was full of achievements for The Wall Street Journal's interactive graphics team. After winning the Pulitzer Prize as part of a large team that investigated Medicare billing practices, we continued experimenting with new tools and technologies, including virtual reality and 3D data visualization."[9] 2016 is a rather important year in the history of virtual reality, as the so-called haptic sensing was previously underdeveloped. The sensor-based tracking allowed users to move freely in a space first implemented by the HTC VIVE SteamVR headset, shown in Figure 9. Haptic sensing involves thinking about the possibilities for human–machine interfaces. These interfaces allow users to interact with the computer through touch and gestures.

Figure 9: HTC VIVE headset
Source: James (2016): op. cit.

This was the time when the GloveOne glove was popular and successful, which was created as part of the KickStarter campaign mentioned earlier. The gloves enabled the user to interact with virtual objects. By 2017, many companies had already started working on products and services based on virtual reality technology, such as HTC, Google, Sony, Facebook, but also Microsoft and Samsung

[9] WSJ News Graphics: The Year in Interactive Graphics. *The Wall Street Journal,* 11 December 2015.

were among the larger companies interested in the topic. Google has announced that it is working on the so-called Google Earth VR project, shown in Figure 10. The program, which uses virtual reality technology can currently be used with HTC and Oculus products.

Figure 10: Google Earth VR project
Source: Burns (2016): op. cit.

In 2018, virtual reality has made significant progress and has already started to be used in a number of areas, such as entertainment, education and healthcare. The Oculus company (Facebook) has unveiled a new prototype headset, called Half Dome, the result of the work of optical scientist Brian Wheelwright and researcher Joyce Fang. A special feature of the prototype was that the varifocal headset already had a 140-degree field of view. "The lenses were designed to work with the active mechanical system to perform over the full varifocal range while maintaining wide field of view. The core of Half Dome hardware isn't optics—it's optomechanics."[10] This year saw the launch of Oculus Go and Oculus Quest, which were already considered standalone virtual reality products, as they do not require a computer or phone to operate. This continued in 2019, as standalone headsets became much easier for consumers to use. Reflecting on the potential of virtual reality technology, additional concepts have become increasingly popular, such as augmented reality and the combination of the two technologies, mixed

[10] Oculus VR: *Introducing the Team behind Half Dome – Facebook Reality Lab's Varifocal Prototype.* 2018.

reality. For the Oculus Quest product, Facebook has pledged to make the product Internet-sharing capable. Several companies are starting to work on mixed reality projects. Oculus Quest 2 (now called Meta Quest 2) launched in 2020, for which Facebook has received a lot of positive feedback (worldwide interest is still high). From now on, issues related to the multifaceted application of immersive technologies will be subject to a rather large and intensive research-based development (exploring the differences between virtual reality, augmented reality, mixed reality and augmented reality terms). Nowadays, needs and technology come together in a fairly high level development in both civilian and military applications. "Virtual Reality is currently in something of a boom period. For the first time in the history of computers, virtual reality has arrived not as potential, or a very expensive yet underperforming accessory, but as a major piece of equipment available to everyone."[11]

[11] Virtual Reality Society: *The Ultimate Guide to Virtual Reality Headsets.* s. a.

Virtual reality in our everyday lives

Technology background

Virtual reality is a multifaceted technology that is under intensive development. It already has intangible but understandable limits. Possibilities for developing the technology may be determined by computational exploration and testing of the limits of human perception. Virtual reality is precisely one of those computer-controlled products that can connect to the infocommunication networks that are part of our everyday lives. Nowadays, the operation of devices that use the Internet (for example TV, mobile phones, tablets, notebooks, etc.) is a matter of course, but in most cases, we are not familiar with the technological background of our home devices and individual networks. However, the really important issue is to be aware of the functional and security principles themselves for all technologies such as virtual reality. In our rapidly evolving world, infocommunication systems are becoming more and more commonplace in homes; therefore, as with smart phones, a basic technological knowledge is required for a virtual reality device.

In the following chapters, the main technologies related to virtual reality will be discussed and a detailed understanding of virtual reality and related immersive technologies will be presented. Three main areas (technological solutions) have been selected, which clearly show that Artificial Intelligence (AI) and the Internet of Things (IoT) are modern technologies close to the immersive technologies, creating interdisciplinary areas of development. In addition, the massive amount of data in virtual space raises the issue of Big Data, which is not a specific technology, but an emerging and important phenomenon in terms of technology. AI has potential in many areas, including the development of virtual spaces. The IoT technology, as for most of the devices used by humans, is an important technical capability for products that represent virtual spaces. The Big Data phenomenon is important to mention when looking at virtual spaces, because virtual reality can be used for a very wide range of purposes (so far without limits) and no one knows what the scale and volume of data needs will be out there. For sure, products will be used worldwide. Today, virtual reality and augmented reality are the most commonly known terms, but the broader domain of this technology is represented by immersive technology. The following are

concepts, definitions and other ideas that contribute to the understanding of the basics of virtual reality and with it of immersive technologies.

Main technologies related to virtual reality

Artificial Intelligence

AI has become a popular and well-liked concept, and many people feel comfortable with the many benefits of the technology. As a separate discipline, the technology is closely related to control theory, operations research, mathematics and decision theory. From the beginning, this discipline has taken as its own human capabilities such as self-improvement, creativity and the use of language. From a methodological point of view, technology fits into the computer sciences and is the only field where the goal is to build autonomously operating machines in a rather changing environment. The field is very diverse, so the following is a brief yet comprehensive review of AI. The interfaces between intelligent systems and artificial intelligence are characterised by rapidly shifting transitions. Development of science and technology is no longer about the desirability of cooperation, but about its indispensability, with convergence and synergy between the different fields. By clarifying the basic concepts of the technology, it is possible to illustrate why the application of AI is so popular and why it may be closely related to immersive technologies. This essential knowledge will help us to better understand what artificial intelligence is.

AI has been conceptualised in many different ways since it entered the public consciousness. The media, governments, companies, academics and universities have come up with different definitions. John McCarthy (computer and cognitive scientist from Stanford University) coined the term artificial intelligence in 1955: "It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable."[12] With this definition in mind, there are

[12] John McCarthy: What Is Artificial Intelligence? *Computer Science Department, Stanford University,* 12 November 2007. 2.

two main aspects of the technology to consider. One of these approaches focuses on the centricity of the AI system, which can be human-centric (philosophical) or rationality-centric (engineering). Another possible approach focuses on the processes and behaviour of the system and provides guidelines for the interpretation of the system. After understanding the concept of AI, it is important to examine and understand the following three types of technology:

- Artificial Narrow Intelligence (ANI)
- Artificial General Intelligence (AGI)
- Artificial Superintelligence (ASI)

As for the types, several definitions can be found in different international journals. A deeper knowledge of the types is an important interest for the companies using and developing the technology, and as a result, one can nowadays read quite sophisticated definitions created by different companies. The main parameters and levels of AI for a given product or service can therefore be defined in relation to the expected capabilities. A great example of this is the definitions published by Microsoft Corporation, a well-known company worldwide, which describes the types of AI as follows:

"Artificial narrow intelligence—sometimes called »weak AI«—refers to the ability of a computer system to perform a narrowly defined task better than a human can. Narrow AI is the highest level of AI development that humanity has reached so far, and every example of AI that you see in the real world falls into this category – including autonomous vehicles and personal digital assistants. That's because even when it seems like AI is thinking for itself in real time, it's actually co-ordinating several narrow processes and making decisions within a pre-determined framework. The AI's »thinking« doesn't involve consciousness or emotion. […]

Artificial general intelligence—sometimes called »strong AI« or »human-level AI«—refers to the ability of a computer system to outperform humans in any intellectual task. It's the type of AI that you see in movies where robots have conscious thoughts and act on their own motives. In theory, a computer system that has achieved general AI would be able to solve deeply complex problems, apply judgment in uncertain situations, and incorporate prior knowledge into its current reasoning. It would be capable of creativity and imagination on par with humans and could take on a far wider range of tasks than narrow AI. […]

A computer system that has achieved artificial super intelligence would have the ability to outperform humans in almost every field, including scientific creativity, general wisdom, and social skills."[13]

Artificial intelligence therefore has an important role to play in the development of immersive technologies. There is a wealth of information that can be presented in virtual space (both automatically and manually controlled) that can be supported by machine learning algorithms.

Other essential knowledge of the technology includes an overview of the field of artificial intelligence, where the place and meaning of the commonly used concepts of machine learning and deep learning are important. It is important to emphasise that AI itself is conceptual, while machine learning and deep learning are explicitly technical definitions. The relationship between the two concepts is illustrated in Figure 11, which shows that deep learning corresponds to machine learning, while machine learning corresponds to a part of artificial intelligence.

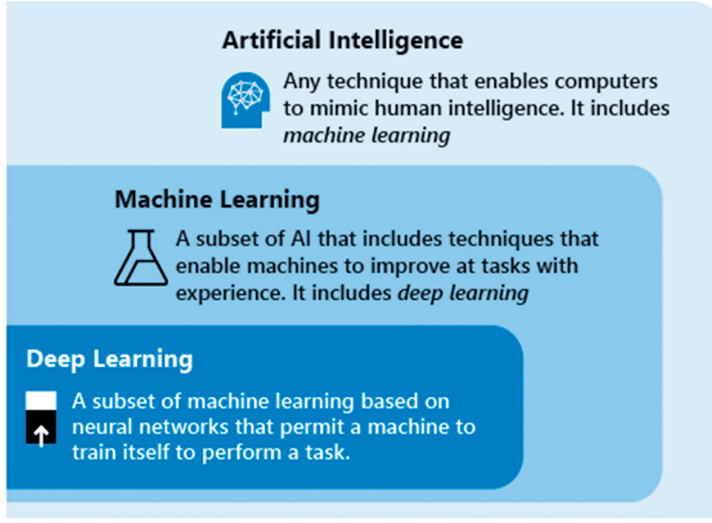

Figure 11: The relation between deep learning, machine learning and artificial intelligence
Source: Microsoft Corporation (2022a): op. cit.

[13] Microsoft Corporation: *What Is Artificial Intelligence?* 2022e.

Sticking to the Microsoft Corporation definitions, the two technical definitions are:

"Machine learning is a process that computer systems follow to achieve artificial intelligence. It uses algorithms to identify patterns within data, and those patterns are then used to create a data model that can make predictions. Machine-learning models are trained on subsets of data. When the data that's used to train the model accurately represents the full dataset that will be analyzed, the algorithm calculates more accurate results. When the machine learning model has been trained well enough to perform its task quickly and accurately enough to be useful and trustworthy, it's achieved narrow AI. […] Deep learning is an advanced type of machine learning that uses networks of algorithms that are inspired by the structure of the brain, known as neural networks. A deep neural network has nested neural nodes, and each question that it answers leads to a set of related questions. Deep learning typically requires a large data set to train on; training sets for deep learning are sometimes made up of millions of data points. After a deep neural network has been trained on these large data sets, it can handle more ambiguity than a shallow network. That makes it useful for applications like image recognition, where the AI needs to find the edges of a shape before it can identify what's in the image."[14]

As part of the development of immersive technologies, innovative products can be created by building complex neural networks and using learning algorithms. Functional elements can be developed that support the user's information environment in a variety of ways.

Internet of Things

The development of IoT is also related to the development of immersive technologies, which has its foundations in the history of the Internet, so a brief overview of the history of the Internet is part of a comprehensive knowledge of IoT. The first important activity in the history of the Internet dates back to 1957, when the Advanced Research Projects Agency was created within the U.S. Department of Defense, which in 1969 set up a packet-switched network called the Advanced Research Projects Agency Network, or ARPAnet, as an experiment. In addition to ARPAnet, a network using similar technology was created specifically for military purposes, called the Military Network, or MILnet. These two networks

[14] Microsoft Corporation (2022e): op. cit.

were later merged in 1983, and the name ARPAnet was retained for the expanded network. ARPAnet was then joined by a number of networks such as MInet (the European equivalent of MILnet), SATnet and WIDEBAND (which are satellite networks), NFSnet (National Science Foundation Network), etc. The combination of these networks gave rise to the aggregated network that we now know as the Internet.

By the 1990s, major computer retail service centres (such as CompuServe) were accessible via the Internet and the range of business applications began to expand rapidly. The Internet has also had an impact on the organisation of information within institutions, giving rise to the so-called Intranet, which uses Internet technology but specifically for the purpose of running a corporate information system. Europe and America are linked by cables across the ocean, but data can also be transmitted via satellite. Intensive, rapid network expansion has been measured in the hundreds, thousands and then tens of thousands. Today, as a related statistic shows, the number of networks connected to the Internet has exceeded 100,000.[15] The convergence of the information technology, communications, telecommunications and entertainment industries and the use of the Internet network as a single communication medium has become a key factor in the development of the Internet. Multimedia applications that require high data transmission speeds (bandwidth) require the development of new technological solutions to ensure the continuous transmission of information (for example sound, images).

All these decades of developments have led to the emergence of the now commonly known Internet of Things technology. The term was first used by Kevin Ashton[16] in a 1999 think piece on the source of data available on the Internet. Ashton believed that the 50 petabytes (53 billion megabytes) of data available at that time were in fact uploaded to the web by humans, who are not capable of capturing significantly more data about their environment and therefore must leave this task to machines, objects. In his opinion, the possibility of tracking and tracing the data available online about our world and objects could bring a lot of benefits to mankind. The IoT was only formally proclaimed in 2005 by the International Telecommunication Union (ITU) in the Internet Reports issue

[15] Mat Ford: Where Are the Internet Networks? *Internet Society,* 25 January 2022.

[16] Kevin Ashton is a British technology pioneer, who invented the term "Internet of Things" to describe a system in which access to the internet is achieved through ubiquitous sensors, including RFID (radio-frequency identification).

of that year: “A new dimension has been added to the world of information and communication technologies (ICTs): from *anytime, any place* connectivity for *anyone,* we will now have connectivity for *anything.* Connections will multiply and create an entirely new dynamic network of networks – an Internet of Things. The Internet of Things is neither science fiction nor industry hype, but is based on solid technological advances and visions of network ubiquity that are zealously being realized.”[17]

IoT technology is a very broad topic, with several approaches. Three of the main approaches are:

- object-oriented approach
- network-oriented approach
- semantics-oriented approach

Closely related to the object-oriented approach is the concept of Electronic Product Code (EPC). It is an approach whereby each object has a unique EPC code that allows it to be easily identified and to communicate with each other and with different information systems. The network-oriented approach is that every object should have a built-in computer capable of connecting to the Internet (see for example the term Web of Things). The semantics-oriented approach focuses on the transformation of the vast amount of data into information, all that can be done in this way with respect to objects. Figure 12 shows that there are quite a lot of products and services in the field of IoT technology, which is why one of the most important things is that it can all be segmented. IoT technology can be divided into three main sub-domains:

- IoT devices
- IoT protocols and connections
- IoT platforms

IoT devices are diverse, with an extremely wide range of devices (for example embedded systems, smart devices, sensors). IoT protocols define how a device can communicate, which requires a network gateway (for example Wi-Fi, 5G). IoT platforms support data management, based on hardware and software protocols (for example cloud-based solutions).[18]

[17] ITU: *The Internet of Things.* Geneva, International Telecommunication Union, 2005. 2.
[18] Microsoft Corporation: *IoT Technologies and Protocols.* 2022c.

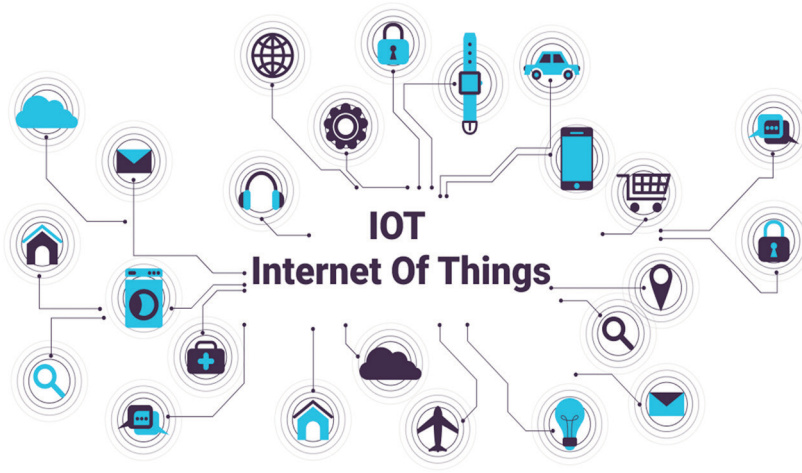

Figure 12: Countless Internet of Things
Source: ZRIX (2022): op. cit.

The Internet of Things technology is therefore aimed at developing devices (becoming smart devices) that are not primarily designed for communication purposes. "It's your equipment, machines, products and devices that are connected to the cloud and outfitted to collect and securely transmit data."[19] Today, such devices as phones, TVs and even watches have become commonplace, followed by, for example, thermostats, washing machines and tea makers, which are now being used in the IoT approach. As can be seen from the main trends for the year 2022, as shown in Figure 13, IoT technology is evolving intensively and is clearly being felt. Information sharing technologies such as IoT are needed in today's society.

IoT is clearly an interdisciplinary field, which is also linked to AI, among others, as a great development opportunity. AI solutions help to ensure that when using IoT technology, the system works organically, on its own, without the need to parameterise everything in advance, plan it carefully and then change it manually when something changes. The IoT digitises and makes available the data in the physical reality and AI can use the large amount of data generated and transform it into action and activity.

[19] Microsoft Corporation: *What Is IoT?* 2022d.

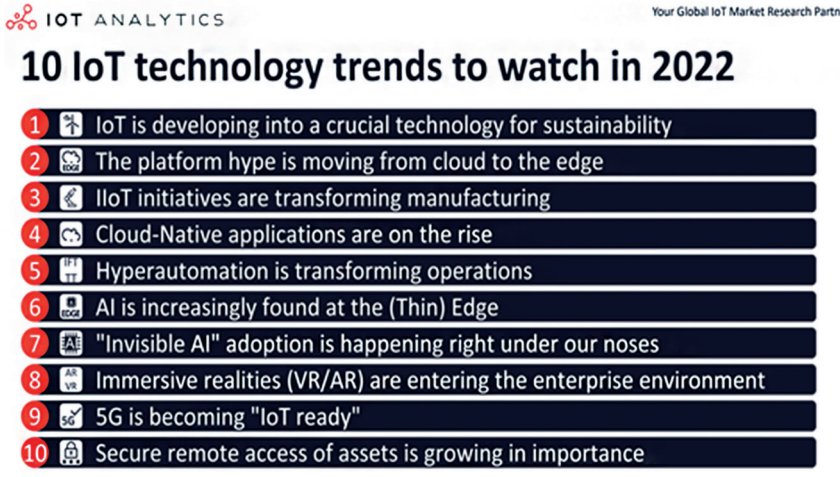

Figure 13: Trends of Internet of Things
Source: Wilford (2022): op. cit.

IoT capability also has a role to play in the context of immersive technologies. As the figure above shows, developments in virtual reality and augmented reality are linked to IoT technology. Wide-area networks, such as 5G technology, are an important part of functional services for the development of immersive technologies.

More and more devices have hardware built in to capture, transmit and receive data, creating the opportunity for these things to communicate with each other. Such devices include virtual reality, virtual space devices. These devices are already being developed to be able to operate in an information system, which requires, among other things, a lot of data and network connections. A key interest in the development of immersive technology is to understand and meet users' needs for the Internet and to integrate related intelligent algorithms.

Big Data

Mass data-driven processes have become particularly important in today's information society. In order to stimulate demand, the IT market has a penchant for introducing new, easy-to-remember terms, behind which a whole trend (and at

the same time a product or service) is built. One such trend has become the term big data, which is based on the collection, structuring and analysis of data in the most comprehensive form possible. It is more or less universally accepted that the world needs to systematically collect and analyse ever-increasing amounts and more diverse forms of data.

The global impact of this has given rise to the Big Data problem. There are several definitions of big data, of which the Cambridge Dictionary has the following: "Very large sets of data that are produced by people using the internet, and that can only be stored, understood, and used with the help of special tools and methods."[20] It is important to note that "Big Data" is not a specific tool or technology, but a concept that is a feature of the 21st century, with a significant role and purpose.

Nowadays, the amount of data is growing exponentially all over the world, there is so much data, it is much harder to work with. We recognise the challenges in all areas of life, whether it is leisure, family or work data. The following examples explains these challenges:

- data needs a lot of storage space
- clunky searches
- clunky sharing
- clunky organisation
- cumbersome to modify or edit
- difficult to maintain data security

Moreover, Big Data is not always a fixed database, but a set of data continuously generated from a particular source, from which we do not take a sample, but can draw conclusions by continuous observation. Among the many technologies involved, there are also ever-evolving technologies, as the data in the virtual space needs to be managed, especially when combined with artificial intelligence, which in any case requires a large database. Both in virtual reality and augmented reality, the quantity and quality of data traffic is evolving at an extraordinary pace. The ability to handle massive amounts of data will be important and essential for these devices that can be connected to the internet.

Globally, the need to transform the processes involved in managing data is not only a technological issue, but also a matter of attitude and culture. The development of the Internet and the emergence of related tools and systems are

[20] Cambridge Dictionary: *Big Data*. s. a.

gradually reinforcing the awareness in the background of the need to apply some method to mass data in order to make it orderly and manageable. Many people are working on the development and implementation of different analytical (data collection and data processing) methods, for which it is worth understanding the following five main characteristics of Big Data (called the "five Vs"), shown in Figure 14: Volume, Velocity, Variety, Veracity and Value. These five characteristics describe the innate, main characteristics of Big Data, which have been further extended by different interpretations. It is a complex technological environment based on massive amounts of data, which requires the creation of a state-of-the-art data analysis system. With the help of data analysing, it is possible to evaluate the data in the most optimal way possible and thus process more data faster and better.

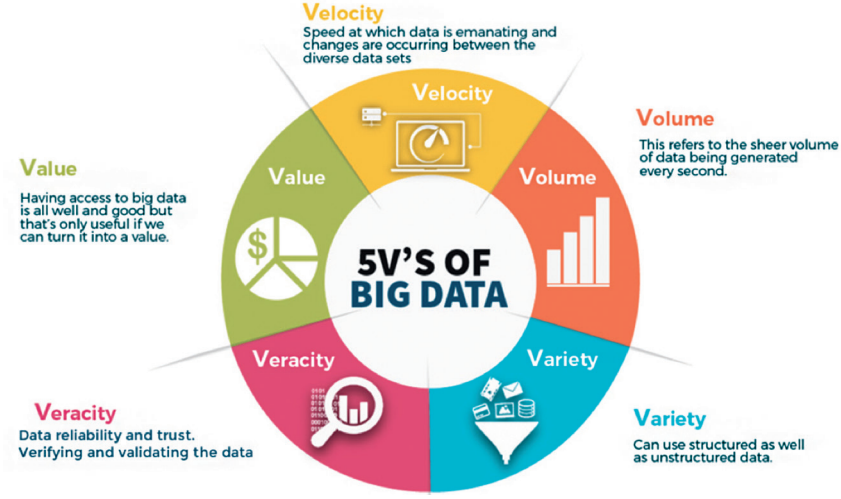

Figure 14: The 5 V's of Big Data
Source: Tech Entice (2019): op. cit.

– Volume: The Volume of data has expanded exponentially over the last few years. This data can be structured, semi-structured and unstructured, and it focuses on the sheer amount of data rather than its content. The main challenges of managing huge data include storage limitations, processing power requirements and bandwidth capabilities.

- Velocity: Time is an important factor when assessing big data as new information emerges continuously throughout the day. Data is generated rapidly, and big data velocity determines the pace at which it is collected from the real world. With everyone coming into the Information Age and producing data at high speeds, the velocity of data is increasing exponentially. The problem with this is that we cannot handle the amount of data coming in. This led to a need for data processing.
- Variety: Along with Volume and Velocity, the diversity of big data or different data types such as images, videos, etc., presents a unique challenge for organisations to manage their wide range of content effectively. It was reported that more than 90% of the world's data was created in the last two years alone. This creates a challenge because there are too many data sources and it is not properly organised and managed.
- Veracity: Big Data contains large quantities of ambiguous and dirty (unverified) data that needs to be cleaned and organised before serving its purpose. Semi-Structured data, for example, is often incomplete or inaccurate, which makes data cleansing a challenging process. Data quality and Data quality management is an issue because unstructured or semi structured data cannot contribute knowledge to a study or research project. If one can never trust all the variables in a set of data, then it is important that one focuses on only those variables which seem most valid and reliable.
- Value: While the other V(s) represent external factors affecting big data, the Value represents the internal factors associated with business strategy and execution. To extract maximum value from Big Data, companies and data scientists need to have a clear goal for what they want to achieve through their analysis. Once this is established, they can determine which information needs to be collected and how it will be used.[21]

Basics of virtual perception

Nowadays, people use machines in their daily lives, which have a significant impact on human perception. Science refers to this kind of interaction as human-computer interaction, which is illustrated in Figure 15. The quality

[21] Excelsior: *Big Data, Explained: The 5Vs of Data.* 2021.

of the interaction is related to the technological characteristics of the human senses and the computer. Virtual reality is a specific form of human-computer interaction within the field of immersive technologies, based on realistic spatial representation and perception. Through interaction, the computer gives the user the illusion and feeling of being part of the computer-generated artificial environment.

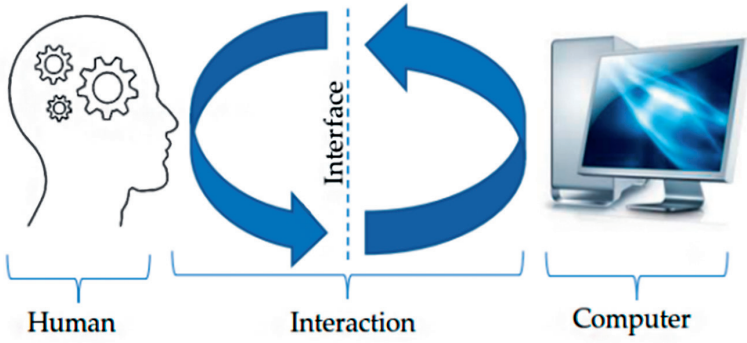

Figure 15: The human–computer interaction
Source: Katona (2021): op. cit. 3.

This is also the case for virtual reality, according to its specific technological capabilities. In relation to interaction, the following perceptual areas are worth mentioning:

- motion and position perception
- hearing
- vision
- touch

Movement and its associated perceptions are quite complex and precise feedback mechanisms. The sense of balance and somatic perception take care of the coordination of movement (and also vision, as it has a role in guiding movement). During the perception of movements to change position, movement and orientation (positioning) follow the laws of the real environment. In the virtual environment, this takes a different form. An important principle is that the digitalisation of users should be done in a way that does not impede freedom

of movement. In the space generated by virtual reality, the user should not be constrained and his or her movement should in theory be infinite.

Today, there are physical implementations supporting virtual reality technology that allow for a highly realistic perception of movement and positioning. The perception of movement is one of the fundamental guidelines for the development of virtual reality tools. In virtual space, devices that enable motion detection are called tracking systems (a system that allows tracking the movements of the head, arms, legs and thus the whole body). The tracking system provides the computer with continuous information about the virtual position of the user. Future goals include the development of virtual devices that can access movement information by connecting to the human nervous system.

Hearing perception is not only about hearing sounds, but also about the spatial direction and distance of each sound source. The sound sources are usually linked by a visual representation, which allows the unity of sight and sound as a perceptual system to be created. The technical level of sound reproduction devices is nowadays quite diverse. The technological level makes it possible to test a wide spectrum of low and high sound sources (audible to the human ear in the frequency range between 20 Hz and 20 kHz). The application of sound effects coupled with virtual space is nowadays done with high technology.

Vision is the perception of the eye and other related organs (the human eye detects electromagnetic radiation between 380 and 750 nm). Virtual systems, virtual environments are a great way to explore the brain activities related to vision. Four-dimensional (4D)[22] visualisation in virtual environments aims to simulate head movements, which are in effect responsible for the user experience. The 4D visualisation capability of virtual reality technology is therefore essential, as it is impossible to simulate human visual perception without it. In many cases, the visual displays of virtual reality systems are capable of producing photo-realistic multidimensional images (with guaranteed high quality), which contribute significantly to the sense of reality of the virtual environment.

Touch is the exploration of the sensation of touch, the illusion of manipulation of objects. The virtual system's tools related to these sensations are focused on the human interaction with the virtual environment. To do this, the so-called somatosensory system of the human body is used. As shown in Figure 16, touch is sensed through two types of mechanoreceptors:

[22] Immersive technologies can be interpreted in four dimensions, three spatial dimensions and the temporal dimension (often called spacetime).

– tactile feedback (pressure information from sensors in the skin)
– kinesthetic feedback (resistance and tension information from muscle tendons)

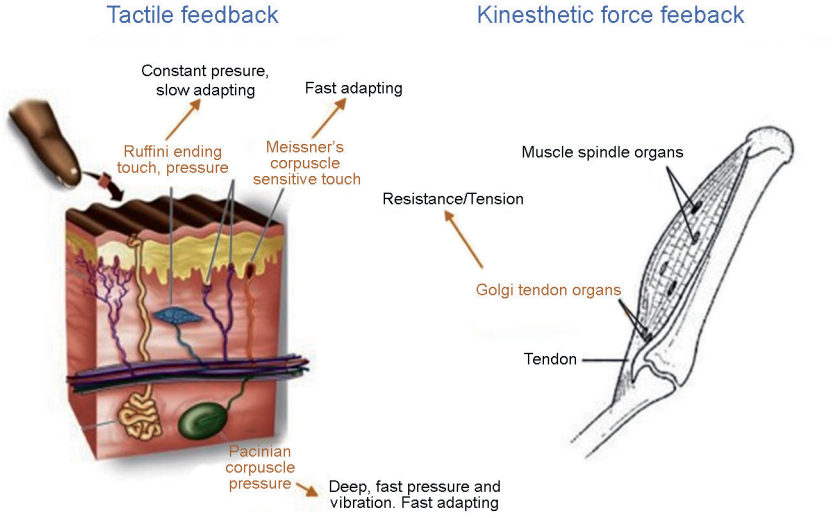

Figure 16: Tactile and kinesthetic force feedback
Source: Juo et al. (2020): op. cit. 290.

Types of virtual reality and immersive technology

Virtual reality can be used in many areas, and the basic types of virtual reality are worth mentioning from a technological point of view. There are several possible solutions for the integration of virtual components in physical space, which can be summarised as the main types of virtual reality. It is important to note that the following main types of virtual reality can be distinguished in terms of the creation of virtual space:

– immersive virtual reality
– desktop virtual reality (cheap, home-made)
– projected virtual reality
– simulation virtual reality

Immersive virtual reality, as the name suggests, is about the effect of immersion that the user experiences during the process, which will be discussed in more detail later. Desktop virtual reality is a virtual environment that can be set up anywhere. Projected virtual reality is a projection of information (virtual program) from a computer into a physical environment. Simulation virtual reality is a reality created in a physical environment where a simulation program can be used to create a realistic experience. It is important to note that an approach that looks at the extent to which the application corresponds to the physical reality helps to explore the differences between the types. "The key feature of all virtual reality systems is that they provide an environment created by the computer or other media where the user feels present, that is, immersed physically, perceptually, and psychologically. Virtual reality systems enable users to become participants in artificial spaces created by the computer."[23]

Of the types, the most relevant for the particularly innovative and multifaceted development approach of virtual reality is the immersive technology (as people are extremely interested in immersive experiences), and therefore a broader understanding of immersive technology will be discussed below. Generally speaking, when we talk about virtual reality, we tend to think about immersive devices and systems, even if we are not necessarily aware of them. The word 'immersion' means a kind of entry, involvement. "Immersion into a virtual reality is a perception of being physically present in a non-physical world."[24] It is well known that virtual reality has become very popular for the experience it provides, including in computer games. Nowadays, quite a lot of games have an integral part of immersion, in other words, the involvement of the user in the story. This includes various computer interfaces, such as the typical head-mounted displays, but also navigation and positioning devices, fibre-optic gloves and surround sound systems. It follows from all this that immersive virtual reality provides a direct, first-person experience. Once immersion as a process is understood, immersive technology can be understood and interpreted. In practice, immersive technologies are becoming part of everyday life, as the demand for immersive experiences is quite high, which has naturally increased market demand. It is notable that, despite this, it is not always obvious what the differences are that

[23] Hilary McLellan – Wyatt McLellan: Virtual Realities. In David H. Jonassen (ed.): *Handbook of Research for Educational Communications and Technology.* Bloomington, The Association for Educational Communications and Technology, 2004. 464.

[24] IGI Global: *What Is Immersive Virtual World.* s. a.

separate and make unique each of the developments in immersive technologies. There are many definitions of evergreen technology in the literature today, of which the following is an example: "Immersive technology is an integration of virtual content with the physical environment in a way that allows the user to engage naturally with the blended reality."[25]

The area of immersive development specifically can be divided into the following four types:

- Development of Virtual Reality (VR)
- Development of Augmented Reality (AR)
- Development of Mixed Reality (MR)
- Development of eXtended Reality (XR)

Understanding these types is of utmost important, even essential, in order to start defining the design, the development and testing processes based on the four dimensions of the technology. Today, virtual reality itself is the most commonly known, but in the following, it will be understood that the needs of the average user in terms of virtual reality experiences are not only present in virtual reality, but also in several types of so-called artificially created reality. It is therefore necessary for users, and even more so for developers, to understand these immersive developments.

As a first type, *virtual reality* is, by its very name, a completely artificial space, where entering (immersion) one can only encounter non-real elements and components (interaction). It is very important to note that the user processes emotions in the brain in a natural, habitual way, and therefore tends to perceive many things as real in the virtual environment. Virtual reality is an artificial reality presented by a computer. In virtual space, realistic sounds and images are generated and played back, which are then recorded in the brain as a real experience.

In contrast, the second type, *augmented reality,* is an immersive technology that can be described as a partly virtual and partly real space, outside of the fully artificial space of virtual reality. The technology of augmented reality builds on top of reality, practically building on reality, adding digital elements and components. As a result, the information content (computer generated), projected to the real world environment as a layer overlaid on the surface of physically

[25] Ivy Wigmore: *Immersive Technology.* 2018.

real objects, i.e. embedded in the real environment. Augmented reality exploits existing reality content and augments it using a tool or tools.

There is also a common development version of virtual reality and augmented reality that has been discussed so far. The third type, *mixed reality,* is a combination of virtual reality and augmented reality, which includes the multiple possibilities of both types of development at the same time. It is also known as hybrid reality because it incorporates elements of both the virtual and the real world. These elements appear simultaneously in the "mixed" space and interact digitally with each other. As shown in Figure 17, mixed reality encompasses both virtual and real environments, a domain that can essentially be interpreted as a reality–virtuality continuum.

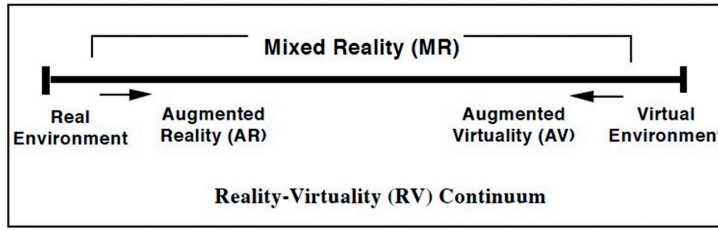

Figure 17: Understanding the domain of mixed reality
Source: Billinghurst (2017): op. cit.

The last, fourth type of immersive technology is *extended reality.* Extended reality differs from the types described so far in that the development process already involves the IoT, artificial intelligence (and even robotics). Extended reality, in addition to being an umbrella term, also complements all other evergreen developments.

Predictions for an immersive future: The revolution in XR technology

A broader interpretation of XR technology

It is safe to say that virtualised worlds, the result of popular and well-liked immersive developments, are now increasingly centred on extended reality technology, which has become popular during the pandemic, has a very significant and innovative potential in the coming years. In recent years, virtual reality,

augmented reality and mixed reality have been popular themes, but this is all set to change somewhat, as extended reality is the real innovation.

Extended reality offers a degree of freedom for both developers and users, and with it an almost inexhaustible source of variety. Compared to virtual reality and augmented reality, new perceptual domains are emerging that can provide users with new experiences. A complex system of immersive effects appears in extended reality, testing the user's senses. To give an example, touch (haptic sensation) and smell (the perception of smells) will also be part of the digital space, the digital experience. These processes and experiences have not been possible until now, which is why the curiosity towards technology is quite unique.

The extended reality technology includes all the immersive technologies (virtual reality, augmented reality and mixed reality). However, it is useful to note that, in terms of the user's approach to the environment, the technology is composed of two major parts: on the one hand, an augmented reality part in which the user is in a real environment, where digital information is within the user's field of view; on the other hand, a virtual reality part in which the user is placed in a completely unique, new virtual environment that is separate from his or her physical environment.

Extended reality may even include mechanisms such as robotics or IoT, but it can also clearly include artificial intelligence. Robotics can enrich the extended reality experience with a number of mechanisms, IoT with a number of network-based functions and AI with a number of unique built-in functions. The pandemic period has been of particular importance for the acquisition of new experiences (demand for them), due to the continuous closures. In the quarantine situation, people were not only isolated from each other, but also from the everyday experience of the experience. The development of immersive technologies, and specifically extended reality, reveals to people in a much more concentrated way the sensations and familiar influences that and how we are used to. As a result, extended reality has taken us to a new level of experience that the masses of users want to experience. With this growing demand, the demand for augmented reality is likely to grow quite rapidly. Year on year, the total investment in immersive technologies worldwide is growing exponentially, which will be discussed in the later chapters on the economic approach. As it was written earlier, extended reality is the umbrella term for all immersive technologies, which also means their simultaneous deployment. The development of virtual reality, augmented reality and mixed reality are each a 'bottomless drawer' in the extended reality cupboard.

Alongside the popularity of the technology, it is also clear that the informational impact of extended reality on the brain of users is significant. In our fast-paced world, we are used to information coming from virtually all sides, all the time, which is why it is important, and therefore worthwhile, to understand the purpose and role of extended reality in more depth. Extended Reality is a technology that will become more and more known worldwide in the future, and at the same time, it will be tried and used by many people. As experience is gathered and developed, extended reality will also gain social acceptance, with positive informative value being an important factor.

The informative effect of extended reality

Virtual reality and augmented reality share the same underlying motif that makes immersive technologies experiential. It is the information, which is implemented as a complex, programmed environment. It should therefore be remembered that extended reality, also known as extended information space has a number of effects on the user, or more precisely on the user's brain. It is nowadays accepted by manufacturers, and even more so by developers, that extended reality technology will become a learning and training tool in the near future. The multiple benefits of this development are a range of information effects, or stimuli for the user. The tools developed from different hardware and software components present the user with a mass of information, including both static and dynamic features. Even during the pandemic, it was already apparent that the demand for extended reality would increase in a prominent way, reflecting people's information needs. Information with family, friends, teachers, colleagues, etc. These experiences (the information environment) are brought much closer by an immersive technology. In the brain, images and sounds contain an enormous amount of information, which one does not always take note of, as it is natural (as is the fact that the brain just works, works and works) in physical reality.

Public development and testing experience show that extended reality technology holds great promise in for example, learning and operating manufacturing processes, because it reduces the cognitive load on the learner, provides opportunities for unlimited practice and accelerates learning. It is interesting to note that, in addition, knowledge retention can be multiplied by the introduction of learning systems that are synchronised with brain function. An important

segment of extended reality is therefore the development of learning technology, which is a key focus for many manufacturers and developers.

Basically, it is our working memory, or short-term memory that is stressed during most working or learning processes, because we can more easily retrieve the information from it. In our short-term memory, we distinguish between two types of cognitive load, internal and external. Internal memory contains the necessary information and aids comprehension. External memory is a distraction, contains unnecessary information and does not contribute to comprehension. This is also true for external inputs and information sets processed during work processes. "The field of immersive learning is still emerging, but with such a broad range of employee-training applications, XR technology will be important to the enterprise of the future."[26]

What this means in practice is that in jobs with high external cognitive load, extended reality can minimise external memory capacity and allow us to focus on the segments that really, actually matter. This reduces the possibility of errors and increases precision. This is quite advantageous in logistics processes, for example, but it is also observed in other sectors where a learning process takes place. It is possible to see how extended reality technology can be used in many ways by studying the information learning processes of the human brain. In terms of the approach to the information space, there is virtually no area or sector where extended reality cannot be used to create an innovative and compelling application. It is our brain that will rival reality when we enter extended reality. Immersive technology exploits our sensory systems, our brain–body interactions. What we can be sure of is that extended reality will not change the world, but rather change us as humans. Learning is a never-ending process throughout a person's life, and extended reality can therefore help us to do this, and its development will provide researchers with new tools to further investigate how our minds work.

Economic perspective

Nowadays, virtual reality or augmented reality, and with it immersive technologies are clearly popular in the business sector. From an economic point of view, it is important to note that the innovation of these technologies is based

[26] Rakesh Raghavan – Prahlad Rao: *Immersive Learning for the Future Workforce.* 2018. 11.

on research and development. It is very difficult to remain marketable without research and development (R&D), as countless companies experience year after year. Research is an essential, daily activity for a competitive company. R&D is not only necessary for self-development, but also, among other things, to assess the current, day-to-day market situation and to keep abreast of modern trends. All this creates a rather tense competitive situation in the economy between companies in order to gain a customer market. Whether the aim is to gain new contacts as a reseller or to ensure user satisfaction with the product or service developed, a solid research background is essential. Of course, engineering knowledge, ingenuity and creativity are important contributors to this, but it is important to note that the success of innovation does not depend on this alone: "Therefore, the success of innovation in a competitive market not only depends on ideas and engineering ability to implement them for advancing utility in a cost-effective manner but, most importantly, on the competition force. For this reason, conventional engineering economics is not sufficient to make design decisions for innovation. It should consider the response of competition affecting the value extraction callability from the engineered innovative ideas."[27]

From an economic point of view, virtual reality and augmented reality technologies can also be considered innovations. In the followings, we will explore which economic areas are most affected by these technologies. From a business perspective, it is useful to examine the impact of these products on the economy. The general opportunities (benefits) that investing in technology can bring to a business in terms of day-to-day operations, irrespective of the specific economic objective, will be discussed. In addition, three arbitrarily selected companies will be listed and their typical products reviewed. We are talking about high quality manufacturers, which will give a more comprehensive picture of the day-to-day situation on the economic market. Lastly, the economic impact of immersive technologies will be examined, supported by statistical forecasts.

The boom is clearly visible in the various segments of Economy. Analyses from many different perspectives have been published on the internet. These include, for example, the number of users of virtual reality and augmented reality,

[27] Rokon Zaman: *Engineering Economics for Innovation.* 2020.

and financial statistics on the technology. Overall, the following main studies can be considered in the economic field in relation to immersive technologies:

- research on manufacturers, products (shared information from popular companies)
- analysis of statistical indicators (changes in the number of users, the number of companies using the technology, etc.)
- history of developments, forecasts (place and changes of technology in the economy, observation of the reality of innovation)

It is relevant to note that the following is intended to demonstrate that immersive technologies do have a significant impact on economic indicators. It is also worth reading the Organisation for Economic Co-operation and Development (OECD) publications for anyone interested in technology. The organisation covers a range of topics, for example digital and innovative solutions. You can find papers on topics such as development, economics, industry and services, science and technology.

Product overview of a few major market participants

Meta Quest 2

After Facebook bought Oculus in 2014, the company did not change its core strategy for the product, which is focused on media, communications, entertainment and education. The former Oculus Quest product was changed to Meta Quest after Facebook itself changed its name to Meta. This gave rise to Meta Quest, and then to its improved product, Meta Quest 2, shown in Figure 18. The basic objectives are to mass produce the glasses and to improve the virtual reality technology used. The development of Meta's product is clearly focused on delivering a high level of immersive virtual reality experience, building on which to incorporate additional immersive technologies. This is of particular interest to the entertainment industry, for example. Meta takes the market quite seriously and has demonstrated this.

Figure 18: Meta Quest 2 product
Source: Meta (s. a.): op. cit.

About the main technical specifications of the product:

- Graphics are displayed on a fast-switch LCD display with a resolution of 1832 × 1920 pixels. Touch data can be processed by touch controllers or by hand tracking.
- A three-dimensional positional speaker is built directly into the headset, enhancing the user's experience of hearing what is around them.
- The processor that does the processing is an ultra-fast QualcommSnapdragon XR2 with 6GB of RAM to deliver the performance.
- The product comes with 128GB or 256GB of storage, depending on your preference.
- Tracking is performed using the 6DOF (6 Degrees of Freedom) principle, whereby head and body movements are processed with realistic accuracy.
- The controllers are quite good, and the Meta Quest product has improved ergonomics that increase stability.
- The head strap has a fairly soft strap that can be easily adjusted to individual sizes.

The company specifically describes that you can download apps from their Meta Quest Store. The Meta Quest 2 is powered by an incredibly precisely designed, well put together and polished software that delivers a high level of experience for users.

Microsoft HoloLens 2

Microsoft unveiled its product HoloLens in 2015, which uses the immersive technology, and has since been updated with a new release, HoloLens 2. To get familiar with the product shown in Figure 19, it is useful to start with the UI (user interface), which provides the primary entry point to the device. The central element of the software UI is a minimal start menu from which the installed applications can be launched. This is a 2D interface where you can select and launch an application to run, as well as perform configuration. The system can run multiple 2D applications at the same time, which can be placed on different flat surfaces (for example on a desktop, wall, cabinet) and are brought into view when the user looks at them.

Figure 19: Microsoft HoloLens 2 product
Source: Microsoft Corporation (2022b): op. cit.

Main technical specifications of the product:

- Graphics for this product are displayed at a resolution of 2048 × 1080 pixels.
- The lenses are equipped with an 8 MP HD camera, a microphone and a number of sensors.
- The display projects colour 3D images into natural space, allowing the user to interact with virtual 3D models and holograms.

- The processor is Qualcomm Snapdragon 850, while the memory is 4GB RAM.
- Storage is 64GB.
- USB-C port, Bluetooth 5 and Wi-Fi 5 support.
- The headband is plastic, adjustable with a twist.
- No hand controllers, eyes and hand gestures are tracked.

HoloLens is able to display a variety of digital objects on its screen and seemingly pin them to physical objects. The objects can be walked around, leaned close to (even viewed from the inside), and the system tracks head position (gaze direction) and, based on positional tracking, the user's view of the virtual object. Devices can also be networked, allowing multiple users to access the same augmented reality. In this case, users see exactly the same environment from different perspectives. An extra feature is that users can also see each other in this virtual space, so they can play or work together. The product is popular with businesses for distance learning and remote collaboration.

Google Glass Enterprise 2

Google released the Google Glass Enterprise Edition 2, a new version of its immersive technology, in 2019. The device shown in Figure 20 is not yet available for direct purchase, but can be accessed by interested companies through Google's reseller channels, system integrators. "Glass Enterprise Edition 2 is a wearable device that helps businesses improve the quality of their output, and help their employees work smarter, faster and safer. It provides hands-on workers and professionals with glanceable, voice-activated assistance that is designed to be worn all day with its comfortable, lightweight profile."[28]

[28] Google LLC: *Glass Enterprise Edition 2.* s. a.

Figure 20: Google Glass Enterprise 2 product
Source: Kothari (2019): op. cit.

Main technical specifications of the product:

- Graphic display resolution of 640 pixels × 360 pixels.
- 8 MP camera for HD images and videos.
- Voice commands, built-in earphones.
- Processor is Qualcomm Snapdragon XR1, while memory is 2GB RAM.
- Storage is 32GB.
- USB-C port, Bluetooth 5 and Wi-Fi 5 support.
- Designed to be worn similar to a pair of reading glasses, which makes it popular. There are no other controllers for this product either.

To summarise, all of the products listed above seek to streamline the development of technological capabilities while seeking the most effective solution to meet the needs of their target customer base. Microsoft, as usual, thinks in terms of both individuals and organisations (for example healthcare). The company's product represents augmented reality, mixed reality and augmented reality technologies, leaving the experience of moving around in real space free. Google boasts a similarly unique product that could be a highly innovative solution for businesses. Google's uniquely designed product is a clear reflection of the ease of everyday use of ever-evolving technology protocols.

Virtual reality as a possible market support

Virtual reality developments can bring innovative solutions to the economy on a wide scale. There is the potential to develop a fairly large customer base of potential businesses interested in the technology. However, it is also worth noting that the technology is not necessarily only viable for specific needs in specific areas. The myriad and diverse businesses often lack the financial resources and capacity to bring their developments to market. They do not have appropriate professional and infrastructural background. These conditions naturally hamper the market position of the enterprise concerned. An intermediate solution, which is essentially a knowledge-based service for market players interested in R&D, can change this situation. The central objective is a virtual environment in which various business support activities could be carried out. Enterprises could be guided through complete design, development and testing processes in a virtual space wherever possible:

- quality and quantity planning of products
- digitise existing, real samples
- optimise different technologies, manufacturing processes and products
- 4D simulation of realistic applications
- implementation modelling, rapid prototyping

Such an option allows companies to save a lot of money when optimising their manufacturing or product development processes by being able to model the related processes in virtual space rather than "live", so that they do not have to pay the consequences of, for example, design errors. Automotive industry is a prime example, but healthcare and energy industries can also benefit from the use of this technology, not to mention the improvement of logistics processes. Such a project can be set up as a private enterprise or as a public company. If a nation can provide such a service (not for profit) to businesses, it can greatly help and boost the innovative economic development of that nation in a short time.

At present, we are seeing the beginnings of immersive technologies in the day-to-day processes of companies around the world. At the same time, virtual worlds are gaining ground in the public consciousness and thus among potential consumers and customers as a result of the continuous technological development. Companies that keep up with technology are increasingly trying to integrate it into their activities and develop their own virtual shops and events. An important change is that new virtual opportunities are also enabling companies

to rethink the way they engage with consumers. For a company, the use of immersive technology can raise a number of perceptibly open questions. The use of technology can certainly be effective for companies, regardless of their different financial goals, in the following main ways:

- for workers (new types of modern working environments and jobs)
- for the company's budget (virtual solutions are more cost-effective than physical solutions)
- the reputation and recognition of the company (striving for modern, innovative solutions)
- the company's interoperability (advanced technological capabilities make it easier and more flexible for managers to interact with other companies)

As a result, the company's market position can be strengthened, but this depends on the extent to which it is involved in virtual, rapidly evolving technologies (sell, in turn sell, produce, develop, or just use, etc.).

The impact of virtual reality on the economy

The ability of immersive technologies to serve people information in a highly effective and experiential way makes it easy to understand why the use of virtual reality and related technologies is growing rapidly. In the context of the economic study of immersive technologies, it is important to understand the two main basic forms of business activity in a company. From an economic activity perspective, it can be said that these technologies are nowadays active in both B2B (Business to Business) and B2C (Business to Customer). A B2C activity is a business that sells its immersive technology services and products to individuals. B2B is a business that resells its services and products to another business. As it is well known, a B2B business is primarily concerned with generating leads,[29] whereas a B2C business is concerned with the satisfaction and loyalty of consumers of

[29] A lead is an interested party (company or person) who has expressed an interest in our company in some way. This interest can be very varied and should therefore be categorised (for example, someone who calls the company and someone who has already requested a quote from the company for virtual reality technology are both considered to be interested). Lead generation is the process by which a business tries to generate as many usable leads as possible in order to increase the number of customers. In the absence of these systematic processes, there will still be interested leads. Some people will find virtual reality products on their own, but it may also be that existing customers recommend the product, etc.

a given technology (in this case, the immersive technology). In terms of economic fields, these are the two areas where virtual reality and related technologies are significant:

- sales sector
- marketing sector

Immersive technologies are clearly useful and profitable in these two sectors because of the worldwide demand. From an economic perspective, it is of course important to think not only in terms of virtual reality, but also in terms of augmented reality, mixed reality and augmented reality capabilities (with an understanding of their specific advantages and disadvantages). As will be shown in the diagrams below, technology will generate significant economic growth in the coming years, with e-commerce accounting for a significant part of this growth. Products that create a virtual environment play a prominent role in the sales sector, as it is a highly innovative and versatile technology. In the marketing sector, it can be argued that it is attention-grabbing and staying power that technology can be particularly useful for.

It is well known that the experiential experience is a key factor in people's decisions about products and services. With this in mind, the immersive technological developments in question give businesses a sense of anticipatory confidence. Augmented reality is particularly effective from a marketing perspective, as advertising surfaces such as bus stops, buildings or dedicated billboards can all be used to deliver digitally transformed experiential content. The associated experiences are obviously only accessible to those interested in using virtual technology products. For the global economy, it is important to note that with the advent of technology, society is facing the rise of a new type of industry in virtual space, which also offers the prospect of new types of jobs. As working from home has become more widespread and accepted, the so-called online teleworking has boomed. Virtual reality, augmented reality, mixed reality and augmented reality offer revolutionary opportunities for workers and employers alike. New products are aimed initially at video game enthusiasts. In the short term, this area offers the fastest sales potential, thanks to the huge interest in the virtual space experience of games.

It is no coincidence that it has burst onto the scene as a popular and innovative area of entertainment. It is important to note that the development of enhanced technology is taking place in parallel with the new 5G technology for mobile networks.

Thinking in terms of these two technologies at the same time makes the business opportunity and potential even more apparent. From an economic point of view, enhanced technology is a clear business case in the following five main areas:

- training
- health care
- education
- marketing and e-Commerce
- entertainment[30]

As Bernard Marr, a world-renowned futurist in business, says: "Thanks to all of this, it's likely that increasingly large amounts of our business lives will be conducted in virtual reality as time goes on."[31] Most investors think of the technology as a goldmine, but of course the sceptics are paying close attention to the risks. A certain high level of knowledge is required for a business to make a decision on the use of technology. As shown in Figure 21, the Compound Annual Growth Rate (CAGR) confirms that the place of virtual reality and augmented reality in the economy is growing at an extraordinary rate.

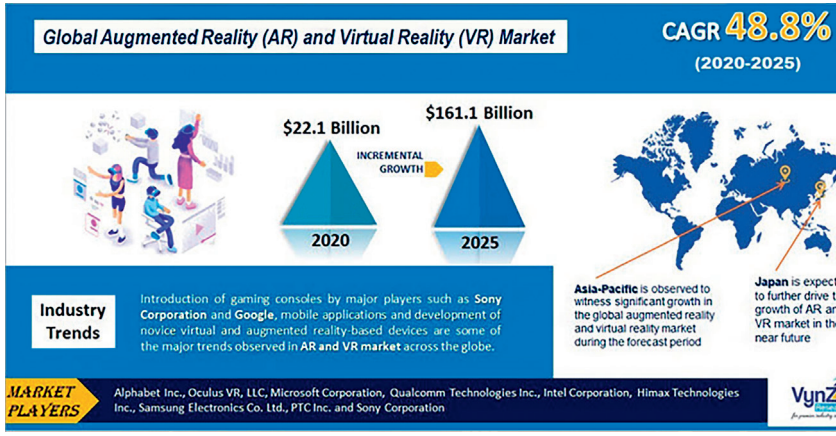

Figure 21: Global growth of Augmented Reality and Virtual Reality market
Source: Software Testing Help (2022): op. cit.

[30] Holopundits: 5 Real-World Applications of Extended Reality Technology. *Holopundits,* 18 October 2021.
[31] Bernard Marr: *The Amazing Ways Companies Use Virtual Reality for Business Success.* 2021.

The understanding of virtual reality, augmented reality, mixed reality and extended reality in the context of economic indicators often blur together. It is usually observed that virtual reality and augmented reality are analysed comparatively or that augmented reality is analysed separately. In general, all the statistics show that the use of these virtual, immersive technologies is growing in economic terms.

Additional applications and uses of virtual reality and related technologies can develop as long as the popularity and market for games remains high. In the midst of this heightened atmosphere, manufacturers are trying to stay competitive by not revealing too many details about their products and services. Due to the innovative economic emergence of immersive technologies, there are currently no worldwide (only some countries) survey data available, and no official statistics for many countries. Figure 22 shows an analysis of the number of users in the United States of America (USA).

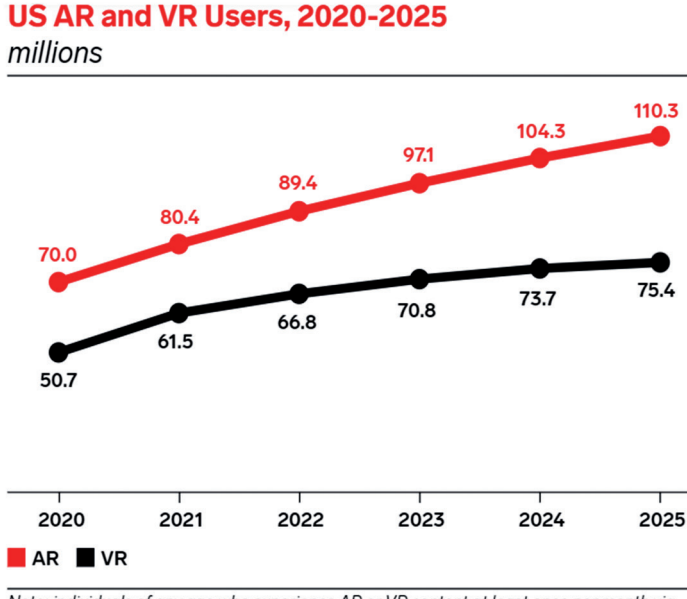

Figure 22: AR and VR product users in the USA (2020–2025)

Source: eMarketer (2022): op. cit.

The forecast in 2022 shows that the number of American users has been growing steadily in recent years and is expected to continue to do so in the coming years. It also shows that there is more interest in innovative capabilities related to augmented reality than virtual reality. In this respect, taking into account both individual and business perspectives, augmented reality is likely to provide the virtual service capability (experience) for which there is greater demand overall.

Based on the statistics above, if this many people in the USA are employed by technology in a few years, one can imagine the impact on our entire economic world. Countless businesses and users will become economic agents of technology.

Developer perspective

Navigating the maze of technological developments is no easy task. This is clearly the case in the world of continuous improvement. By exploiting the personal perception of the user, a number of development directions can be targeted in the creation of a virtual world. It is important to note that a precise and accurate set of requirements is essential for development. The requirements also fundamentally determine the development direction for immersive technologies. Generally speaking, all of the immersive technologies, virtual reality, augmented reality, mixed reality and extended reality developments are very popular. The following principles should be considered before embarking on any development:

- defining the target audience (for example selecting age range and area of interest, assessing information needs, etc.)
- acquisition of knowledge for development (courses, available media, expert contributions, etc.)
- availability of the necessary background infrastructure for development (platform, tools, human resources, contacts, etc.)

Nowadays, development is typically done using agile methodologies. Figure 23 shows a development methodology published by a company called VR Vision.

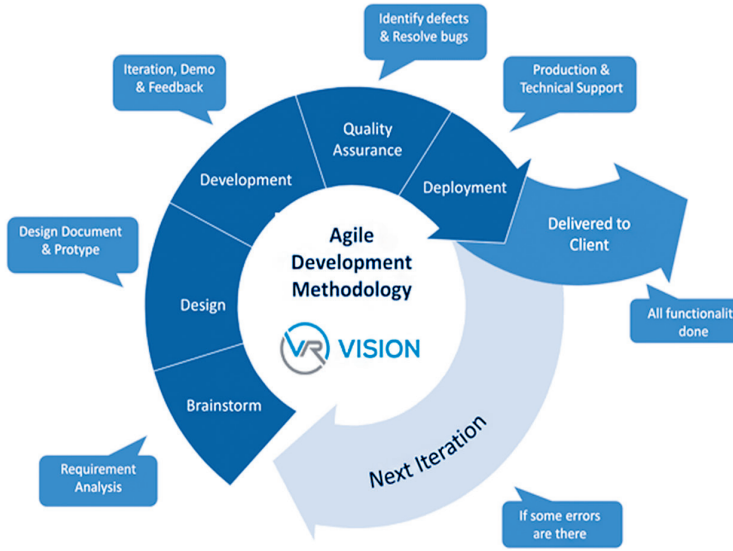

Figure 23: Agile methodology by VR Vision
Source: Fade (2019): op. cit.

In the context of developing immersive technologies, it is therefore necessary to build a logic, a framework that creates the right starting point. In the different iterations of agile development, the definition and analysis of requirements, the design and programming processes, the detection and fixing of bugs, and technical collaboration are all key aspects. In order to take an explicitly developmental approach, design, development and testing processes, as well as applicable areas will be explored, extending the ideas of immersive technology.

About planning

As with any development, it is important to take into account the technological changes involved when designing immersive technologies. This is particularly true in the case of virtual reality, which requires thinking in four dimensions. In today's rapidly evolving world, three- and four-dimensional solutions are becoming increasingly popular after two-dimensional options. The intensity of development is significant and this has led to an increasing demand for

development in four dimensions. The experience provided by four-dimensional virtual reality has depth, touch and new types of sensations, which is why two-dimensional visualisation can seem boring.

So when designing virtual reality, it is important to break out of the traditional two-dimensional, square world. As in the real world, we need to get (not just as observers, but rather as participants) the experience and the product being developed. Only with four-dimensional design is it possible for the artificial space being designed to fit into the real space, which is also four-dimensional. It is advisable to try out virtual reality (or other immersive technology) with a tool before developing your own. Once you have gained experience, it is much easier to think about what functionality is worth designing.

From a design perspective, it is important to emphasise and understand that the main strength of virtual reality lies in the user experience, as can be seen in computer games (for example, where three- and four-dimensional visualisations are being developed that already provide a spatial sense). Naturally, the outcome of the impact of the user experience is made up of several components, not to mention that every person is different (different needs and different opinions with different priorities). So as a developer, you may want to consider the statistics and key aspects of user experience. For example, a key aspect might be to look at the needs of people of different ages in relation to experiences, or to explore the positive or negative opinions associated with different types of experiences. The user experience, the influence on emotions, lies in the presentation, the visual quality of the virtual space in which masses of interactions take place. It is important to note that the experience of the myriad of user-generated (interactions) in a four-dimensional virtual space plays a role in its evolution, which will also improve planning methods and processes.

The design should think about and focus on how people will be able to use the product, in other words, how difficult or easy it will be for them to control it, among other things. The user needs a high level of concentration when using the virtual space, coupled with appropriate ease of use. Under no circumstances should the user be overloaded, which is clearly a matter of planning. Virtual Reality is a new and unconstrained technology that requires careful planning to avoid overly negative reviews. The design of visual cues and guidance is an important foundation for achieving the intended experience. During the planning phase, once the basic and specific user needs have been realised, it is important to establish a fairly precise set of requirements and to select and

implement a development methodology. The requirements framework should be interpreted by all those involved in the development.

Overall, planning requires knowledge that takes into account the needs and goals of both users and developers. In the following, two general methodologies will be discussed that can provide a theoretical basis for the development of most technologies, including virtual reality, augmented reality, mixed reality and extended reality.

DevOps methodology

DevOps is generally understood to be a methodology that automates processes between developers and other IT professionals in order to develop, test and release software and systems faster and more reliably. There is no single agreed standard to define the term, but the methodology clearly brings together separate functional areas. In effect, the methodology links development and operations. The representation of DevOps is shown in Figure 24, where continuous communication, integration and feedback are clearly in the foreground.

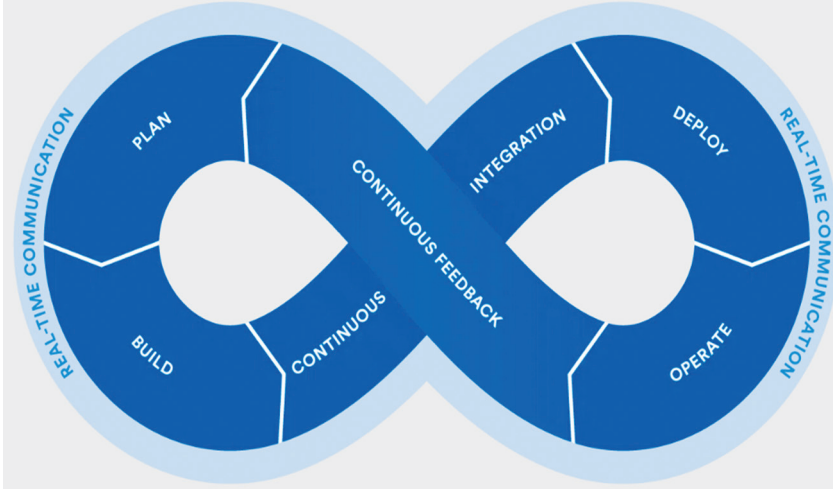

Figure 24: DevOps methodology
Source: Ismail (2019): op. cit.

The concept of DevOps is based on building a culture of collaboration between development groups. The benefits include increased trust, more efficient development of software and systems, the ability to quickly resolve critical issues, and more flexibility to manage unplanned workflows. The building blocks of the DevOps methodology began to come together sometime in 2007, when the IT operations and developer communities emphasised a shared vision that challenged the traditional software development model (which functionally separated developers from other groups). The groups were judged by separate goals, leadership, performance indicators and in most cases worked in separate buildings.

Since its introduction, DevOps has become more widely recognised across all areas of software development and with it IT. It covers so many areas that the methodology can be used for the specific requirements of, for example, civilian and military organisations. The methodology can be used mainly for research-based development, but it can also provide practices for the development and operation of existing systems (for example addressing integration issues). The DevOps approach includes high levels of trust, exemplary leadership and organisational management. The result is high levels of reliability, stability and security at ever lower costs and effort. A deeper understanding of systems thinking and improvement processes will help to implement the methodology.

DevOps uses agile methods for planning and development, one possible interpretation of which is: "The Agile methodology is a way to manage a project by breaking it up into several phases. It involves constant collaboration with stakeholders and continuous improvement at every stage. Once the work begins, teams cycle through a process of planning, executing, and evaluating. Continuous collaboration is vital, both with team members and project stakeholders."[32]

The application of the methodology cannot happen from one day to the next, but is rather the result of a longer process that can later become part of the daily routine of the organisation. By understanding DevOps and making small, incremental changes, development and other operations groups can work together on a whole new vision. To start the methodology, it is necessary to lay down common goals and guidelines, working as a team, taking into account the development potential of individuals and creating an environment for dedicated work. DevOps includes technical, business and social benefits, which include:

[32] Wrike: *What Is Agile Methodology in Project Management?* s. a.

- continuous availability of up-to-date software
- less sophisticated development management
- faster problem resolution
- a stable operating environment
- improved communication and collaboration
- openness to introducing new solutions
- more effective, creative teamwork
- higher professional commitment

Using DevOps methodology can therefore lead to more efficient work in an organisation. Groups of employees working as a team, working closely together on day-to-day tasks, can achieve superior development and operational timelines, reliability, functionality and innovation.

SecOps methodology

DevOps processes and cultural concepts improve the ability of developers and other IT professionals to do reliable work quickly and efficiently, but security is not at the centre of the methodology. As a solution to this, SecOps is an enhanced methodology that provides security throughout the lifecycle of a software or system. Security is not just a task for the security team, but more of an organisational responsibility. For example, taking into account the attack potential of the supply chain, it is necessary to ensure that security is applied from the initial stages of development through the entire lifecycle. In many cases, organisations rely on cloud solutions to manage operations and resources, making it increasingly difficult to respond and detect security risks posed by applications, endpoints, infrastructure and users. One of the most common problems organisations face is the establishment of effective communication and collaboration.

For example, using this methodology, wireless network applications can have a development group to fix any bugs that arise, an operational group to manage and test the effectiveness of the application, and a security group to maintain the security posture of the application and respond to potential threats. An integrated security methodology is needed to operate complex support systems and the practical application of SecOps, as shown in Figure 25, can provide a solution.

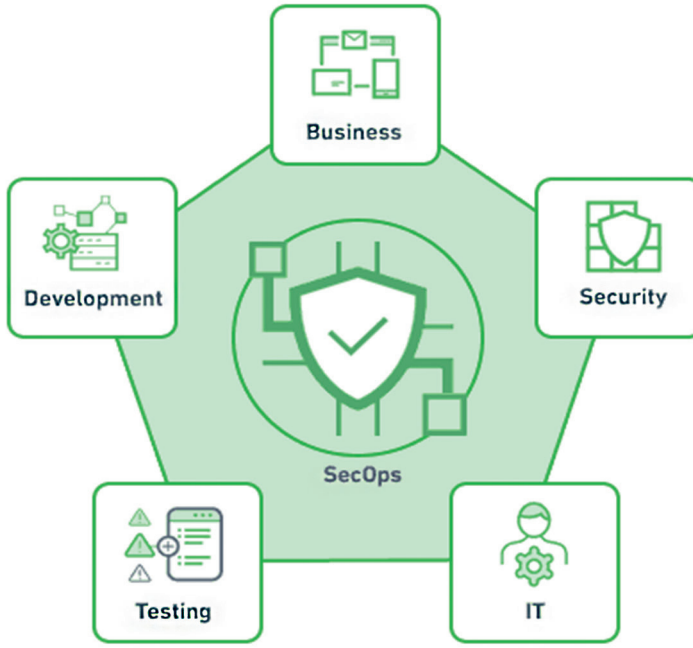

Figure 25: SecOps methodology
Source: Exabeam (s. a.): op. cit.

The SecOps methodology is based on a collaboration between the security team and the employee groups, whereby tools, processes and technologies are integrated to achieve the security objectives of the organisation. In the process, risks are reduced and business resilience and reliability are improved. The application of this methodology can greatly facilitate the security setup of applications. SecOps aims to achieve agile, collaborative development by recommending the use of the most effective security practices possible. It is a commitment that includes the continuous presence and improvement of security. The application of this methodology to the development and operational processes of systems results in a high level of transparency and state-of-the-art security. As with the DevOps methodology, SecOps can be used for both civil and military research-based

developments, as well as for existing operational systems and software. The main benefit of SecOps is the increased collaboration between the IT security group and the other groups. The creation of a SecOps security group with an operations centre results in the following three general benefits:

- fewer security gaps
- fewer security vulnerabilities
- higher, even multi-level security status

By automating defence procedures, the ability to detect, alert and respond to threats can be improved and upgraded. The products and services developed have lower vulnerabilities as soon as a security-aware methodology is implemented. Collaborative network monitoring makes it more effective:

- early detection and response to attacks on systems
- reduce the number of breaches and vulnerabilities
- protect data and maintain confidentiality and security requirements

About development

Developer interpretation of virtual reality and augmented reality

First of all, as a developer it is most important to have a deeper, more detailed understanding of virtual reality and augmented reality (which represent the foundations of immersive technologies). In the following, these two main development directions will be described in more detail, which will also provide a basic understanding of the development of the other two technologies, mixed reality and augmented reality. It is necessary for developers to be informed within the field of virtual reality and augmented reality. This will help to identify the development plan and to effectively find the source of further knowledge needed.

The development of virtual reality can be divided into three types:

- Fully immersive VR is the type that provides the most realistic virtual experience. It involves head-mounted displays (HMDs), headphones and other equipment to simulate as many senses as possible and to establish a realistic experience. In fully immersive VR, users are completely isolated from their physical surroundings.

- Semi-immersive VR allows users to experience virtual environments while remaining connected to their physical surroundings. In this sense, semi-immersive VR provides a partial virtual experience. The video below demonstrates an example of semi-immersive VR in pilot training where the control panel is real while windows displaying virtual content.
- Non-immersive VR refers to the type of VR that provides computer-generated environments without the feel of immersion. Video games are common examples of non-immersive virtual reality.[33]

The development of augmented reality can be divided into two types:

- Marker-based AR applications are triggered by specific physical images (markers) captured by the camera to position the digital content on top of it. A marker can be an object or a visual such as logos, posters, or QR codes. The business card acts as a marker for the AR application which displays additional digital information after it encounters the card.
- Markerless AR does not depend on markers and lets users decide where to display the digital content. Markerless AR applications rely on the camera, GPS, compass and accelerometer of the device to gather information about the environment. Concerning markerless AR technology, there are three different types:
  - Superimposition-based AR detects the objects in the real world and partially or fully replaces their original view.
  - Projection-based AR does not need a display device as it projects light onto a surface to display digital objects.
  - Location-based AR provides augmentation in specific places. It uses the device's GPS and compass to position the virtual object at a point of interest. Pokemon GO mobile game is a popular example that uses location-based AR.[34]
  - For developers, it is therefore important to be able to define the virtual space, which requires knowledge of the types listed. Taking this idea further, the following section will discuss the necessary knowledge components for developers.

[33] Cem Dilmegani: *Ultimate Guide to Virtual Reality (VR): What It Is, Types and Uses.* 2022.
[34] Cem Dilmegani: *Ultimate Guide to Augmented Reality (AR): What It Is, Types and Uses.* 2022.

Developer skills needed

In order for developers to start 4D development, it is important to both choose the right development tools and understand how to use them. Pervasive technologies require quite strong 4D design and graphics programming, so it is in this area that skilled developers can create. There are now a variety of environments and tools available for development in 4D, which are evolving in parallel with the advent of innovative technology. As visual studio used for desktop 2D programming, there are frameworks available and evolving for 4D development. It is important to note that there are a number of considerations that go into the choice of framework (by lead developers), a general example of which is:

- the technological purpose for which it can be developed (VR, AR, MR, or XR)
- what kind of developer background it has (is it continuously developed, is there customer support available)
- what programming languages can be used (C#, C/C++, Java, JavaScript, Python)[35]
- what are the financial costs (free, free for a certain period, paid or variants thereof)
- which development platform it can be installed on (Windows, Linux, etc.)

It is essential that the developer is aware of the previously selected development methodology (see DevOps, SecOps) and understand the framework chosen for development. Specifically, from a programming perspective, the developer should preferably understand containers (for example Docker, Kubernetes), cloud services (for example Azure), different data structures (for example array, map), version handling (for example Git), integrated development environments (for example Eclipse), databases (for example MySQL, PostgreSQL) and the programming languages already mentioned for development.[36]

Coming back to frameworks, perhaps the three most popular are Unreal Engine, Vuforia and Unity. It is worth looking at analysis sites that rank development environments according to certain criteria. According to one such analysis,[37] Vuforia is the best design program for advanced developers, while

[35] OpenWorldLearning: *What Programming Language to Use with Augmented Reality?* 2022.
[36] Javinpaul: *11 Essential Skills Software Developers Should Learn in 2022.* 2020.
[37] Jacob Cass: *10+ Best Software for AR and VR Design in 2022.* 2022.

Unity is the best option for a free trial of such a development environment. There are many opportunities to learn how to use these programs, including web interfaces, which is the primary way to do so nowadays, in both Vuforia and Unity. It is worth mentioning for example the Pluralsight website for popular developer training.

Finally, it is also necessary to talk about the personal skills of developers. As with most, virtual reality and augmented reality development should be done in teams. In addition, the developer needs to have a high level of mathematical aptitude, problem-solving skills, organisation and time management skills, accuracy (attention to detail) and a willingness to self-develop in relation to the technology. The development environment should be designed to help the developer to learn about the immersive technology as efficiently as possible. Developers are also testing from which they gain a wealth of experience.

A key interest of developers is to understand the tasks required for their own work and to master the technical material and the associated development and testing environment. It is quite easy to acquire professional knowledge in a pleasant and harmless environment from a developer's point of view.

About testing

The rules and guidelines for testing immersive technologies follow the general rules and guidelines for IT development. The difference of course lies in the complexity of the technology. Developing in four dimensions generates a much larger number of test cases than for example in a two-dimensional program. Virtual Reality, augmented reality, mixed reality and extended reality technologies can be defined with specific testing techniques based on general principles. Where possible (even in partnership with development, see DevOps and SecOps), it is recommended that testing should be planned and executed according to some methodology. Testing can be clearly divided into two broad groups:

- functional testing processes
- non-functional testing processes

Functional testing ensures that the software product is working properly, while non-functional testing aims to check so-called non-functional aspects, such as

software performance, usability, reliability, etc.[38] The tasks of testing include, among others, appointing the testing team, setting up the testing room, organising the tasks, designing the processes and tests, generating the test data, running the tests and evaluating them. The number of tests produced and the size of the test sets are increasing rapidly. Continuously expanding and keeping a complex, multi-element test suite up to date and running requires effective support.

Non-functional testing

The purpose of non-functional testing is to determine whether the software response time is fast enough to meet business requirements. There is overlap in the literature between certain types of tests because of similarities in their operation and application. Although these test types differ in only a few aspects of their objectives, they provide different values in relation to the software.

Non-functional testing options include:

- accessibility testing
- compliance testing
- compatibility testing
- efficiency testing
- install/uninstall testing
- load testing
- operational testing
- performance testing
- portability testing
- recovery testing
- reliability testing
- scalability testing
- security testing
- stress testing
- usability testing
- volume testing
- white-box testing

[38] Stephonsays: *What Is the Difference between Functional and Non-Functional Tests?* 2021.

The accessibility test determines whether the software can be used or is accessible to people with disabilities (for example visually impaired, hearing impaired, learning disabled or elderly). This is particularly important when designing products with immersive technology.

Compliance testing is designed to validate that a product meets the principles and standards that apply to it. It is also necessary to involve requirements. The compatibility test checks the behaviour and operation of the software (including web servers, networks). An efficiency testing is a test of the amount of resources needed to perform a given function.

An installation or uninstallation test can be performed to verify that the software that creates the virtual space is installed with all the necessary components. This testing is important because installation is the first interaction with end users. Load testing is used to determine how much load or maximum traffic it can handle without degradation in performance, helping to find its maximum capacity and detect any problems that may arise. Operational testing is performed while the application is running, prior to the production phase (a form of evaluation), to ensure that the complex virtual system and its components are fit for purpose.

A performance test is used to determine how the virtual system performs in terms of responsiveness and stability under a given workload. To perform a performance test, the system is usually overloaded. Portability testing can determine how easy or difficult it is to move the ubiquitous product or its software-only component from one environment to another. A recovery testing is a test of the virtual software or its complex system to see how well it can recover from crashes, hardware failures and other such problems. Reliability testing is a test that checks whether the software is able to perform an error-free operation over a certain period of time, correctly and as its name implies, reliably. Scalability testing is a little different (it can be interpreted as a testing method) than the previous ones. Testing measures the performance of an application based on user requests or on increasing or decreasing the number of other attributes (hardware and software components) that affect performance.

Security tests are designed to check the security of virtual software against internal and external threats. For example, a security test examines the extent to which the virtual environment, the system itself, can be penetrated specifically to obtain information. In security testing, two groups are present in the virtual environment, one group tries to compromise the system and the other tries to protect it. For immersive technologies, this can be particularly relevant for networked, Internet-based operations. The stress test checks the complex system

of the virtual product or service, i.e. how and under what event it can fail. In a stress test, the system is subjected to an explicitly high load (for example, complex and continuous database queries are popular). This test will certainly show the sensitive, overloaded points of the virtual system.

Usability testing involves users testing the immersive technology application or system, during which the testers observe the users and check the functioning of the applications. Documentation of any problems encountered is ongoing throughout the test. Volume testing is performed by putting the software or application under load to check the behaviour and response time of the system. White-box testing can test the internal structure or functionality of the virtual product application. For testing, the internal perspective of the system is used to design the test cases. To perform white-box testing, it is necessary to know the internal software and code functionality (developers can be of great help here).[39]

Non-functional tests are therefore quite cumbersome in the testing processes. However, functional tests are equally essential for comprehensive testing in order to detect and correct bugs during the development of immersive technologies.

Functional testing

There are a number of options available for functional testing that can be considered for immersive technologies. The following types of tests are described:

- alpha testing
- beta testing
- black-box testing
- exception handling testing
- exploratory testing
- gray-box testing
- GUI (graphical user interface) testing
- mocking testing
- sanity testing
- smoke testing
- stubbing testing
- user acceptance testing
- test-driven development

[39] ProofIT: *Types of Non-Functional Software Testing.* 2021b.

Alpha testing tries to identify all possible bugs in the software before it is released to users. Alpha testing attempts to simulate real users and therefore tests the execution of tasks that a typical user might perform. These tests are carried out before the application is made available to external users, i.e. before it is released for beta testing. Alpha testing is usually done in-house at the system test level. This type of testing is most common for out-of-the-box applications, but can also be used for custom-built applications on demand.

Beta testing is usually done by the client/end user. This is the final stage of testing before an application or software is released. The beta version of the software is marked as unstable by the vendor and the stable version is always made available. The purpose of beta versions is to allow users who want to learn new features to gain insight into the changes before they are made available to all users in a company or organisation. Beta testing is conducted to ensure that there are no major bugs in the software and that it meets business requirements from an end-user perspective. Beta testing can be categorised into the acceptance test level. Black-box testing is a software testing method that only tests the requirements and functionality of a single application. It tests only the "outputs", the internal system design is not considered. This testing method can be applied at all levels of software testing. For this type of testing, exceptions are handled. That is, by handling run-time errors, we ensure that the test execution flow is not interrupted. Thus, when testing the software, we skip the faulty statements and continue with the rest of the test execution.

Exploratory tests are ad hoc, i.e. test cases are created on the run, during test design and implementation. Exploratory tests are usually informal, with debugging done by the testing team. Gray-box testing is a combination of white-box and black-box testing. The name of the testing represents that the software is like a semi-transparent or grey box into which the tester has limited visibility, the internal structure of the software is only partially known. This type of testing usually focuses on context-specific bugs in web systems. The purpose of graphical user interface testing is to validate this interface against the business requirements. This testing is usually done through various test cases. This testing involves the verification and alignment of screens with controls, input fields, menus, buttons, icons and all the bars (toolbar, menu bar, dialog boxes, windows, etc.) together with the requirement sponsor. For mocking testing, a mock version of a real software is created that simulates the behaviour of the real software. This type of test is used to make test runs faster and more reliable. For

unit testing, mocking is used. Sanitary testing determines whether the architecture of a new application or software is stable enough to be subjected to serious testing. If the software crashes during sanitary testing, an application is built to fix it. Smoke testing provides information about the stability of the system/application architecture. Smoke testing checks if there are any serious bugs in the software that could prevent the testing team from testing the application in more detail. Stubbing, or spot-check testing is used when the implementation interacts only with certain behaviour of the object. Test-driven development is a style of programming in which coding, testing and design are intertwined. Unit tests are run by developers and where they fail, a new code is written to ensure the test succeeds.[40]

When creating a test plan for the development of an immersive technology, it is therefore necessary to take into account all possible factors that may have a multiple impact on the number of test cases required. Separate tests can be defined and performed for hardware and software. Thorough testing of different components and different expected capabilities will all affect the quality of the product or service. Main types of tests, judged in general terms are:

- units
- integration
- regression
- system-wide

Testing should be done with minimal risk (preferably on a separate network), be targeted and very thorough. It is important to document the test results, as they will be used for further analysis. Figure 26 illustrates a comprehensive three-step testing process that can be integrated into the Agile methodology.

The purpose of the tests is to detect faults and demonstrate the expected four-dimensional capabilities of all hardware and software components of the system. With the right methodology in place, the continuous testing of devices and the corresponding development can be carried out in a flexible manner.

[40] ProofIT: *Types of Functional Software Testing.* 2021a.

Figure 26: Agile three-step testing
Source: EPS Software Engineering AG (s. a.): op. cit.

Main areas of the development

The last decade has seen the emergence of a number of promising immersive technologies that have become quite popular today. But technology has not yet permeated our everyday lives, with trust issues presumably lurking in the background. In case of games, there is perhaps no greater risk or responsibility in using technology than organising a six-month virtual course. This is a growing tendency, more and more people are now trying out different immersive, virtual solutions.

One thing is sure, the pandemic has brought about a major change in this area, as we have been confined to our four walls and more than ever we have longed to experience community programmes that mimic reality. The pandemic has triggered a kind of openness in people, which has been accompanied by a parallel explosion of demands and ideas for some kind of virtual opportunity to avoid feeling cut off from the outside world. The coronavirus has forced hundreds of millions, even billions, of people around the world to make austerity cuts

that have significantly shaped, among other things, how we plan our shopping, when and where we travel, or how we attend our next work conference. Meanwhile, many of us are escaping from reality into the online space in our homes, taking advantage of games and other programmes. The situation has driven forward-thinking industry players to develop and deploy immersive technology.

Virtual Reality, augmented reality, mixed reality and augmented reality are among the most important trends for the coming years, which have seen a rather dynamic development and could share a market worth thousands of billions of dollars with the pioneers of immersive technology developments. Many people are drawing parallels between the development of immersive technologies and artificial intelligence, robotics and even IoT. This is no coincidence, as virtual reality developments are an emerging interdisciplinary field with both civilian and military applications.

The next few years could see the application of technology really kick into high gear as it becomes more and more a part of our everyday lives. Developers and users are increasingly aware of the importance of immersive technologies and with them the potential area of virtual products development. The most popular areas include the games industry, education and even healthcare. As most people can sense, the development potential in this field is virtually inexhaustible, as it can be applied in so many areas (and even within a given area). It is important to note that all of the immersive technologies can be considered in the context of development areas, and therefore all of these can provide multiple innovative solutions. For the sake of illustration, five selected areas are examined in more detail below:

- education
- tourism
- healthcare
- finance
- entertainment

The chosen areas are certainly great examples of the application of immersive technologies. Virtual Reality, augmented reality, mixed reality and extended reality are all great opportunities for development in a wide range of areas. Through the examples of the following areas, the support of various professional processes and activities with these innovative technologies is particularly effective in the different information environments surrounding people.

Education

Education is one of the most successful sectors in terms of the applicability of immersive technologies. Education, as it is well-known can be delivered face-to-face or via a virtual network (online). In both cases, care must be taken to ensure that the training process is as designed and that the curriculum and knowledge is embedded in the minds of the students in the way they want. In addition to traditional face-to-face training, online training has an increasingly successful track record. In the world of working people, online learning opportunities are particularly effective. Most people train for many years, even after their first university education. It is therefore important to take into account the specific needs and time schedules of different age groups (children and adults) in order to make use of today's modern and innovative technologies in this sector.

Figure 27: Immersive technology in education
Source: Zimmerman (2019): op. cit.

The role of online meetings is precisely to overcome distances and bring together people with similar needs. This is also true for educational purposes, where virtual facilities provide a new kind of backdrop, raising the quality of education and the learning experience to a higher level. Taking into account the different sectors, education at the societal level is highly diversified. As illustrated in Figure 27, virtual reality technology can be effective in a wide range of learning

contexts and can be used for virtually any kind of vocational training. It can also be used to stimulate interest in subjects that are less receptive to the current younger generation.

The well-designed, experiential, theoretical virtual training courses contribute to the acquisition of practical experience and with it the knowledge of the taught subject matter (for example driving skills or industrial activities, etc.). Technology also makes it easy to motivate students to learn outside the classroom. Looking to the future, it is expected that within a few years a significant proportion of learners will have a device capable of installing and running virtual space applications. A new type of phone, a new capability is likely to be envisaged for this purpose, as smartphones are the devices that students always carry with them (the phone is thus the artificial, yet immediate, information environment for students). It will therefore not be necessary to purchase any specific hardware, but rather to develop applications for the hardware of the phones.

In addition to the innovative features and versatile educational applications of immersive technology, it has the added advantage of not requiring additional human resources. There is no need for a dedicated IT expert to develop and maintain the curriculum, teachers will be able to manage the virtual space themselves without programming and with general IT skills. One thing is for sure, then, the benefits and effectiveness of immersive technologies for education are many. Engineering thinking to support education through virtual space is taking place worldwide, which will significantly boost the quality indicators and potential of the sector. In particular, it is worth highlighting the potential of immersive technology to boost anyone's creativity and motivation to learn, regardless of age. "No matter the age, creativity is an important part of learning. AR/VR offers various ways to boost creativity. When it comes to engineering students, creativity is basically the essence of the industry. Students are training for a career in an industry that is always on the cusp of new technologies."[41] The use of immersive technology makes teaching more effective and at the same time allows for active involvement of students in the learning process. Immersive technologies make lessons more engaging and more experiential than ever before.

[41] Jeffrey Heimgartner: *Using AR/VR for Innovative Engineering Education.* 2021.

Tourism

In our fast-moving world, leisure activities have a very important role to play. People are curious and most of them are open to exploration, planned or spontaneous leisure activities. Individual and collective experiences are a systematic part of everyday life. Like other sectors, tourism is undergoing significant developments thanks to technological changes. It is also important to note that virtual reality allows us to talk about experiences that we cannot easily have in reality. A great example of this is the virtual experience of a place that can be important for a later decision (to get to know a place that we will actually go to later). To be complete, it can be said that virtual reality and with it the use of innovative and immersive technologies for tourism purposes provide significant development directions for:

- new types of tourism experiences (including those that are physically impossible or difficult to access, such as places that are difficult to reach)
- technological support for real travel stages (before the trip, during the trip, at the destination)
- the development of cities (with the popularity of four-dimensional modelling of cities, the demand for smart cities is growing)
- realistic four-dimensional modelling of tourist attractions around the world and their sharing on the Internet (accessible to everyone)
- exploring the potential of new virtual workplaces (organising virtual tours)

The direction of development of cities using smart management models can be linked to immersive technology. The aim is to boost the attractiveness of a city for tourists, for which the immersive technologies that offer experiences can be used. A great example, shown in Figure 28 is the Virtual Helsinki team who modelled and created the virtual capital Helsinki. Through them, anyone can see the capital in an immersive experience and, as the website wittily puts it (without snow boots). The tourist services offered by smart cities are quite beneficial for the image of the city. They can, for example, help to effectively manage larger crowds (informative projections) and provide them with high quality, instant knowledge (translation tools).

Figure 28: The virtual Helsinki
Source: Semlani (2018): op. cit.

Virtual tourism also offers opportunities for new types of jobs in tour organisation and guiding. Virtual guided tours also allow a guide to lead a much larger group of people than usual, up to hundreds of thousands of people through a city. The development and use of virtual tour guiding is now practically worldwide, whether in Asia, Europe or America. In New York, for example, you can take a guided virtual tour of Central Park.[42] In Berlin, a tour guide Jeremy Minsburg, offers several virtual sightseeing tours.[43] In addition to supporting real travel, immersive technology can help in many ways. At the planning stage, travellers gather information to avoid disappointment and find the best deals for them (as many use Google Street View to do).

Virtual reality allows them to experience the experience in advance. Travellers can use the technology to draw inspiration from possible destinations, reducing the chance of disappointment. The outward and return journeys are usually the least favourite part of the journey, often inconvenient, stressful and boring. Travel service providers can improve all this with virtual reality technology. With virtual reality products and related software, travellers can better unwind

[42] Central Park: *SummerStage 360° VR Tour.* s. a.
[43] Jeremy Minsberg: *The Berlin Expert.* s. a.

while travelling, and time passes faster when having fun. Technology can also help you get to your destination. Guests can experience more virtual experiences through hotels. Hotels can use virtual reality to showcase their services or the attractions of the area (historical sites, tourist destinations, etc.).

The use of virtual space in this sector is one of the most popular today. It can also be a way to brighten up the grey weekdays of those who cannot afford to travel extensively but would like to spend a small amount of money to visit a remote country. Virtual reality technology can therefore be used by tourism to explore both the real travel experience and the new experiences offered by entirely new 4D virtual tourist attractions. Travel experiences can therefore be made more complete thanks to the addition of entertainment and information content.

Healthcare

There is a growing awareness among all people that a healthy lifestyle is important in life. This awareness is reinforced by, among other things, experiencing stress at work, feeling a sense of relaxation in leisure time, or building harmony within the family. Health will always be a topical and multifaceted sector whose services people naturally need and will continue to need in the future. The technological development of the sector is being observed worldwide, thanks to the rapid development of infocommunication technologies (data transmission, hardware and software). The effective development of administrative facilities for the benefit of people's own health is a major task for public authorities, since the needs and circumstances of different age groups must be taken into account. By creating our online health profile, it is nowadays becoming easier and easier to manage our affairs. Supporting healthcare through virtual spaces has both functional and security benefits. One of the benefits is that by storing data in online spaces, people's specific health issues can be much better tracked. The potential application of immersive technologies in healthcare is significant, and indeed there has been a tremendous interest in this sector. Medicine is highly diversified (jobs with different needs), and virtual support for these needs has become topical in the current developments. As a first step in development, the focus should be on identifying the main areas. In a general approach, two main application areas in the healthcare sector are considered:

- training, practice (cognitive and physical skills in virtual space
- patient care (cognitive skills and with them mental health care)

As shown in Figure 29, the training allows staff (especially doctors) to practise safely and freely, so they can gain experience in virtual space. Virtual or augmented reality can be used to warn healthcare workers (doctors, nurses, other workers) of a myriad of risks or hazards at work. Doctors, nurses, paramedics and other staff can benefit from this:

- practise their professional skills in a virtual reality
- with an augmented reality, a wealth of virtual information is presented to assist them as they move between different locations or work in the same place in the hospital

Figure 29: Immersive technology supports doctors
Source: Dybsky (2021): op. cit.

Doctors can gain a lot of experience by performing surgery on a virtual patient (the surgery itself, but also the teamwork and information needs involved). Doctors are notoriously short of time and have a busy day, which an augmented reality can make extremely effective by displaying information on the move (for example about their own patients or their colleagues). Nurses can also train themselves in virtual reality, even practising team collaboration. And by using augmented reality, routine daily tasks can be carried out more efficiently. For example, one software can help find patients' veins before needle pricks, but

another can display an updated spreadsheet of daily tasks. In case of paramedics, training can also be highlighted, in this case to practise time management or situational awareness in a safe environment. As a result, the decision-making skills of paramedics can be improved enormously. In the context of an augmented reality, a myriad of information can be presented to the paramedic, such as information specific to the paramedic and his vehicle.

In addition to this, as shown in Figure 30, immersive technologies can be used to improve and maintain the mental health of patients. Virtual reality has already been adopted in therapy applications where it is used to treat patients suffering from phobias and anxiety disorders. Combined with biosensors that monitor physiological responses such as heart rate and sweating, therapists can better understand how patients respond to stressful situations in a safe, virtual environment. In obstetrics, for example the technology is being used to reduce pain during labour. Interestingly, virtual reality is now also being used to help people with autism develop social and communication skills. Immersive technology is therefore useful both in diagnosing and treating patients with cognitive impairment.

Figure 30: Nurse uses virtual reality as a mental help
Source: Akash (2020): op. cit.

In summary, immersive technology is being used in an increasing number of medical fields. The technologies can help healthcare professionals in countless everyday tasks. These innovations are leading to improved patient outcomes and reduced costs of treatment, creating a highly advanced health information system supported by virtual spaces. Looking to the future, it will be useful to look at immersive technologies as a kind of medical assistant/support and to continue to develop with this in mind.

Finance

Functional and security processes in the financial sector has continuously been supported by infocommunication systems. Today, the way money is managed is changing and with it, finance is undergoing a digital transformation. The willingness and openness of users to adopt innovative solutions is important. Technological change affects all segments (whether spending, borrowing, investing) and all customer segments (whether individuals or businesses) from a financial perspective. It is important to note that households are financially responsible for:

- real assets (real estate used as the household's residence, other real estate, vehicles, valuables, businesses)
- financial assets (bank accounts, investments, pension savings)

All financial institutions need to consider at least five criteria for technological change: transparency, availability, price, convenience and trust. If innovative, modernising measures are successfully implemented, financial institutions will be able to retain customers and attract new ones. In today's fast-paced world, it is essential that services are quickly accessible and preferably mobile. Many financial service companies are open to the introduction of virtual reality and augmented reality technologies. Taking into account the main features of the technology and the main financial services, the use of virtual reality can certainly be useful in the following areas (both for staff and customers):

- training
- data visualisation
- payments
- virtual banking

Most financial institutions are working on creating a virtual environment (essentially a virtual bank branch) where customers and financial advisors can interact with each other. This can therefore be beneficial for both financial staff and customers using the services. Virtual reality and augmented reality technologies will certainly improve employee meetings and training. For customers, insurance (building, vehicle, life and accident), banking (virtual branches) and payment solutions are all areas for improvement. To cite a few examples, the French bank BNP Paribas is offering its customers a virtual reality-based application and related new services. Worldpay has a virtual, next-generation payment service for both small and large purchases. Citibank has created a holographic workstation to take its merchant services to the next level. "To challenge ourselves, we wanted to explore the ramifications and possibilities of mixed reality in an industry focused on something other than imagery. The world of financial trading was an excellent field to explore whether mixed reality could have an impact."[44] Financial institutions are constantly looking for innovative solutions, but are also careful to ensure that customers do not react badly to these innovations. For consumers, new virtual connectivity is a source of confidence (banking in a pleasant, easy-to-use virtual space is more attractive to many than going to a branch when time is short). Virtual reality and augmented reality will also allow customers to bank in entirely new ways in the future.

The list of advanced capabilities thus demonstrates the viability of immersive technologies in the financial sector, both for customers and for those working in this field. The implementation of innovative changes is always important for these measures, which can make people's day-to-day financial control more efficient.

Entertainment

Nowadays, it is no surprise to anyone that the main branches of the entertainment industry reach users through online channels. This trend in the entertainment industry is set to continue to grow in the coming years, driven by the virtual experiences offered by immersive technologies. From games to films, from music to shows and competitions (sporting events, theatre, etc.), practically all entertainment events of interest are available on social networks in mass quantities.

[44] 8Ninths: *Citi Holographic Workstation for Financial Trading.* s. a.

The internet therefore makes the whole spectrum of entertainment available on digital channels without leaving the comfort of our homes. Today, everything is streamed to the consumer: music (for example Spotify, Soundcloud, Amazon Music, Apple Music, etc.), movies and TV shows (Netflix, Amazon Prime Video, Apple Tv Plus), and social platforms used by huge numbers of people every day, such as Facebook, Twitter, Instagram and the increasingly popular TikTok. In the entertainment industry, the dominant digital trends can be divided into two main types. The second category includes emerging trends such as blockchain technology, cryptocurrencies and 4D virtual spaces.

In case of virtual reality and augmented reality, it can be argued that these technologies have been made popular by the entertainment industry. In the computer games sector, budget and immersive experience analysis[45] are important for the games industry. Game companies are able to offer users a better experience than ever before. Figure 31 shows a popular computer game using virtual reality technology.

Figure 31: The immersive experience of Half Life: Alyx game
Source: Newcome-Beill (2021): op. cit.

[45] Hamish Hector: *Best VR Games: Top Virtual Reality Experiences to Play Right Now.* 2022.

In the entertainment industry, there are countless services where immersive technology could set a whole new trend in the sector. The 4D (and mobile accessibility) of these media services, available across different platforms, represents a huge market opportunity for the entertainment industry. Given the technological potential of virtual reality, augmented reality, mixed reality, extended reality, the role of responsible regulation and, with it, full information in the entertainment industry will be more important than ever.

Social perspective

In the context of immersive developments, especially in case of virtual reality, it is important to address the associated social impacts. Increasingly common, immersive technologies are taking the existing, familiar information space to a higher level. We must therefore not forget the social impacts that can change people, individuals, their personalities and their perception of their environment. The role of virtual spaces in shaping people's personalities is clearly important and decisive in the everyday lives of very many people. Constant engagement in social spaces can easily become addictive. The same is true for the use of immersive technologies. The virtual world offers great experiences that can easily eclipse the values of the real world. It is therefore important to examine the main areas and environments that can be affected by virtual space and virtual reality. In the following, we will look at both the role of the virtual world in shaping people's personalities and the main environments that are present in people's everyday lives. The presence of the information society itself, the role of the virtual community and the associated changes in individual ethics are important factors in the changes in personalities. With regard to the environments that mainly affect the individual, in the following three most important environments will be mentioned:

- family environment
- work environment
- leisure environment

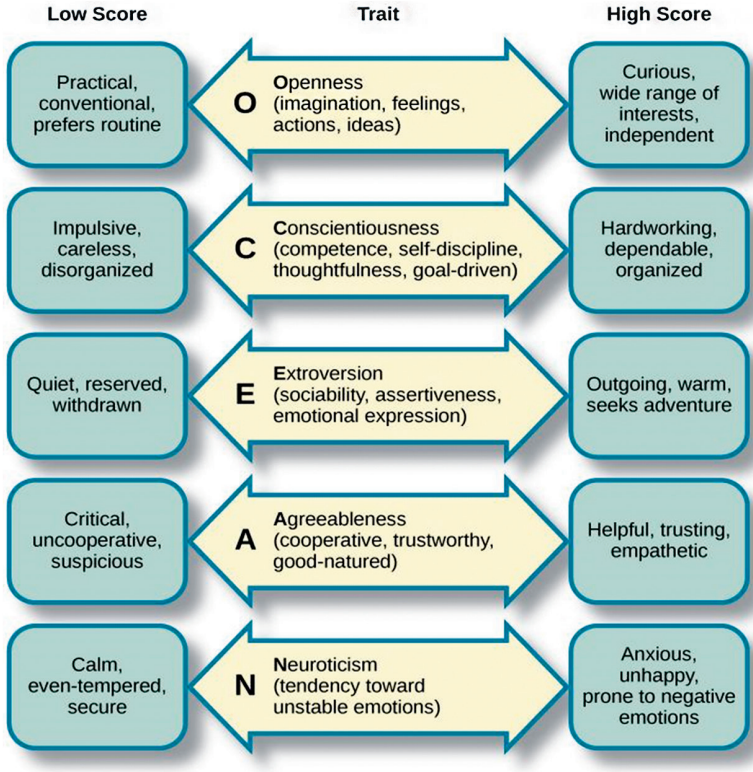

Figure 32: The Big Five model of personality
Source: Lim (2020): op. cit.

Humans are surrounded by an ever-increasing information environment, the effects of which have been relatively little addressed in contemporary society. It is important to note that this includes the so-called OCEAN personality model shown in Figure 32, which allows each person to decide which characteristics (trait score) describe him or her.

The personality-shaping power of the virtual world and virtual reality

The relationship between the information society and virtual reality

In today's information society, the technique of direct influence is slowly being replaced by a method of indirect control, the process of which can be traced. It can be argued that indirect control is more dangerous than direct control, since it does not make it obvious and does not give priority to the possibility of observation. In the age of media such as radio, television or the Internet, a widespread view is that cyberspace is now commonly accepted as a global and complex surveillance system. The idea of controlling cyberspace has entered the minds of quite a few people, and not without reason. These ideas form the basis of philosophies that tend to view the result of the technological revolution, the emergence of the information society, in a negative light. The virtual world, the technology of virtual reality does not receive exclusively positive criticism in this way of thinking, and pessimistic ideas naturally also emerge. In social science, virtual reality and virtual space itself are seen, with some optimism, as a force for community building.

The members of virtual communities change rapidly, and this type of community without borders has no written rules, bounded by some accepted norm. The norms, the moral rules of virtual worlds are constantly changing in the absence of control, and with them the personalities of the members. It is not possible to keep or enforce things or rules for virtual actors. In virtual space, there is no executive power in the traditional sense, no controlling entity, and most of the time the norms do not follow any clear-cut form. Virtual reality allows the creation of artificial environments in which the user, the individual can experience the possible development of real situations in the artificial environment, and can try out and practise the behaviour in real situations. The virtual space is therefore a place where rules similar to those in the real world are applied.

The role of information through virtual space is extremely significant for the mental well-being of the individual user. It is important to note that virtual space can reinforce an individual's false sense of freedom, but it can also, for example, weaken the self-control learned in virtual space. It is above all the younger generation that is at risk from the loosening of the fixed patterns of behaviour already learned in real society, and today's parents may feel less ownership of the information society, following old, natural patterns of behaviour. Mass media

tools influence people without their being aware of the elementary impact they have on them. Nevertheless, it is fair to say that many people believe that their sense of freedom has not changed. Of course, this is everyone's own responsibility and requires conscious behaviour in today's digital world, in which we are surrounded by countless infocommunication systems. Everyone is able to maintain their abstinence from using virtual spaces (their belief in freedom), but in today's society it is inevitable that most people will not connect to one or more virtual systems (for work, entertainment and other reasons).

With the advent of the information society, the media has thus been transformed significantly, and the virtual personality is becoming more and more natural. The change is not only structural but also strategic. The digitisation of data makes it possible to deliver virtually any form of information to people. In the information society, virtual platforms allow us to access the content we want, at the place and time we want, in the way we want. In addition, active online presence (anonymous comments, fake user names, targeted comments, for example political comments for the benefit of power) is already doing so. On the one hand, this is having a considerable impact on the ethical system we have been used to, and on the other hand, virtual reality and virtual spaces are rearranging the natural world we are used to experiencing in real space.

General features of virtual communities

Nowadays, it can be said that the individual in a virtual community is completely disconnected from his or her real self, but this cannot be considered another personality. In the virtual community, the person (virtual reality character) retains his or her real character, and the pseudonym can serve both offensive and defensive purposes. The Internet as a virtual environment provides an excellent opportunity to observe and learn patterns of behaviour. The popular community based on virtual reality technology also provides a sense of belonging, as it is now possible to appear in a multi-character virtual environment with other, otherwise real, people. A member of a virtual reality community integrates into his or her environment by adopting the behavioural patterns that others exhibit, or even expect. In the community learning theory approach, the role of environmental reinforcements in shaping an individual's person is as important as the pattern of what is seen. In addition to the behavioural patterns, there is a need for a demonstration of liking, which encourages the individual to repeat

his or her behaviour and to make further improvements. For a person who is struggling with problems in the real world, the virtual space is only directly useful to the extent that he or she can discuss his or her problems and perhaps find sympathetic ears. Decisions in one's life generate recurring thoughts, for which there is clearly a great need for other people's opinions. It is important to note that the problems discussed in virtual reality are problems that exist in physical reality and will not always disappear or necessarily be resolved.

The individual drawn into virtual reality is limited in the expression of his or her emotions and does not necessarily receive the kind of emotional feedback that he or she would receive in physical space, by its very nature. The characters themselves are aware of their limitations, and in many cases the successes and failures of their virtual characters can further diminish their self-esteem in physical reality. Success can be worsened because the individual may think that they can function better in the virtual world, making the physical space unworkable in comparison and therefore not necessarily important. Failure may be because the individual may think that they cannot even perform well in the virtual space, and the physical space is even more so. The virtual person is not identified by users with their real self, so the success achieved by the virtual alter ego (avatar) will not be the success of the real self. The individual is constantly comparing himself to the character he is portraying. For all these reasons, it is important to consider the advantages and disadvantages of the virtual world, and with it the opportunities offered by the popular and well-known virtual reality communities. It is easy for an individual's self-image to deteriorate, and this is the case for many children today. Feelings of failure can lead to a return to the virtual persona that one has created, until the real persona becomes addictive.

For many people, the wide personality differences between the virtual and real worlds prevent them from consciously using what they experience in the virtual world to apply tried and tested behaviours that work and to apply communication techniques successfully in the real world. Virtual reality technology therefore requires a high degree of conscious personalisation, as it is easy for individuals to forget themselves and devote energy to building a virtual image instead of their real identity. In the context of virtual communities, this can also be understood as a successful or unsuccessful psychotherapy, whereby the experiences in the virtual world and community are integrated into the real personality. In conclusion, it is important to note that everything that a person experiences in their life has an impact on them. Experiences related to personal behaviour in the community are an important source of energy for maintaining a physical and mental balance,

which is also increasingly influenced by being in the virtual world. Humans are social beings, which is why alongside modern-day virtual social opportunities, we need to be more vigilant about the correct cultivation of our real personalities, as this can be traced back to the manifestation of ethics.

Ethical impact

As with most virtual technologies, the ethical implications of virtual reality are worth mentioning. Virtual reality today is not necessarily a single-player experience, there are many opportunities to participate in multi-player programmes (for example, a virtual workplace meeting, or similarly in the case of computer games). Ethical changes and related issues arise in several respects. The human ethical order can easily be upset if there is an almost addiction to the virtual presence in order to maintain a virtual identity. This can be observed, for example, in the emergence of a constant desire for validation, which can lead to a sense of lack of self-realisation. A fundamental characteristic of the ethics of virtual identities is that there is no so-called observer to speak out in any way against inappropriate behaviour. This can also be interpreted as the absence of broad social control in the virtual space and the absence of written, in other words strict rules. It follows that participants feel protected against any sanctions and do not take responsibility for their actions.

There is a palpable awareness of virtual reality as an artificial environment for self-expression, for pushing the boundaries of the so-called self. From this point of view, it can be said that virtual reality is an environment for observation, for trying out different behaviours, for practising. Virtual reality is also closely related to artificial or alternative reality, simulation. From an ethical point of view, the virtual world is most often perceived by most people as an interface where general norms, personal inhibitions do not apply and as a consequence, whoever enters it can do practically anything, with only their own imagination setting an apparent limit to their actions.

A fundamental ethical issue arises in a world which people see as a copy of reality, where behaviour is limited by fantasy rather than rules, where an adolescent can fulfil his or her every desire, where we can play with the objects and people around us without any sense of responsibility or fear, where we can do anything in our virtual environment.

In the virtual space, individuals can try out techniques that are not comparable to the ethical standards of the real world. The user may be able to react in the safety of the virtual space in ways that they would not do in the real world, such as insulting someone without any lasting consequences. In virtual space, the only consequence is that the person who does not like the behaviour of others is excluded from the group. This is of course mainly imaginable in situations such as virtual reality games rather than a workplace meeting. However, changes in an individual's ethics in the real world can also have much more serious and irreversible consequences for non-compliance, whether it is an action in the family or even in a group of friends. The experiences generated by virtual reality, and with them the sense of freedom, can easily change our ethical behaviour. It is important to bear this in mind, as people tend to interpret the ethical boundaries surrounding technologies such as virtual reality in their own particular way, with a certain degree of permissiveness. In such a world, how can traditional moral and ethical norms prevail and should they?

We can say that:

"The utilitarian philosophy of choosing actions that maximize happiness and minimize pain for the greatest number can also justify the causing of harm, again for the greater good. […] Careful attention needs to be paid to the presentation of violence or abusive behavior in these contexts. […] It should be clear what the legal and ethical responsibilities are for actions carried out at a distance if embodied in a virtual body or a remote robot controlled by some interface."[46]

Assessment of major environments around people in relation to the application of virtual technology

Family environment

The emergence of immersive technologies can play an important role in people's private lives if a family decides to buy a virtual reality product. This socially based affair has been little explored, as it is not yet a prevalent or experienced change. Naturally, family members of older generations and values (parents, grandparents) are less open to this issue than younger generations (children, young adults, young parents). Family morality and harmony are easily influenced

[46] Mel Slater et al.: The Ethics of Realism in Virtual and Augmented Reality. *Frontiers,* 1 (2020).

by technology that adds virtual elements to the familiar family atmosphere and to the real space of the family. It is important to note that the use of virtual spaces, decided at family level, is a rather responsible decision on the part of adults, since it adds new elements and new experiences to the family home. Of course, whether we are talking about virtual reality, augmented reality, mixed reality or extended reality, conscious family thinking is a sine qua non for the use of immersive technology. Technology can be applied in a variety of ways, taking into account a family's behavioural habits, its home and other aspects. With all this in mind, it is not surprising that many families are shying away from new technology, as instinctive fears are triggered. Parents fear for their children first and foremost, not to mention the fact that the technology is not yet particularly affordable. Fear of a possible change in the child's behaviour in the wrong direction, and fear of a possible weakening of the family's cohesion.

At present, we have no really conclusive data and knowledge about the long-term effects of virtual reality on children. We can be sure that more research is needed on virtual reality, which will take years. The technology should be safe for children under 18 years of age, as the development of the prefrontal cortex of the brain accelerates in mid-childhood. Disrupting this process has a serious impact on children's memory and with it their cognitive abilities (for example, their ability to approach a task flexibly). In the short term, for example focusing on virtual objects can lead to eye strain, but in the long term, the health effects and consequences are still unknown. The following three preliminary measures are certainly possible:

- health assessments for children and adults (the whole family)
- introducing moderation (especially for children)
- discussing the possible effects of virtual reality within the family

This is similar to desktop computer use, as children's addiction to computers has been a hot topic for some time now. A joint study[47] by Stanford researchers and Common Sense Media found that parents are extremely concerned about the use of virtual reality. The first step is therefore to carry out a basic health assessment similar to that for desktop computer use, including eye tests, fatigue, emotional effects, etc. Understanding and clarifying the cognitive abilities will clearly help to kick-start the conscious use of virtual reality. Moderation can be useful in

[47] Jennifer Huber: *Stanford and Common Sense Media Explore Effects of Virtual Reality on Kids.* 2018.

many respects, if it can be effectively implemented without outs (for example thinking of the periodic indulgence of parents, which can lead them to act while feeling sorry for their children). Moderation can be different for each family, and can include, for example, the following three basic rules:

- time limit (use of virtual reality broken down into periods, usually hours)
- content limit (allowing and disallowing the use of programs in the virtual space)
- authorisation limit (virtual reality can only be used with parental supervision)

Work environment

After the family environment, the main general activity of people is work, which takes place in the workplace, both in the virtual and the real environment. People spend a relatively large amount of time at work, which depends on many aspects. For example, it may depend on the working hours (typically 4, 6, 8 or up to 12 hours), the type of work (mental or physical), the feelings towards work (many people tend to work overtime in order to return home satisfied) and other factors. This means that the work environment has a major impact on a person's physical and mental health and well-being. In many companies, there is a drive for innovative solutions and openness. For example, this includes the use of various technologies such as robotics or artificial intelligence. There are also a number of mobility goals that have been introduced to increase the employee's sense of freedom. A good example is home office, which has become quite necessary and in many cases has been implemented due to the virus situation. Of course, not all workplaces can think about innovative technologies, but where it is possible and motivated, virtual reality and with it, immersive technologies can be considered. For many companies, it is important to be technologically up-to-date and at the same time maintain a suitable environment for their employees.

Workplace environments are diverse and multifaceted, but perhaps the most common characteristic can be traced back to the words: Workplace is workplace. In the work environment, we often act in a state of emotional upheaval, under the pressure of countless tasks and responsibilities. Using virtual spaces can easily change our personal attitudes towards our colleagues (for example emails, chat messages, online meetings). Positive attitudes play an important role in maintaining a relaxed and pleasant work environment. "When something is going

wrong, the first thing people usually say is to 'stay strong and stay positive'. Those little affirmations sometimes do work, and it's important to remember that words can go a long way during a time of negativity, especially in the workplace. Always looking on the bright side 'may sound cheesy, but just positive thinking, smiling and positivity in general are the main staples of a positive personal attitude'."[48] Every person should therefore be accepted in the workplace as they are. It is worth taking into account the unwritten law that: what I give, I will get back.

With a focus on modern goals, the use of virtual reality gives you many opportunities to create a rather pleasant working environment. The creation of a virtual environment, a virtual reality in the workplace can also cover a number of areas, of which the following are examples:

- human resource activities (remote conduct of interview meetings and tests)
- virtual environments in the workplace (safe professional training in hazardous environments, or virtual support for an office environment)
- management and other professional meetings (creating virtual office environments both within and between companies)

Through constructive discussions, the use of virtual reality can also have a very positive effect. On the one hand, it can bring work members closer together to communicate on a topic, and on the other hand, they can discover a great innovative technology together. Taking all these related advantages and disadvantages into account, it is important to integrate virtual spaces into the work environment. Virtual reality can therefore be used to simulate work environments, or even to create a virtual environment for recruitment, where candidates can show what they can do (from home) in the simulation. By using technology, virtual experiences can not only allow the workforce to enjoy, but also to feel safer in their work environment, motivating them to work in a valued and respectful way.

Leisure environment

In addition to the family and work environment, particular attention should also be paid to leisure activities, which in the future could easily be influenced by virtual space, virtual reality. In addition to work and family activities (chats,

[48] Jennifer Post: *How to Develop a Positive Attitude in the Workplace.* 2022.

meetings, other activities), everyone is looking for time for themselves, so-called self-time. There are as many people as there are needs and with them as many ways of spending time. Some people especially like hiking, some like going to the theatre, some like fishing. There are many different personalities, but all of them can be influenced in basically the same way by the increasingly mass virtual environments. For many of us, leisure time brings nature to mind, which is no coincidence. Nature is the most pure form of real life, of the real world. This is why most people consciously want to experience leisure time with the greatest possible clarity and realism.

Virtual reality has gone viral and the possibilities have been transformed by the increased, yet enclosed, leisure time. There have been increasing demands and ideas on how leisure activities can be replaced by virtual space, to be experienced in the best possible way. Nowadays, this has reached a level where concrete businesses have been set up to do this. The possibilities of tourism and with it leisure activities have been transformed by virtual reality and the immersive solutions that go with it. Important awareness-raising is needed to ensure that the real value of leisure activities is maintained alongside virtual opportunities. Today, for example, virtual reality can be used to experience journeys with a very deep sense of emotion that include stunning graphic elements. Leisure activities include a lot of things, depending mostly on what your favourite hobby is. An important criterion is that they can be divided into active and passive leisure activities. There is no big surprise as to which leisure activities belong to which group.

The active form of leisure activities is extremely diverse, the possibilities are almost endless. Active leisure always involves some level of physical activity. Individual and team sports have many positive effects on people, and a varied environment is particularly refreshing, for example through the following activities:

- hiking, major urban walks
- individual cross-country running
- swimming in different styles
- cycling

Passive leisure activities are free of any particular physical activity. Sit comfortably and watch a good movie, go to the cinema or stick to sports and get together for an exciting match. But reading a novel or doing a crossword puzzle is not physically demanding. It is important to note that active, but especially passive,

leisure activities can have negative effects, even increasing the level of stress. Bearing this in mind, it should be noted that the use of virtual spaces, and with them virtual reality, is essentially based on a passive activity (such as lying on the phone for long hours watching funny videos). In terms of leisure activities, we should not allow ourselves to be drawn into a passive lifestyle just because it offers fantastic experiences that we have never had before. Of course, not everything can be replaced by virtual elements, but it is important to remember that the virtual world can be addictive. Real leisure activities can be sidelined as virtual experiences become not just accepted but expected. Immersive technologies have the potential to trigger experiences that people cannot have or find difficult to have in the physical world (space, time, whatever). A balance must therefore be struck to ensure that virtual experiences and real experiences can coexist in leisure time. Everyone needs a little relaxation and recharging from time to time. If we are interested in spending some time in virtual reality, we need to be aware of the feeling of lack of active relaxation.

Possible future vision, the world of metaverse

The immersive technology and the conquest of virtual spaces itself is bringing quite a change to the information landscape of our society. Technologies are intertwined and vast amounts of mass information are constantly being collected, stored, processed and transmitted in a huge data explosion. Nowadays, a complex concept that encompasses this trend, the metaverse has become increasingly well known. But what does the term mean?

Interestingly, the term metaverse has only recently become popular, although it is actually an older concept: "Author Neal Stephenson coined the term "metaverse" in his 1992 science-fiction novel "Snow Crash," which envisions a virtual reality-based successor to the internet. In the novel, people use digital avatars of themselves to explore the online world, often as a way of escaping a dystopian reality."[49]

The term already existed, it is the technology that has been applied to it and made it into a reality. It is important to note that no one yet knows exactly what form the metaverse symbolised in Figure 33 will take in people's lives.

[49] Tom Huddleston Jr.: *This 29 Year Old Book Predicted the 'Metaverse' – And Some of Facebook's Plans Are Eerily Similar.* 2021.

The figure illustrates that our profile in virtual space will play a more important role than ever in the near future, using the new type of evergreen possibilities offered by the Internet. The metaverse is based on the idea of a global network of predominantly 3D content organised in space, which will be available to all, in unlimited quantities. In some definitions, the metaverse is effectively the real-time 3D internet.

Matthew Ball (Founder/CEO at Ball Metaverse Research Partners) says: "The Metaverse is a massively scaled and interoperable network of real-time rendered 3D virtual worlds which can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments."[50]

Figure 33: Virtual and physical persona layers in the future Metaverse
Source: Elliot (2021): op. cit.

It is the internet that artificially connects our society, which is why this global network can be the gateway to the multidimensional virtual world we want to create. "Essentially, the metaverse is supposed to be a 3D version of the internet that is seen as the logical next stage of development, and would ideally be

[50] Matthew Ball: *Framework for the Metaverse.* 2021.

accessed through a single gateway."[51] It is well known that Facebook has changed its name to Meta to show its commitment to the metaverse. Mark Zuckerberg (Facebook inventor and CEO) from his 2021 annual Connect company conference statement: "I believe that metaverse is the next chapter for the internet."[52]

There are seven theoretical rules that help all people to orient themselves in the interpretation of the term metaverse in its theoretical informational approach. These are:

- There is only one metaverse (taking into account the possible dark side of the network): this is the set of all publicly available virtual worlds, real-time 3D content and related media, connected by a global network that is not controlled by anyone and available to all.
- The metaverse is for everyone: based on definitions of the broadest social rules, adapted to a wide range of use cases and user personas.
- No one controls the metaverse: It is a universal common tool for digital communication and commerce, dictated by need, managed according to common interests, for the benefit of most people.
- The metaverse is completely open: It is an ecosystem that is interoperable, meaning that it is built on technologies based on the collaboration of different IT systems. They are interconnected through rigorously defined and widely accepted free and open communication standards.
- Metaverse is hardware independent: It is characterised by spatially organised, predominantly real-time 3D content. For this content to be accessible to all, it must be displayed on the widest range of hardware, it must be accessible from anywhere.
- The metaverse is a computer network: it connects the world's publicly available virtual experiences, using its massive, real-time 3D content and associated media. It collects, stores, processes and transmits information based on computer network protocols. It is therefore not a program, but rather an extended network.
- The metaverse is the Internet itself. The Internet is evolving and offering entirely new information services, making it practically a metaverse.

[51] Shamani Joshi: *What Is the Metaverse? An Explanation for People Who Don't Get It.* 2022.

[52] Jonathan Vanian: Mark Zuckerberg Is Obsessed with the Metaverse. Here's What that Sci-Fi Term Means. *Fortune,* 28 October 2021.

Well, metaverse can therefore be imagined as a global, worldwide network. Currently, the metaverse is one of the biggest technology trend, with many predictions that it will transform our society over the coming years as it evolves and expands. The boundaries are blurring and over time, activities in the metaverse will become commonplace in everyday life. Through metaverse, the physical and digital worlds can meet. A complex world where the internet surrounds the participants, creating their own avatar. It enables activities that were previously only accessible in a physical way, such as work, entertainment, meetings, etc. Metaverse is a significant innovation in the human-computer interface based on modern technologies. It is not surprising that there is growing interest in military applications in addition to civilian spheres. Thinking in global network, mapping the military needs (maybe we can call it "the military perspective of the metaverse") for immersive technologies is a fairly topical R&D activity.

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Approach to virtual reality for military purposes

Foreword

In addition to the civilian application of immersive technologies, their military application must not be forgotten. Military operations have changed significantly in the 20th century, which in the 21st century will be even more intense and complex. As in many other sectors, there is a constant need for modernisation in the military. "A capability-based application of military force based on a policy-defined mission, coordinated by purpose, location and time, is called a military operation."[53] There has always been, is and will continue to be a need for technological development and modernisation in support of military operations. These developments are driven by different information requirements at different levels of military operations (tactical, operational, strategic). It is important to note that military developments today are clearly determined by developments in the civilian environment, which was not the case in the 20th century. The specific policies of the great powers (the interest of staying in power) force them to constantly develop technology, which in turn creates a competitive situation (see the perennial rivalry between the USA and Russia).

Nowadays, as a result of such competition and the intense development efforts worldwide, in which military superiority is gained by the military force that can integrate civilian knowledge into the development of military equipment and systems, and with it into the development of the various military sectors. Worldwide, the activities of the different military services (for example land forces, navy and air force) are supported by specific information and communication technologies, which are applied in a network-based operational capability. The exchange of information between different systems is nowadays a massive feature of military operations. Each force has its own specific information requirements, which can be very diverse within a force (taking into account, for example, the different types of vehicles, equipment and the different deployments of soldiers). The following section will examine the potential for military development of

[53] István Szendy: *Hadügy és hadviselés.* Budapest, Dialóg Campus, 2017. 97 (translated by the author).

immersive technologies. The main aspects to be examined will be the needs of different forces and of different military units. Five main areas have been selected to ensure that the results provide a comprehensive picture of any other military area. The formations are examined in a frequently used division of activities, also with a view to outlining the possibilities for the development of immersive technologies. It is important to emphasise that only land forces are examined, which can be used to plan the development needs of any other force, and with it the specific military force of any nation. The method of grouping the units will be based on the known division of the Land Forces of the Hungarian Defence Forces, which can also be further developed in relation to the specific military forces of any nation.

In the following, military interpretations, including those of the NATO Alliance and other public documents and information considered scientifically will be used to examine the military development potential of immersive technologies. In addition, the main related areas of development will be described (see interoperability, network-based operational capability, cyber defence). The aim is to obtain a comprehensive knowledge, in which the military development options for immersive technologies will be described. As with the exploration of civilian options, the applicability of these technologies to military forces is limited only by personal boundaries and how military users can imagine the use of the technology. In the next chapters, the application of immersive technologies will be examined, specifically in a military context. The aim is to provide the reader with a basic, global picture of the applicability of these technologies.

Major development-related military capabilities

Interoperability

Nowadays, many infocommunication systems are facing some of the most basic challenges, such as the ability to become interoperable. Solving and maintaining the interoperability of information-based systems is a high-priority military task. In order to achieve interoperability between different information systems, it is necessary to define precisely the requirements for the exchange of information between infocommunication systems. Achieving interoperability for military forces is both an individual and a common interest of the participants, and NATO member states are actively working on this.

It is worth noting that in the related NATO document, interoperability is defined as: "The ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives."[54] In many cases, the devices and systems used by the military forces have been developed according to different proprietary manufacturer's programming.

Looking to the future, the military forces must be able to develop the conditions for achieving interoperability, which will of course take a long time, see Multilateral Interoperability Program (MIP), Artillery Systems Cooperation Agreement (ASCA), Federated Mission Networking (FMN) in the context of the NATO alliance. "Interoperability is the ability to operate together using harmonised standards, doctrines, procedures and equipment. It is essential to the work of an alliance of multiple countries with national defence forces, and is equally important for working together with partners that wish to contribute in supporting NATO in achieving its tactical, operational and strategic objectives. Much of day-to-day cooperation in NATO – including with partners – is focused on achieving this interoperability."[55]

The internal structure (including the ordering of data), content and format of information and other characteristics can all be described in terms of interoperability requirements. Interoperability can therefore be understood as a framework for the operational environment of information (and the exchange of information). NATO has defined interoperability capability in support of technological developments in the following four dimensions:

- technical dimension (including hardware, equipment, armaments and systems)
- procedural dimension (including doctrines and procedures)
- human dimension (including terminology and training)
- information dimension (as a critical transversal element)[56]

Interoperability is an important capability from both a national and an alliance military perspective and NATO has been working on it for a long time, while new technologies are emerging in the military forces of member countries. This is also the case for immersive technologies, for whose innovative products

[54] NATO: *AAP-06 Glossary of Terms and Definitions.* 2021a. 71.
[55] NATO: *Partnership Interoperability Initiative.* 2022b.
[56] NATO: *Interoperability: Connecting Forces.* 2022a.

interoperability is an important criterion. Different levels of interoperability development have been identified, which are:

- Level 0 – Isolated interoperability in a manual environment
- Level 1 – Connected interoperability in a peer-to-peer environment
- Level 2 – Functional interoperability in a distributed environment
- Level 3 – Domain interoperability in an integrated environment
- Level 4 – Enterprise interoperability in a universal environment[57]

To achieve interoperability, the right information environment (hardware and software conditions) must be provided, both for development and for cooperation between the related organisations. The interoperability challenge can be said to exist mainly when the information stored and managed by IT systems includes the information defined in the information exchange requirements and these systems are able to transmit and receive the information, but there are differences in interpretation (content or form of messages, representation).

NATO has introduced the Multilateral Interoperability Program to achieve interoperability capability, which is a systemic development of cooperation between member countries' individual systems. "The aim of the Multilateral Interoperability Programme (MIP) is to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to the lowest appropriate level, in order to support combined and joint operations; and pursue the advancement of digitization in the international arena, including NATO."[58] As shown in Figure 34, on the associated website of Systematic, the program is based on the so-called JC3IEDM model, which is defined in the NATO associated document (STANAG 5525, Joint C3 Information Exchange Data Model – JC3IEDM). The model allows the technological development of military forces to be carried out according to a common framework, which shows more and more effective results in military operations every year.

[57] NATO: *AJP-6 Allied Joint Doctrine for Communication and Information Systems.* 2017. B-2.
[58] NATO: *Current and Future MIP Capabilities for Coalition Interoperability.* 2005a.

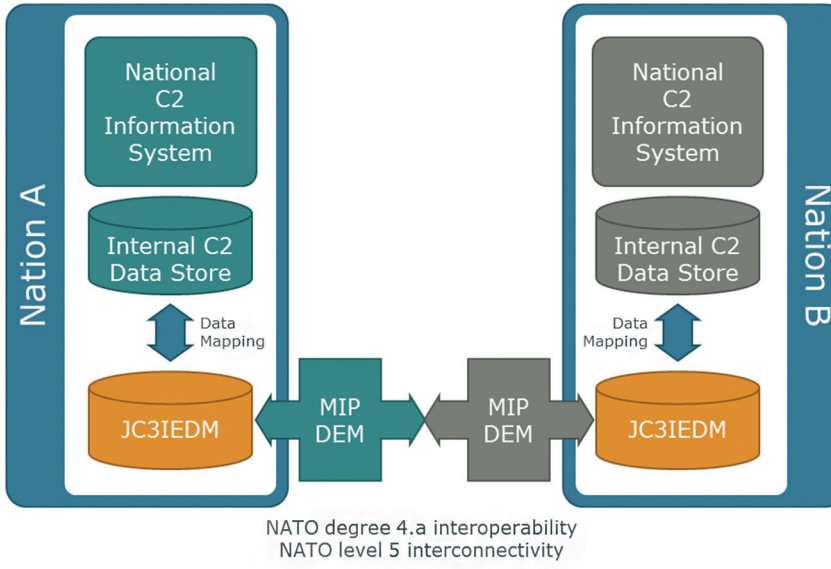

Figure 34: Interoperability capability based on the JC3IEDM model
Source: Systematic (s. a.): op. cit.

Military forces are therefore defining a strategy at national and federal level based on common data models for the systems they use. In essence, this concerns all technological developments relevant to military operations, including immersive technologies. The interoperability capability is closely related to the network-based capability, hence, if information exchange can be performed between two stations (even between two different national specific control and command systems) when interoperability is present, it will also provide the network-based operational capability described below.

Network-based capability

Information technology support for contemporary military operations involves the networked use of infocommunication tools and systems. The thinking about network-based military operations and the definition of related concepts and strategies has been going on quite intensively since the turn of the century. A good

example for an overview of this is the examination of the related NATO concepts and documentation. The NATO C3 Board (NATO Consultation, Command and Control Board – NC3B) decided at its Prague Summit in 2002 to introduce a new approach, the NNEC, linked to the NATO Feasibility Study published in 2005: "The NATO C3 Board (NC3B) agreed that there was a need to develop a NATO concept to adapt national initiatives such as the U.S. Network-Centric Warfare (NCW) and the U.K. Network Enabled Capability (NEC) to the NATO context. This NATO concept is referred to as "NATO Network Enabled Capability" (NNEC)."[59] The command and control system for military operations can be effectively supported by the development of network-based capabilities. With the introduction of the conceptual principles, an important objective for NATO is the development of advanced technology support for the NATO Response Force (NRF). The concept of NNEC is defined in the following way: "The Alliance's technical ability to federate the various components of the operational environment, from the strategic level (including NATO HQ) down to the tactical levels, through a networking and information infrastructure."[60]

Network-based capability includes, among other things, infocommunication systems (for example fire control or detection systems), various sensors and other network devices (for example switch, router). Networks must have interoperable capabilities to be properly implemented, working together to support the collection, storage, processing and transmission of information. According to that study: "Firstly, there is the need to extend communication networking capabilities to 'wherever they are needed, whenever they are needed', implying the need for a 'flexible global networking capability'. Secondly, there is a need to support smaller, modular, multinational force structures such as the NRF, generating new information-sharing and security requirements that will increase critically of interoperability requirements and could redraw NATO/national interoperability boundaries. Thirdly, there is the need to support the rotation of national force elements within the NRF and to support seamless interoperability with force elements from non-NATO nations that may not even be identified until a mission is already underway. These points imply the need for an unprecedented degree of flexibility, agility, adaptability and interoperability in the force structures involved and in the networking and information systems that support

[59] NATO: *NATO Network Enabled Capability – Feasibility Study Executive Summary Version 2.0.* 2005b. 1.

[60] NATO (2017): op. cit. 1–4.

them."[61] "The main objective of the NNEC programme, illustrated by the slogan "Share to Win", is to initiate a culture change that begins with people. Interacting with each other and sharing information will lead to better situational awareness and faster decision making, which ultimately saves lives, resources and improves collaboration between nations."[62] Later, the NNEC concept was used in the new 2012 NATO FMN programme mentioned earlier.

Figure 35 describes the main aspects of the FMN concept, based on which NATO member states work together to coordinate planning and develop the operational and technical capabilities.

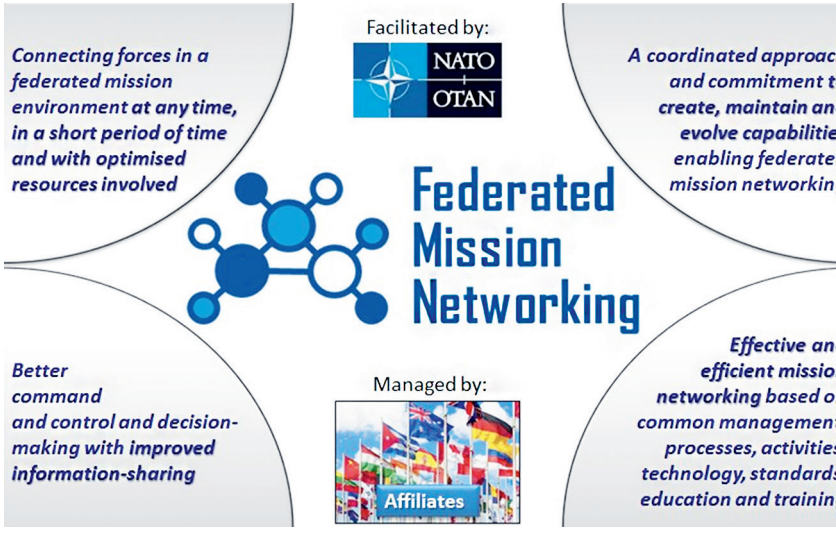

Figure 35: Main aspects of NATO Federated Mission Networking
Source: NATO (2018): op. cit.

The relevant requirements, architecture, standards, procedures and technical instructions are documented in the so-called *FMN Spiral Specifications.* The FMN Spiral Specifications are based on well-known standards and best practices.

[61] NATO (2005b): op. cit. 2.
[62] NATO: *NATO Network Enabled Capability.* 2015a.

As shown in Figure 36, a milestone corresponds to a spiral and a spiral has four phases: specification, development, training (with Verification and Validation) and operational phase.

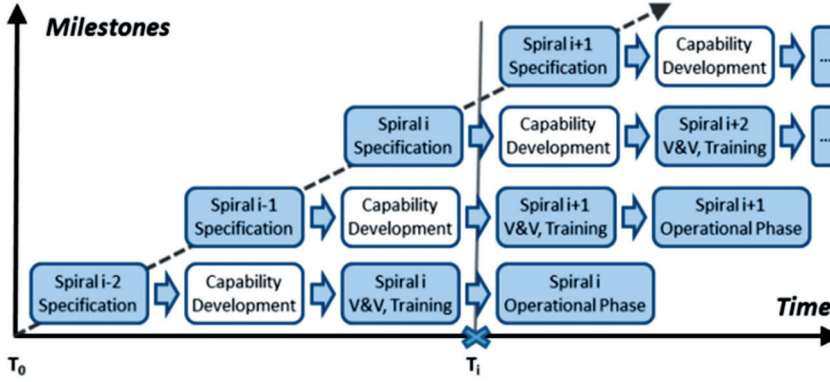

Figure 36: NATO Federation Mission Networking spirals
Source: Pullen et al. (s. a.): op. cit. 4.

Network-based operational capability development requirements cover all related products and services, including the use of immersive technologies. In terms of supporting soldiers with virtual environments, there is a need to formulate development guidelines that are implemented in infocommunication networks.

Cyber defence

In parallel with networked concepts, place and tasks of military operations in cyberspace are also changing, and the concept of cyberspace is being revisited. There are several definitions based on different sources of interpretation that converge on fundamental common threads. NATO defines cyberspace as: "The global domain consisting of all interconnected communication, information technology and other electronic systems, networks and their data, including those which are separated or independent, which process, store or transmit data."[63] In addition to the evolution of the infocommunication networks of military forces,

[63] NATO (2021a): op. cit. 37.

operations in cyberspace are nowadays facing new types of challenges. Cooperation between member states of the NATO military alliance has also developed specifically for cyber defence purposes. Major events that have influenced the direction of capability development from a NATO cyber defence perspective are:

- 2002 – cyber defence became part of the political agenda (Prague Summit)
- 2008 – the first cyber defence policy was prepared
- 2010 – cyber defence was included in the Strategic Concept (Lisbon Summit)
- 2011 – the Cyber Defence Policy was updated
- 2012 – an action plan was created for Cyber Defence Policy
- 2014 – the Cyber Defence Policy was approved (Wales Summit)
- 2016 – cyberspace was recognised as a domain of operations (Warsaw Summit)
- 2018 – the new Cyberspace Operations Centre plan was agreed (Brussel Summit)
- 2019 – Allies endorsed a NATO guide (to respond malicious cyber activities)
- 2021 – new Comprehensive Cyber Defence Policy was endorsed (Alliance's resilience)

NATO Cyber Security Centre (NCSC) is the organisation, which is "responsible for the planning and implementation of the full lifecycle management activities related to cyber security. In carrying out this responsibility, the NCSC provides cyberspace specialists. Provides security-related services covering the scientific, technical, procurement, operational spectrum, maintenance and sustainment support." NATO is also working with the European Union. „In light of common challenges, NATO and the EU are strengthening their cooperation on cyber defence, notably in the areas of information exchange, training, research and exercises".[64] NATO Consultation, Control and Command Board (NC3B) deals with the technical and implementation aspects of cyber defence. For cyber defence surveillance, the NATO Communications and Information Agency (NCIA) was created by merging seven agencies, which is responsible for infocommunication systems and related cyber activities. The NATO Cyber Defence Management Board (NATO CDMB) is responsible for coordinating the cyber defence of

[64] NATO: *Cyber Defence.* 2022c.

NATO's military and civilian organisations. The directorate is composed of military, political and technical leaders. Its main task is organising the capability to respond to attacks on NATO and its member states and providing assistance to help member states develop cyber defences. Also relevant to the development of cyber defences is the NATO Cooperative Cyber Defence Centre of Excellence (NATO CCDCOE), established in Tallinn, 2008. The tasks of the organisation are as follows:

- helping to build national cyber defence capabilities
- supporting the development of national doctrines, concepts and strategies
- providing education, ongoing training and exercises (see Figure 37)
- legal analysis of cyber warfare and related international frameworks

Figure 37: Locked Shields exercise at NATO CCDCOE
Source: CCDCOE (s. a.): op. cit.

NATO is developing its cyber defence capability to create a capability that is available to member countries 24 hours a day. Cyber defence operates in a centralised alliance system, with the individual cyber defence capabilities of member countries being significant. Cyber defence processes are implemented in a networked way, thanks to close cooperation between member countries.

The NATO Computer Incident Response Capability (NCIRC), which embodies the Alliance's cyber defence, has been registered by the NCIA. "The NATO Computer Incident Response Capability (NCIRC), based at SHAPE in Mons, Belgium, protects NATO's own networks by providing centralised and round-the-clock cyber defence support. This capability evolves on a continual basis and maintains pace with the rapidly changing threat and technology environment. NATO has also established a Cyberspace Operations Centre in Mons, Belgium. The Centre supports military commanders with situational awareness to inform the Alliance's operations and missions. It also coordinates NATO's operational activity in cyberspace, ensuring freedom to act in this domain and making operations more resilient to cyber threats. To facilitate an Alliance-wide common approach to cyber defence capability development, NATO also defines targets for Allied countries' implementation of national cyber defence capabilities via the NATO Defence Planning Process."[65]

So, with the use of rapidly evolving technologies, it is quite important to develop protection mechanisms. The massive use of infocommunication networks by military forces requires careful cyber defence planning. The potential for attacks on computer-controlled networks and devices has increased significantly, which also raises topical and significant issues for immersive technology, as computer-based systems created using virtual reality and augmented reality technologies can also be attacked in cyberspace, so that the exploration of their defence capabilities will be an important criterion in the complex operational capabilities of military forces (for example C2IS systems mentioned in the context of interoperability).

Exploring virtual development opportunities

The possible areas for development can be simplified to these two main questions and look for answers and examples:

- What military functional capabilities can immersive technologies support in military operations?
- What military security capabilities can immersive technologies support in military operations?

[65] NATO (2022c): op. cit.

Taking into account the above two components, the questions are of course extremely complex and numerous, and they can be grouped and sorted according to different criteria. Thus, the analysis of the military field can be grouped as follows:

- by types of service, including branches and special area units as well (land forces, navy, air forces, cyberspace)
- by scope of activities of military units (combat, combat support and combat service support forces)
- by activity sectors (military industry, education)
- by immersive technology (virtual reality, augmented reality, mixed reality, extended reality)

In the following, military development opportunities will be examined from the military sectors and units perspective. As the composition of the military forces worldwide is very diverse, it is important to emphasise that the analysis is limited to the land force, the results of which can be applied to the development of other forces. The aim of the studies is to identify options that can be applied in practice and that could prove effective in a number of military domains.

Investigations by sectors

Military forces have a wide range of tasks, which means that identifying areas for improvement is not an easy task. It is important to note that the type of operation carried out by a given military force determines the requirements. Within the requirements, the necessary infocommunication and related technology needs are identified. Therefore, the type of military operation is the one that influences the requirements for the immersive technology at issue in this case.

At the very least, the functional and security requirements of information can be outlined for all immersive technologies, be they virtual reality, augmented reality, mixed reality or extended reality. It is also important to note that virtual military space has functional and security components.

Of course, these aspects can also be mixed as development options. For example, there are areas where virtual reality and augmented reality may be more appropriate, but there may also be effective combinations of these development areas. There are development needs that may address specific team needs and

others that may be applicable to a force as a whole. The following five military areas are examined:

- defence industry
- logistics
- education
- healthcare
- personnel measures

Defence industry

The importance of the defence industry for the military forces is unquestionable, as in many respects it includes the advanced development and production of military vehicles, equipment and related systems. The defence industry typically has a strong economic influence at both national and international level. The reasons for this are to be found in the infrastructural set-up and the foreign and domestic political situation of the nation concerned. On the international market, there are numerous military procurement processes from year to year. International cooperation in the defence industry (especially in the field of military procurement) is therefore of paramount importance in contemporary warfare. In case of research and development cooperation and procurement of military equipment, it is also important to take into account the technological knowledge that a nation may acquire during a particular programme or meeting. At present, the mapping of military development directions and the collection of related information on immersive technology is naturally an ongoing process among countries worldwide.

All of this research also affects the military industry, particularly in nations where this area is particularly diverse (for example, where aircraft, land vehicles or even naval vessels are produced). NATO's approach in this area also includes the exploration and integration of potential development opportunities for defence industry among all member countries. NATO has named this ongoing process of action Trans-Atlantic Defence technological and Industrial Cooperation (TADIC). It is also important to note that NATO holds special forums every year (i.e. NATO Industry Forums),[66] for which a special department, the NATO Industrial Advisory Group (NIAG) has been set up. "The NATO Industrial

[66] NATO: *NATO Industry Forum*. 2021c.

Advisory Group facilitates helping us find the innovation where it is and proposing to us the relevant and performing open architecture on which we can build lasting capabilities."[67] The defence industry, through its products and services, has a major influence on the evolution of warfare. A distinctive feature of the defence industry is the research and development activity carried out here, which is concentrated at the cutting edge of technology. Military superiority lies in the ability of a non-military force to integrate the technological knowledge of civilian sectors, a current challenge in the current context of intensive development. The approach to improving NATO's industrial engagement is based on three pillars:

- Structure: A framework that describes NATO and Industry roles in both non-procurement and procurement phases, on the basis of existing arrangements and NATO bodies.
- Rules: A set of principles that clarify the NATO–Industry relationship and modalities for engagement, allowing for enhanced visibility of NATO needs, increasing transparency of NATO processes, improving ways to identify opportunities for industry and identifying methods for industry to demonstrate how to apply their contributions to NATO capabilities.
- Delivery: An implementation plan that describes actions required, sets out a timetable and assigns responsibilities for execution and for reviewing the results, bearing in mind that NATO has no direct leverage on industry and market regulation.[68]

This suggests the need to define rigorous technological, supply and economic principles and objectives for the development processes in the defence industry, which can be supported by a virtual environment.

Innovative technologies are a challenge for the defence industry in all respects, which is one of the reasons why the NATO alliance emphasises the importance of regular meetings between member countries. "The level of attendance and interaction clearly demonstrated the attractiveness of the NATO Industry Forum as a key venue for open and frank debate on engagement and cooperation between NATO and Industry in the development of future capabilities."[69] Among the innovative technology options, virtual reality is currently the most prominent,

[67] NATO: *The ACT-NIAG Framework: Enhancing the Interdependency between NATO and Industry.* 2022d.

[68] NATO: *Framework for NATO Industry Engagement.* 2013. 2.

[69] NATO: *NATO Industry Forum Report.* 2021b. 3.

with a wide range of applications in industrial processes. The technology is equally applicable to the production and procurement of military-related products and services. As regards the use of virtual space in military processes, it is worth observing the largest companies in the defence sector.[70] In terms of technological production and manufacturing, virtual reality, and with it immersive technologies, can be used in all three main logical processes:

- initial processes (for example for procurement and planning, with a range of testing options)
- transformation and development processes (for example developing the capabilities of assets)
- closing processes (for example testing of a military product by the customer's military force before purchase)

As shown symbolically in Figure 38, virtual reality can also be used in maintenance tasks, where, for example, artificial intelligence can be used to identify different faulty parts on the models of any vehicle or device.

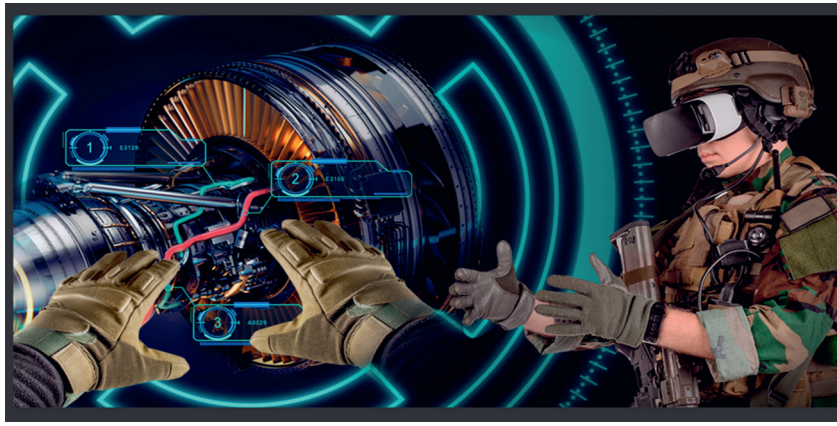

Figure 38: Illustration of the military industrial process supported by virtual environment
Source: Hayden (2020): op. cit.

The defence industry is an extremely diverse field, where virtual reality can change the way products are designed, either in concept or in testing. It can

[70] Defense News: *Top 100 for 2021.*

be a particularly powerful technology application for industries that embrace Industry 4.0, such as the defence industry. In the development of weapons, vehicles and other military products and services, virtual reality helps engineers test the results expected in a real military environment for which immersive technology can also provide advanced analysis in military development.[71]

Logistics

Military logistics is an extremely complex field, as you only have to think of the number of soldiers' food, clothing, technical and other needs that need to be met. This needs to be achieved at multiple operational levels and across multiple forces. The logistics support system (in terms of functions and tasks) is similar in the civilian and military domains. As in the case of a large company, the logistical processes of a military force are a daily activity. NATO terminology defines logistics as "the science of planning and carrying out the movement and maintenance of forces". Military logistics is a complex and unified system, which generally consists of two parts, two subsystems, producer and user logistics. The execution of producer and user logistics tasks is carried out at different military levels (tactical, operational, strategic). The complexity of military logistics is illustrated by the fact that the logistics processes include the following four main activities:

- the identification of needs
- procurement
- distribution
- conservation

In addition to the processes and functions of military logistics, it is important to mention the related principles that must be followed to make a coherent logistics system sustainable. The NATO principles include national and collective responsibility, authority, primacy of operational requirements, cooperation and coordination, assured provision, sufficiency, efficiency, simplicity, flexibility, visibility.[72] All these related logistical tasks are carried out in the following five areas:

[71] Sandrine Lasserre: *4 Use Cases for Virtual Reality in the Military and Defense Industry.* 2021.
[72] NATO: *AJP-04 Allied Joint Doctrine for Logistics.* 2018b. 1-1.

- materiel
- personnel
- facilities
- service
- health

It can be concluded from the above that the mass of tasks associated with logistics processes are extremely complex and require a significant technological background. Supporting physical activities in a virtual environment is also possible in this sector. The main functions of military logistics (planning, procurement, maintenance, transport, supply) can all be supported by immersive technology. For example, a virtual reality can be used as a training tool to perform different tasks, thus supporting logistics training. Virtually any kind of immersive technology can be envisaged to perform real-time, day-to-day tasks. For example, augmented reality with user glasses to indicate task statuses (completed or not), operation chat, new incoming task notification are among the possible improvements. Also using artificial intelligence, extended reality technology can now perform (offer to the user) logistical tasks that can take the soldier quite a long time to compute. A great example is the continuous, real-time inventory of various materiel (be it clothing, fuel or rations).

For soldiers, the logistics field is where an enormous amount of information is collected, stored, processed and transmitted. Complex logistics information environments (for example, warehousing, material handling, data analysis) can be supported to a high standard by immersive technologies.

Education

Training requires a rather complex and indispensable education system, given the general and specific needs of military operations. In many countries, familiarisation with military operations and learning of the related curricula can be started as early as secondary school education and continued through university courses. It is important to highlight the specific and distinct roles of junior non-commissioned officers, warrant officers, officers and senior officers, as well as the specific and distinct roles of high command and staff training, which are themselves important basic elements of the military education system. Each level of command requires a different teaching method but the use of immersive

technology at all levels adds a lot to the effectiveness of training and education (for example combat vehicle driving simulators, operator simulators, planning simulators, etc.).

Military training builds on these existing foundations, both theoretical and practical. The health and physical fitness required to meet these requirements, as well as psychological fitness, are also essential in order to be able to teach and acquire the military professional skills (for example in the case of military reconnaissance or rifle marksmanship). It is important to bear in mind that military training requires continuous and regular updating of knowledge, since military vehicles, equipment, systems (and thus even operational planning), in short, everything is evolving and modernising practically year by year. The training of soldiers in theoretical and practical skills must therefore always be organised in such a way that the knowledge acquired can be applied in real situations.

Military education is multifaceted and requires a significant technological background. Fortunately, like many fields, education is increasingly surrounded by infocommunication tools and systems that provide state-of-the-art technological support. Similar to civilian life, there are essentially two main types of military education in terms of the educational environment:

- physical environment, with personal participation
- virtual environments, with online or face-to-face participation (for example, in the case of simulations)

A soldier is deployed in various missions, both inside and outside the country. This makes it very difficult to organise group training with personal participation. The development of virtual environments is proving to be advantageous in many respects for training, which can thus be planned in a mobile way, even in addition to day-to-day military activities. The use of immersive technologies, in particular virtual reality, creates the potential for cost-effective and safe development of soldiers' skills. Virtual reality-based systems nowadays also provide the possibility to use a real weapon for training in virtual space with a special controller or input device (some form of hand tracking and accurate modelling of weapons). In the course of this, for example, aiming and aiming movements can be practised very well.

Soldiers can experience the exercises together or individually in the virtual space. For the various armed forces, a wide range of specialised training can be carried out in virtual space, one of the best examples being flight simulators.

Another key area of simulation is the training of sub-units, where the simulation space can be used to simulate sub-units to perform the tasks of different levels of military sub-units and to coordinate the execution of tasks between real and simulated sub-units. Training in virtual space is surprisingly effective for virtually any soldier, offering both security and advanced technological support to gain the necessary experience.

NATO will seek to initiate and implement joint developments in military training supported by virtual reality, taking into account security and functional capabilities. To this end, a dedicated organisation, the NATO Modelling and Simulation Centre of Excellence (NATO M&S COE), is now dedicated to this innovative technological area. As it can be seen in Figure 39, NATO's vision for simulation is quite complex and involves the use of immersive technologies. "The vision of the Centre is to contribute to NATO Transformation by championing the exploitation of M&S to its full potential across NATO and Nations to enhance both operational effectiveness and resource management."[73]

Figure 39: A snapshot of the NATO military simulation programme
Source: NATO M&S COE (s. a.a): op. cit.

[73] NATO M&S COE: *Mission and Vision.* s. a.b.

The importance and role of health assistance is evident both at home and abroad. The functioning of the military health care system worldwide, in relation to any nation, is due to the unfailing and tenacious service of health professionals. The health sector is the heart and soul of the military forces. This career certainly deserves special respect in the military service. Of course, this military field can also boast continuous development in terms of infocommunication technologies. In order to understand the military service and to explore the possibilities for technological support, it is worthwhile to look at the following two knowledge components:

- military medical training (the acquisition of knowledge)
- military health system (use of knowledge)

This puts the focus on the situation of prospective soldiers in training and those already serving. As regards training, it is important to mention a kind of generalised career model for military medicine, which can be divided into three main stages:

- period of university education (specific curriculum)
- residency period (post-university training, practice)
- team service (including further training and prospective career development)

First of all, the period of university education is a very heavy curriculum. It is extremely emotionally demanding when, for the first time in their lives, students are confronted with the difficulties (often with helplessness) of a military career in the medical field during clinical training.

Later, the residency period is even more demanding, requiring enormous responsibility. Residency usually involves night duty for soldiers, which is accompanied by an unpredictable work schedule. In the absence of professional experience, soldiers find it difficult to make decisions (for example on the fate of patients). To overcome this, they gain a wealth of experience despite the stress, which they can confidently use later on in their team service. Soldiers need to be familiar with the institutions, systems and equipment relevant to their profession.

In the NATO context, the activities of the NATO Centre of Excellence for Military Medicine (NATO MILMED COE) include, among other things, the provision of basic medical and leadership training. “Cooperation through

common understanding and organized teamwork is essential to provide expected standards of care in multinational healthcare facilities. Shared clinical procedures, coordination of educational and training requirements, regular exchange of training programs, and evaluation of collective medical capabilities are only some of the synergies that need constant refinement among the Allies in order to ensure combat readiness of the multinational medical force."[74]

Any immersive technology (virtual reality, augmented reality, mixed reality, extended reality) can be used to implement all these processes more efficiently. In addition to the acquisition of exercises, the complex system of military health care can be supported by virtual space in a similar way. In the performance of everyday tasks (whether training or live situation), immersive technology can help to manage information appropriately and gain a rich experience. Figure 40 shows a virtual reality-based program from a company called SimX, which was created specifically for training soldiers. The company focuses on all aspects of healthcare that can be supported by virtual technology.

Figure 40: The use of virtual reality in healthcare
Source: SimX (s. a.): op. cit.

[74] NATO MILMED COE: *Training.* s. a.

Personnel measures

Soldiers are quite often pressed for time while on duty, especially when their usual weekly working hours suddenly change. In such cases, soldiers may be deployed for longer periods to a particular location. It is therefore essential that the personal management of military personnel can be both functional and secure, and this requires appropriate technological support. Military organisations generally maintain a centralised institutional system to carry out their day-to-day personnel management tasks.

It is important to note that we are not only talking about soldiers, but also about all persons serving in the military forces, including reservists, young students, defence personnel, civil servants and other employees. A military central personnel registry institution deals with the electronic labour registration system. This includes, among other things, the management of personnel records in accordance with the law (for example, document management, personal data), planning and implementation of personnel administration tasks. All this can be achieved through the necessary infocommunication system, proposals for its modernisation are being developed. This could involve the use of immersive technologies. As regards the related human resources measures, the following main areas should be mentioned:

- recruitment (combined with presentations)
- human resource management
- administrative measures
- personnel measures
- career development measures

All of the measures listed can be supported by some form of virtual environment-enabling immersive technologies. In terms of recruitment, some of the work can be facilitated. As already mentioned, the use of virtual reality is an excellent way of assessing cognitive abilities, so that, for example, the psychological aptitude of a potential soldier can be assessed using this technology. Human resource management can be implemented either through virtual reality or augmented reality, whereby important exchanges of information can take place between the individuals and organisations involved. It is also possible, for example to virtually involve new employees in an area where there is a shortage, thus facilitating the acquisition of experience and skills.

Management actions can be similarly envisaged, whereby management meetings and discussions, workshops, forums, training courses in particular can be supported by virtual reality or augmented reality. A number of things can also be imagined in terms of virtual spaces for career planning (for example, online interviews). Individual goals are usually identified for career planning. A specific program could be designed, for example using augmented reality to provide the necessary career information and to enable participation in meetings and events to achieve the goals. Most video conferencing applications already support sharing virtual offices. It is the possibility of technology support for human resources measures that makes the current thinking really interesting.

Clearly, a virtual space programme could be developed for the soldiers' own actions, which could effectively be a virtual profile of the soldier within the organisation. Taking into account both functional and security needs, communication and specifically information modules can be built in so that soldiers can successfully manage their personal affairs through the right network and immersive technologies.

Assessment by military units

Military units are referred to in various ways in terms of their tasks and objectives. The main methods of grouping include grouping by size (i.e. squad, platoon, company, battalion, brigade, regiment, and so on) and by the activities of these units. In the following, the activity subdivision will be used, with a brief overview of the tasks of subunits and units. The fundamental aspect of the study is to understand the tasks and information needs of the different forces and to identify the technological potential that can be derived from them. The military units listed complement each other, support each other and carry out their combat activities jointly on the basis of their specific tasks.

Combat activity basically describes the tasks of the combat forces, which are supported by combat support and combat service support forces. Combat activities are aimed at disabling the enemy. Combat support activities are not aimed at the direct destruction of the enemy but at the protection and preservation of the own units and the creation of favourable conditions for combat operations contribute in part to this. Combat activities can be divided into the following four main types:

- single arms operations
- combined arms operations
- single services operations
- joint combined operations

In the context of military operations, there are some organisations whose task is to directly encounter the enemy, some that provide direct support (for example, intelligence gathering by reconnaissance forces) and some that support the objectives of the military operation through their back-office processes (for example, logistics). Either way, each activity has its own technological development potential. Both virtual reality and augmented reality, as two main areas of development, can provide useful and effective support to military operations. Immersive technologies can support military operations in all of the tasks in the division of tasks described earlier. In order to demonstrate this, the different military tasks are examined in more detail below.

The aim is to examine the possibilities of immersive technology in the light of the task system. There are two possible ways of subdividing soldiers according to their activities. The first is the subdivision according to the units with the same elements performing the same military task, in which case we can talk about units of arms (for example infantry, tankers, artillery and air defence units, which are armed forces) or specialised units (for example reconnaissance and electronic warfare, which provide data). The second subdivision can be divided into four different categories according to the roles they play in combat activities. The following subdivision will be used to examine the military potential of immersive technology:

- combat forces
- combat support forces
- combat service support forces
- special operation forces

The different categories also have different goals, that is why the focus is on the technological support possibilities for each unit's specific military activities. These units work together and the technological differences are easily reflected in the results. So, it is very necessary to apply the immersive technologies in a comprehensive way, including all the military units involved.

Combat forces

For combat forces, the right technical and cognitive skills are essential to fight the enemy, and they are used in their activities to achieve their objectives. The operational activity of combat forces is called combat activity. The operational activities of units which are aimed at and ultimately result in the direct destruction or neutralisation of the enemy are called combat operations, the operational activities of combat forces.

Based on the division of combat activities and their purpose, the combat forces are defined as follows: "Combat forces are those branches and specialised units of the armed forces which, in the context of a general or force-wide operation, conduct some form of military operations in their defined theatre of operations in order to achieve the objectives defined in their mission."[75] As has already been mentioned, the task of combat forces is to engage directly with the enemy and, consequently, to fight in direct contact based on their specific capabilities. The concentration of combat forces requires a high command priority: to achieve decisive success, combat power must be concentrated at the critical point and time. Superiority of force does not only and not primarily mean numerical superiority, but also qualitative superiority (training, practical skill, cohesion, high morale, timing, skilful choice of targets and use of modern technical equipment).

The general objective of combat forces (both offensive and defensive) is to break up and destroy the enemy's grouping and to hold or take possession of important and significant areas, terrain or objects. Combat forces perform their tasks in both peace and war, in peacetime they often perform guarding and transport tasks, while in war the main combat tasks of soldiers include the destruction and neutralisation of enemy forces and assets, the reduction and breaking of the enemy's resistance, and the capture and occupation of important districts and objects. The following two military units can be classified as combat forces:

- infantry forces
- armour forces

Combat forces use different combat techniques and methods in their activities. In carrying out their specific tasks, combat forces can nowadays achieve a very high level of network-based capability by using their digital systems. Because of their direct contact with the enemy, it is particularly important for combat

[75] Szendy (2017): op. cit. 114.

forces to have all possible technological support. Virtual capabilities can be integrated as a new information technology into the activities of the combat forces. Today's modern firearms generally have parameters that can be carried and handled by a single soldier.

During the performance of their duties (both in peace and war), infantry soldiers/units exchange a variety of information that supports successful execution. Suppose they have a complex digital system into which a virtual subsystem can be inserted. With regard to soldiers, it is worth mentioning the Adaptive Virtual Reality Training (AVRT) system developed by AVRT: "The AVRT – Adaptive Virtual Reality Training platform is a cutting edge, fully immersive and wireless free-roam VR system. Designed for the training of Emergency Services, Military and High-Risk operatives, in scenarios that may be difficult or prohibitive to simulate otherwise."[76]

Virtual reality, as will become commonplace for the rest of the military, can be of particular help in training. Two things should be highlighted here: firstly, the practice of the technical skills of the infantry soldier's own weapons (dismantling and reassembling the weapon, for several types of weapons) and secondly, the practice of operations, which saves space and time (for example in a suitably designed room, where a given squadron sub-unit can practise). Secondly, virtual reality can be used for situations where the soldier who is shooting has time to immerse himself in a full virtual environment. Examples include situation reporting, where the infantry soldier can virtually appear at the command and control point. For the soldier, augmented reality can help by displaying a range of information. In this case, it is important to consider the key information from an operational perspective. This can be sub-unit or unit information (for example, identifiers, names, statuses describing whether communication is available with the soldier), weapon information (for example, identification of the soldier's own weapon, weapon ammunition data), communication information (for example, radio main data, status, alert on calls), operational and real-time information, global positioning information for geo-location (for example, digital real-time compass and coordinates), operational chat window information, and the now essential tracking of own forces (based on incoming geo-information).

Mixed reality could mean the development of all these possibilities on a common platform. In this context, for example, the AR and VR functions (its display) of the common operational picture (COP) could be set on a selection

[76] AVRT: *AVRT – A New Dawn for Training.* s. a.

basis. Extended reality can help in solutions such as AI-based reconnaissance capabilities (generally speaking for own forces, enemy forces, assets), even identification of specific persons, objects, which can be used by gunnery soldiers both while standing and moving. Of course, this requires a database that is accessible anytime and anywhere (for example for which it is advisable to use IoT technology) and that contains the data (in quality and quantity) needed for recognition. Extended reality technology can be used to recognise the hand gestures of gunners in virtual space, enabling them to perform command and control tasks, such as monitoring and driving vehicle systems, or controlling Unmanned Ground Vehicles (UGV) and Unmanned Aerial Vehicles (UAV). These virtual solutions are of course also subject to authorisation issues, i.e. the ability to maintain a database of authorisations (with detailed information on them) during the course of extended reality gunnery tasks. The development of technological equipment for infantry soldiers has recently become extremely popular. It is the riflemen for whom the design and development of so-called digital military projects has begun. Developments have started in many countries under different project names, as well as in NATO member states (for example Land Warrior in America, Gladius in Germany, Future Integrated Soldier in Great Britain). Examples of functional concepts based on digital technology for soldiers are: positioning, target marking system, digital voice and data communication, management support system, energy supply system, sensory monitoring system, weapons system, clustered information system, modern uniform solutions.[77]

For the infantry soldier, the focus is therefore clearly on the development of specialised digital soldier systems, which can certainly be supported by immersive technology. The specific tools for rifle soldiers that may need some kind of information exchange capability can certainly be considered for the technological development of virtual reality, augmented reality, mixed reality and augmented reality. To this can be added additional infocommunication interfaces (such as vehicles, driving points, etc.) as further immersive technology development possibilities.

There are also many options for supporting tankers with immersive technology. In the following, we will therefore focus on the tasks of tanks and the virtual solutions that can be associated with them. Virtual reality can clearly be used to train soldiers for their specific tasks, taking into account the specific needs of tank crews. This is

[77] Szilveszter Szeleczki: Outlining a Set of Theory-based Requirements for the Future Digital Soldier. *AARMS,* 19, no. 1 (2020). 102–103.

also true for the commander, who can easily exercise his role in virtual reality, and for the various operators, who can receive specific practical training.

In a simulated virtual environment, the driver can gain considerable driving experience in a safe and variable terrain, learning about the design, the interconnections and practically all the parameters of the tank. In addition, as early as 2014, virtual reality technology was used to assist the driver in a real-life situation, with the help of remote cameras: "The virtual-reality Oculus Rift headset has been put to a novel use by the Norwegian army – helping soldiers to drive tanks. By mounting cameras on the outside of the tank, soldiers were able to create a 360-degree feed to the Oculus headset, worn by the driver." This is a very advantageous feature, as many tanks make it quite difficult for the driver to see out of the small windows. For the tank squadron, the use of virtual reality technology can be used to practise combat operations, driving and command and control, as well as tank maintenance procedures. In case of the driver and commander, it is worth mentioning that the IronVision helmet of Elbit Systems is designed to ensure that no crew member has to leave the tank, providing a 360-degree view through the tank's armour of X-ray images.

We are talking about an existing technology: "It employs sensor and display technology originally developed for fighter and helicopter pilots to provide a virtual 360º panoramic view of the battlefield to tank commanders and crews." As mentioned on the company's official IronVision product page, these developments could be closely related to the application of virtual reality and even extended technology in tank.

For tankers, an augmented reality platform similar to that of rifle soldiers could be envisaged, in addition to the armoured vehicle, corresponding to the individual assignment of personnel. Similarly, it would include own force tracking information, global positioning information, operational chat information, as well as key information related to the combat vehicle (status of armament and other subsystems), key information related to the own sub-unit, and logistics information (important to track the armament and related logistics functions and information from one location). In case of armoured vehicle drivers, the vehicle's augmented reality platform can be integrated with the vehicle's on-board cameras, providing the driver with a virtually transparent all-around view surrounding the vehicle, with virtual signs of the planned waypoints, navigation points, key objects, the position of friendly and hostile forces, and so on.

As a mixed reality option, the development of a platform based on the information listed so far, virtual reality and augmented reality at the same time, can

be easily imagined. It will allow any soldier in the tank squadron to observe in real time important information about the tank and its crew, whether they are inside or outside.

As a complex subsystem, this mixed reality would be connected to the basic armoured vehicle system and would be developed for fixed (mainly virtual reality) and mobile (mainly augmented reality) use. Artificial intelligence could be used here to imagine extended reality, for example to speed up decision-making (machine suggestions, display of comments, etc.).

Combat support forces

Before examining the possible support of combat support forces with immersive technology, the main tasks involved are reviewed. Combat support forces are those forces that provide direct or indirect support to combat forces, thereby creating conditions more conducive to the successful execution of their mission. It is worth noting that artillery and air defence units have the general task of destroying the enemy with weapons, yet they are not combat support units, as they do not engage the enemy directly. The activities of combat support forces are understood to be: "The operational activities of units which are aimed at or result in the release and successful employment in the operation of military capabilities which are not available to the combat forces but which ensure the successful and effective execution of the direct destruction or neutralisation of the enemy are called combat support operations."[78] The combat support forces are highly prepared and have the specialised expertise appropriate to their ranks in order to be able to carry out their tasks effectively. These forces include the following military units:

- artillery
- air defence
- reconnaissance
- technical
- chemical defence
- electronic warfare
- signal

[78] Szendy (2017): op. cit. 115.

The role of the artillery soldier is carried out in four important areas: leadership, manoeuvre, firepower and force protection. At this field, five subsystems can be distinguished in an artillery system: the command communication and information subsystem, fire control (guns, mortars, launchers) subsystem, the munitions subsystem, the supply (logistics) subsystem and the Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) subsystem. The areas of the artillery that can be supported by immersive technology can be linked to the subsystems mentioned above. Virtual technology can certainly be used to train artillery tasks, which can provide a lot of experience in the operation of the different subsystems and the complex system of artillery. Augmented reality can be used to assist in real-time communication and virtual representation of information from artillery assets. Since reconnaissance is also present in artillery, similar ideas can be developed for this subsystem as for the reconnaissance soldiers. With the development of augmented reality, a complex system of these artillery capabilities can be envisaged. The development of extended realities could already include the application of artificial intelligence to fire control assets (for example to predict ammunition depletion or important data of the logistics subsystem).

The basic tasks of the air defence forces are to protect ground units and objects from the air attack assets of the opposing side. Air defence units are already present at battalion level. Of course, the tasks are also divided among the air defence units. There are some that can use their assets to destroy aircraft that appear at a great distance and others that can destroy aircraft (planes, helicopters, drones) operating at close or short range. Accordingly, their technical means include large anti-aircraft missiles, mounted and unmounted machine guns, as well as shoulder-launched anti-aircraft missiles. When supporting air defence forces with virtual reality technology, the virtual simulation of air defences is also an option, which is the perfect way to train soldiers in their tasks. Various types of forecasting play a significant role here, where the additional fields of augmented reality, mixed reality and augmented reality can also be used.

The air defence soldier can also be informed through a special augmented reality glasses about various data of interest to him (for example, airspace events, SOS alerts and other air defence information). Mixed reality can be used to create a complex tool that can be used in training and real practice. For extended reality, again IoT, artificial intelligence and even robotics could be considered. Air defence information could be provided by robots, AI could provide the possibility to recognise hand gestures in a fast and realistic situation (for example, trained hand gestures could be used to send an alert or even a fire order).

Reconnaissance soldiers provide information to the commander. Their task is usually focused on obtaining information about the location, activities, equipment, fighting procedures and the characteristics of the terrain unknown to the opposing forces. Time plays an important role in their activities to support the commander's decision-making. The information they acquire is transmitted to the commander or to the tribe assisting the commander by various means, such as radio. Military reconnaissance forces include team scouts and depth scouts. Troop scouts provide military units in combat with data on the enemy forces in front of them. Depth scouts operate beyond the enemy's lines, away from the front line, in great depth, usually delivered by air. Their equipment consists of small arms (for example, pistol, machine gun, dagger), survival equipment (for example, fire starting equipment), data acquisition and processing equipment (for example, binoculars, compass, navigation equipment) and data transmission equipment (for example, radio, satellite mobile phone). It is important to mention that nowadays unmanned systems (UGV, UAV) are also an important element of reconnaissance, which are controlled and exchanged by the reconnaissance soldiers. For reconnaissance units, virtual reality can be used to safely practise infocommunication and weapons capabilities, as well as survival skills (such as staying reasonably close to the enemy without being detected). For data acquisition exercises, virtual reality technology-enhanced control of unmanned systems can be integrated. For augmented reality, a platform could be envisaged to collect, store, process and transmit data. In the context of extended reality, the virtual possibilities discussed so far could be combined with artificial intelligence and IoT solutions for reconnaissance being an obvious option. Artificial intelligence can be used to make many objects, persons and vehicles easier to recognise, signalling this to the reconnaissance vehicle on its own platform, while IoT technologies can be used to improve, among other things, the ability to control unmanned devices, which in turn improves virtual capabilities.

Soldiers need roads, bridges to carry out their movements. It is the job of the technical soldiers to create all these conditions in the face of changing terrain. In the defence of areas, demolition equipment is often used to slow down the enemy's movements, often involving the destruction of bridges or natural formations. Equipment is also needed to help with camouflage and fortification tasks in order to protect own forces. The technical units, with the help of their special equipment and vehicles, support the own forces in maintaining the appropriate condition and availability of the terrain. The specific task of the technical units is based on excellent human situational awareness and a properly

usable technological background. There are many opportunities to support these soldiers with immersive technology. The potential of virtual reality in training should be highlighted. Time is of essence in bridge building and other tasks. Virtual reality is an excellent tool for practising the rapid and thorough removal of obstacles. In case of augmented reality, it is worth mentioning the various situational information and alert messages, as well as the possibilities for a basic rapid exchange of information. With augmented reality, the technical team can obtain a range of relevant information about an emerging problem and the status of vehicles and equipment (for example, whether or not they are in use).

With mixed reality, the potential of virtual reality and augmented reality can be presented as a joint technology (for example, the use of training or real operational functions can be selected). Extended reality technology can support, among other things, AI-based solutions that support situational awareness as an automatic or manual function (it is a matter of performing different calculations, which are used to compare the computer with the learned patterns and provide a recommendation to the soldier). All this means that algorithms can be used, among other things, to determine whether a bridge or a road can be built at a given location or whether a platoon of technicians should try to build one at another.

In wars, toxic substances are sometimes used against enemy forces. Chemical defence units were created to protect their own forces. Chemical defence units are responsible for defending against chemical weapons, biological weapons and nuclear weapons. The execution of their tasks can be divided into two main parts, the alerting of affected (at risk) soldiers and the development and implementation of a survival procedure. The units use decontamination tools and equipment (chemical detection, data processing and transmission, decontamination – elimination of the effects of contamination, chemical pollution) to carry out their tasks. The necessary technological equipment is also of considerable importance to this unit. When considering the options for supporting chemical soldiers with immersive technology, the focus is naturally on chemicals. The training system developed for this area in virtual reality can help in the recognition of chemicals, knowledge of their characteristics and the tasks related to the necessary measures. For example, the recognition of chemicals (characterisation) and related actions can be practised in virtual reality. Augmented Reality can also help to provide brief information on chemicals and the measures to be taken through a pair of glasses (via a large database). Mixed Reality offers the possibility to develop products that can be used in training and in practice. Extended reality technology

can use artificial intelligence to identify the composition, name, etc. of chemicals based on different samples.

The tasks of electronic warfare units include for example obtaining data on the enemy, jamming and intercepting the opposing side's communications and information technology equipment, and thus preventing the enemy from leading. These units use their assets to provide protection against electronic detection, reconnaissance, jamming and interception in both visible and invisible areas. Such devices may include, for example reflecting devices, locators or jamming and identification devices. The areas of electronic warfare units are electronic support activities, electronic counter-measures and electronic defence. With regard to electronic warfare, the field of immersive technologies offers a wide range of applications. Virtual reality and augmented reality (and with it mixed reality) can be used, for example, for simulations and in real exercises (for example, to graphically display radio sources and to indicate directions for accurate positioning). Using artificial intelligence or IoT, the extended reality technology provides a great opportunity to quickly access intelligence information from data processing (machine learning of patterns from databases of devices, vehicles).

Signal units establish and maintain wireless (for example microwave systems) or wired (for example, telephone systems) communications for military units and to support IT and information security activities. In order to carry out their assigned tasks (infocommunication networks), the signal units need to have access to a wide range of deployable and stationary systems. To support their efforts, virtual reality can be used in practice, in addition to organising training, for one of the main activities specific to them: network organisation and architecture. Reporting soldiers will have to create networks based on the information they need, which can also be done using augmented reality (for example, displaying network names and frequencies as needed while moving). Mixed reality can be imagined as a complex system of all these. Extended reality can also use artificial intelligence to provide, for example, alert messages (when organising networks with identical network addresses or frequencies).

Combat service support forces

As with other units, combat support forces play an important role in military operations. The combat activities of these units include providing conditions in the following three areas:

- materiel
- technical
- administrative

Combat service support forces are specialised forces providing all-round support and insurance, which carry out their professional activities in the interests of the combat forces or combat support forces in some form of military operation defined for them, in the context of combined or force operations, and fight their professional battles in the operations, in order to achieve the objectives defined for the combat forces.[79] The combat service support forces include the following military units:

- logistical support
  - supply
  - repair
  - transport
  - infrastructure
- medical support

Combat support therefore means the provision of the material, technical and administrative conditions necessary for combat operations, for which both combat and combat support forces work together with the units. The operational activities of units which are intended to support and ensure all aspects of operations in order to guarantee the successful and effective direct destruction or neutralisation of the enemy and which result in the successful and effective execution of such operations are referred to as combat support operations, the operational activities of combat support forces.

Logistics support is concerned with planning and organising the supply, movement and sustainment of military forces. Logistical tasks are performed by supply, repair, transport and accommodation units (for example, provision of food, clothing, fuel). As already mentioned, military logistics is a complex activity for which immersive technology can be used particularly effectively. The basic task of supply lines is to deliver military equipment, materiel (for example ammunition, fuel) and foodstuffs to the users in a timely manner. These convoys are equipped with means of transport and equipment to ensure the transport of technical equipment and the movement and storage of the material received.

[79] Szendy (2017): op. cit. 119–120.

Virtual reality or augmented reality (including mixed reality) can be used to organise and manage logistics. Management could also involve the use of tools such as unmanned systems (UGV, UAV). The use of artificial intelligence would make it possible to support organisation with machine algorithms that would continuously monitor demand and supply information in real time, providing recommendations to the supplying soldiers.

Maintenance units are responsible for the operation and maintenance of various equipment and vehicles. To repair damage sustained in the field, it may be necessary to operate workshops (for example weapons, vehicles, communications equipment), taking into account the size and equipment of the unit. For the tasks of these soldiers, immersive technologies can help, not to mention all, to keep track of orders and the forces, equipment and vehicles needed for repairs. Both virtual reality and augmented reality technologies can be envisaged, as well as mixed reality. The tasks of repair lines can of course also be supported by artificial intelligence (for example, order management or fault detection assessment using machine algorithms) or robotics (for example, virtual control of robotic repair tasks), which can also be used to implement augmented reality technology. Transport squadrons can be supported by immersive technologies by providing navigation guidance, indicating the most relevant data of the associated vehicles. One of the main tasks of the accommodation units is to create, regulate and ensure the conditions for the accommodation of military organisations in the field, and to obtain and store the necessary specialised material for the accommodation in the field. Immersive technologies can be used to plan camps and carry out storage tasks. The tasks of the medical soldiers include the preservation of the health of soldiers, the treatment of sick soldiers and the care of the wounded or injured during combat activities. Health care is provided at several levels. To care for the wounded, a transport system is needed to ensure that the wounded are continuously transported to the appropriate treatment points, aid stations, centres or hospitals. All of this has already been discussed in relation to the use of immersive technologies and the possibilities for medical training (technical) and the rehabilitation of the wounded (cognitive) should be highlighted.

Special operation forces

Special military operations are those undertakings (activities) carried out by military units or paramilitary groups specially organised and trained to achieve

military, diplomatic, economic or psychological effects, with only their specific capabilities, or specially designed military units or groups.[80] Special operations have specific information needs. The planning and rehearsal of specific operations is clearly significant in the context of the bond, and can be supported by the use of immersive technologies. The virtual reality game Onward from Downpour Interactive is already capable of performing certain activities (such as communication, tactical advancement or even various building inspection tasks). "Onward is a Mil-Sim paced tactical multiplayer shooter, being developed for virtual reality head mounted displays. Players will use coordination, communication, and marksmanship skill to complete objectives in online infantry combat."[81] The company LeadTech produces accessories that can be used to model real weapons in virtual space, allowing for example to practise magazine swapping. As regards motion capture, Motion Reality, a company that deals with real-time virtual reality simulation, is worth mentioning.

In summary, the focus for special operations activities is on specific needs and their development. Using AI and IoT communication protocols, additional augmented reality technology capabilities (for example tactical chat, face and object recognition on the move) can be implemented. Supporting special operations forces with immersive technology is linked to tactical systems thinking, which will be discussed in more detail below.

Tactical systems

The development of tactical systems has recently become a very hot area worldwide, where the related developments mentioned above (network-based operational capability, interoperability capability and cyber defence) are particularly important. Tactical military operations are typically many in a year worldwide, as this level is the basis for higher-level military operations. There is a clear sense, both in nation-specific developments and in those related to NATO alliance objectives, that we are living in an era of networked warfare and that a digital revolution is underway, with advanced and high-tech systems supporting military operations.

[80] Szendy (2017): op. cit. 123.

[81] Onward: *Become Fully Immersed in the Firefight!* s. a.

Regarding the support of combat systems through virtual space, we should consider the needs of the different units and senior leadership, available info-communication technologies and related tools. The common information system used in military operations is the command and control system. The command and control system brings soldiers together during operations and is considered the most basic system (compared to other systems such as fire control, reconnaissance and others). For the sake of completeness, it is important to mention what the term means. NATO defines the command and control system as: "The authority, responsibilities and activities of military commanders in the direction and coordination of military forces as well as the implementation of orders related to the execution of operations."[82]

Command and control includes the following main processes:

- information management
- decision management
- implementation management

In order for national and federal command and control to function properly, the necessary components of an information system must be developed. The result is the so-called C2IS (Command and Control Information System), which in NATO's related document means: "An integrated system comprised of doctrine, procedures, organizational structure, personnel, equipment, facilities and communications which provides authorities at all levels with timely and adequate data to plan, direct and control their activities."[83] All of this can be achieved with greater capability in the C5ISR (Command, Control, Communications, Computers, Cyberspace, Intelligence, Surveillance, Reconnaissance) capability.

Operations involve a massive exchange of information, which can already be supported by these immersive technologies. After the various ties mentioned earlier, a slightly more comprehensive approach is now required in order to look at the ever-present technology as a tactical system. For instance, in the USA, it can already be seen that the development of immersive technology for military purposes is quite intensive. Special products (glasses) with military design and capabilities are being produced for soldiers. The project is called the Integrated Visual Augmented System, which has required an extremely high level of design, development and testing to reach the capabilities currently achieved. Figure 41

[82] NATO (2021a): op. cit. 29.

[83] NATO: *AAP-39 NATO Handbook of Land Operations Terminology.* 2015b. 2–27.

shows a symbolic picture of the military development of the immersive technology. An effective outcome can certainly be achieved in terms of developments to meet the specific needs of combat forces, combat support forces and combat service support forces. There are numerous possibilities for programming and creating different environments for virtual testing of military operations. Processes using infocommunication technologies in military operations can be widely learned and mastered, helping soldiers to acquire a routine that can be used in real situations.

Figure 41: Integrated Visual Augmented System
Source: Morozov (s. a.): op. cit.

The ability of information to work with a network-based solution is certainly an important part of a systemic approach to immersive technology. It is important to emphasise here the previous ideas (information requirements) related to combat forces, combat support forces and combat service support forces. From the perspective of immersive technology, the following main actions are required for the augmented tactical system:

- identifying the specific information needs of the units
- identification of the specific information needs of the military high command
- the definition of virtual modules by information needs, in particular in relation to the concept of a 4D operations planning platform at the main command post

- definition of interoperability requirements for virtual modules
- definition of network-based requirements for virtual modules
- definition of cyber protection requirements for virtual modules
- the arrangements for all these in relation to joint operations (see NATO requirements documents)

As a result, the main modules that are needed by all the units in the same way can be developed. Examples include global positioning, tactical chat and tracking your forces on the map. In terms of positioning, one could, for example, indicate the direction of one's own lead point (4D arrow symbol), if necessary, and also display own forces and enemy forces in 4D on the map.

In addition, specific modules for the different units can be designed. A complex system can be developed that can be used day and night, and in both training and real operations, as described in the U.S. development effort: "The US Army is actively researching the potential of AR and VR technology both for training and for use out in the field. AR equipment is becoming a big part of this development."[84]

Cooperation between organisations

For the military forces, cooperation and liaison with different organisations are of particular importance. The existence of an inter-organisational infocommunication system is essential for the execution of tasks in the defence sector in wartime, in peacetime and in times of crisis. From the point of view of a nation, it is necessary to establish a coherent, modern and, preferably, usable system between defence organisations for activities within, at and beyond the borders, preferably in all situations. In general, the following main types of organisation work closely with the military forces in the defence sector:

- police/border protection
- disaster management
- customs office
- counter-terrorism
- execution of a sentence

[84] Rob Spiegel: The Fundamentals of AR and VR – And How the Military Is Using Them. *Design News,* 22 November 2021.

As regards the use of immersive technologies, it offers a wide range of development opportunities for cooperation between defence organisations. Manual and automatic functions can be developed in a complex virtual system (for example, the possibility of sending and sharing information). The related developments should also be made mobile, so that the products can be used not only sitting at a desk in the office, but also in the field of operations, on the move. In any case, it is advisable to think in terms of complex functionality, in which both general and specific needs can be programmed. To explore these needs, the focus should of course be on efficient solutions for information exchange between organisations.

Virtual reality can be used to organise and conduct meetings and discussions, whereby managers from different organisations can meet in a virtual space. In this virtual space, a number of development directions can be envisaged in relation to three-dimensional objects. For example, it is conceivable to include tools, vehicles or other objects for demonstration purposes in the virtual space, which could be used to answer important strategic questions by the participants, who would also be present virtually at the meeting place. There is also the possibility of immersive developments that allow soldiers and police officers to enter the perspective of a wide field of view camera, while carrying out a border mission.

Augmented reality easily puts mobility and information exchange at the heart of the development. In the operational field, an augmented reality technology can create fused capabilities between information from the military force and others (such as the police). A soldier's own glasses can project police data (for example, on a particular person or object). Augmented reality can also provide basic functions such as Blue Force Tracking, Tactical Chat, and the sending and receiving of specific symbols from organisations. All of this can be mixed with the potential of virtual reality to develop highly effective capabilities.

Thinking in terms of collaboration between organisations, AI and IoT, as well as robotics, also hold huge potential for immersive technology. IoT can of course be harnessed in the creation of a communications network, whereby specific assets of organisations can be networked in a uniform way. In terms of artificial intelligence for example, the own learning algorithms and associated servers of organisations could be linked together, resulting in a military being able to identify a person in the field of operation from a police database, through a computer. The robots could be controlled in the same way by organisations thanks to a common, extended technology. With all these ideas in mind, there is surely a lot of potential for developing defence-global, collaborative, immersive technology.

Summary

Our modern information society is characterised by intense technological change. People are surrounded by a myriad of information in their daily lives. Whatever the personal activity, infocommunication tools and their network-based systems are virtually ubiquitous. Information is exchanged on a daily basis through infocommunication networks, with virtual environments playing an increasingly important role. As a result, related technologies, such as immersive technologies, are constantly evolving.

Developments in two, three and four dimensions have become increasingly popular for the creation of virtual environments. The development thinking in virtual reality is becoming more sophisticated as time goes by. From the historical background described earlier, it is clear that people have long been interested in exploring the possibilities of developing immersive experiences. By the 21st century, there are already quite a number of people involved in the development of immersive technologies and the creation of related services and products. The development of all these functional and security capabilities is being accompanied by technologies such as artificial intelligence, the internet of things and the phenomenon of big data for data analysis. There is now a wealth of documentation available to help understand the different types of immersive technologies, including the differences between virtual reality, augmented reality, mixed reality and extended reality.

In many respects, immersive technologies have an impact on the information society today. As discussed above, economic, developmental and social impacts have been highlighted. By approaching the issue from these perspectives, the social relevance of these immersive technologies has been demonstrated. The knowledge and proposals for the development of these technologies, economic indicators and forecasts, and the main possible impacts in social contexts are mentioned.

On the economic side, popular products have been developed by famous companies such as Microsoft, Meta and Google. These products have a significant market role, which is reflected in the economic indicators. It was also mentioned that activities in the virtual environment could be seen as a kind of public assistance, whereby different companies could freely exercise their own ideas and the related design, development and testing processes without any risk. This is, of course, only a hypothesis, but it is equally an opportunity for

any nation to boost the economic and technological development of different businesses. The economic studies have shown that there is clearly a significant place for evergreen technologies in the sales and marketing sector. Increasing technological demands and the corresponding increase in users also lead to a rise in economic indicators.

In terms of development, it is highly recommended to acquire a deeper understanding of the use of immersive technologies and to organise the design, development and testing processes thoroughly. Several methodologies can be used for development, including DevOps and SecOps methodologies, as well as the popular agile approach to development. Key design ideas and recommended activities were shared. Skills that are expected of developers in the development process were highlighted, such as problem-solving skills, organisation and time management skills and programming languages. Development requires continuous testing, for which two types of testing were described, functional and non-functional. With regard to the immersive technologies, a number of test cases can be created for development in four dimensions. It is essential to create the right environment for the different development processes, ensuring that the products can be tested in four dimensions and in a free-moving environment.

It is strongly recommended that professional groups involved in development focus on collaborative processes, which provide a great opportunity for high-level development of virtual reality, augmented reality, mixed reality and extended reality supported by additional technologies. There is clear evidence of a strong interest in delivering immersive experiences. In the development areas described, such as education, tourism, health, finance and personal administration, the diversity of the potential of technology has become apparent. Examples were presented in each of these areas, demonstrating the relevance and versatility of the related developments.

For the sake of completeness, topics related to virtual environments, such as the social impact of related technologies were also mentioned. Apart from the economic and development approach, the social perspective of virtual environments is clearly a less popular area. Nevertheless, it is clear from what has been described that this formal approach is highly recommended, as it raises unseen effects such as the forces of personalisation, ethical changes and manifestations of virtual environments. It is worth observing how virtual environments relate to our contemporary information-based society. The main physical environments surrounding people are specifically mentioned, such as family, workplace and

leisure activities. Every possible opportunity should be taken to ensure that the use of virtual environments in addition to real ones does not upset the physical and mental balance. It has been demonstrated that these invisible effects (for example addiction, behavioural disorders) should be kept under control.

In addition to the civilian applications of immersive technologies, military applications are also becoming increasingly common. As in the civilian field, military development is a kind of interdisciplinary technological concept. In order to understand military objectives, it is important to read documents that explicitly describe military requirements, of which NATO requirements are a great example. For NATO, several documents have been used to describe technologies considered important for the development of virtual environments, such as interoperability, network operations capability, cyber defence, among others. Immersive technologies can be clearly envisioned as networked, for which the appropriate interoperability capability needs to be developed from both a functional and a security perspective. Cyber defence is nowadays a very important part of military operations, involving virtually all technologies.

The military forces have a rather complex organisational structure, as exemplified by the Hungarian Defence Forces. There are many development opportunities for the various armed forces, in which immersive technologies can play an important role. As described earlier, this paper deals mainly with land force, which is a great starting point for exploring the development potential of any force. The paper provides information on various military sectors and formations, for which virtual reality, augmented reality, mixed reality and extended reality have all emerged as great development opportunities.

The potential for the application of immersive technology in the military, logistics, education, health and various personal measures is described. A number of developments have already taken place in the military domain, which have also led to the development of ever-technological support for the various military units. For military units, there are specific needs that can be met by technological developments. From the military application perspective, the support of the tactical systems explained with virtual environments supporting the continuous exchange of information within a team with new functionalities was discussed. Focusing on the overall activities of the military organisation, the cooperation of military forces with other organisations was discussed, whereby immersive technologies also offer state-of-the-art possibilities.

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Conclusions

Our information society is clearly characterised by a number of intense technological developments. These developments are present in both the civil and military domains. The development of immersive technologies is emerging as an innovative opportunity, and in many different ways. Virtual reality, augmented reality, mixed reality and extended reality can all make people's daily lives more efficient. In many respects, immersive technologies have an impact on people's sense of reality and on a wide range of aspects of it.

From the civil world, it is essential to consider the social advantages and disadvantages of virtual environments. From an economic point of view, virtual reality products will increasingly appear in various statistics. There is a sense of competition between related companies, which is natural for an innovative technology. As a result, a wide range of functionalities can be achieved, as a number of development options are being considered by the professionals of the various companies. The development of products from Microsoft, Meta and Google is clearly being observed by the leaders of civil and military organisations. In the civilian sector, specific areas in which the technologies in question have already been used have been presented, demonstrating the effectiveness of these innovative products in all-day operations. As regards development companies, it is essential to acquire a comprehensive knowledge of the immersive technologies and it is recommended that market analyses are carried out before any company starts development. These are rapidly evolving technologies and it is worth joining their development at the right time.

The metaverse was also introduced as a currently rather futuristic vision of virtual environments. There is certainly a reality to it, as Mark Zuckerberg argues, and in the future people will be increasingly surrounded by virtual spaces, which could lead to a reform of the Internet itself, creating a four-dimensional global network. Thinking in this way will certainly contribute to the future effective use of virtual reality and with it of ubiquitous technologies worldwide.

In addition to civilian applications, the military use of immersive technologies is also an area that raises a number of issues. In this specific field, it is important to understand the impact of immersive technologies on military forces. It is essential to clarify the capabilities required for military infocommunication systems, thus outlining the so-called interdisciplinary field of development. The link between cyber defence, interoperability and the development of network-based

operational capabilities and the development of immersive technologies has been demonstrated. In addition, artificial intelligence, or IoT, as described from the civilian side, can certainly be linked to the development of virtual environments specifically for military purposes.

In the midst of these developments, command and control systems at different levels (tactical, operational and strategic) can be supported by immersive technologies. The role and development potential of integration is particularly important for virtual reality, augmented reality, mixed reality and extended reality products that meet military requirements. In addition, military leaders should already be thinking about military metaverse concepts. Multi-domain operations and with it the Common Operation Picture (COP) can be supported by immersive technologies. A global vision of all these will be necessary in the future. In any case, it is advisable to think in terms of integrated systems for training and real-world exercises for the various vehicles and equipment, as the power of all these has been proven. As a result of the development of specialised digital military systems, immersive technologies will clearly contribute more than ever before to the modern and more efficient implementation of an integrated Battle Management System (BMS).

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Today, our society is surrounded by cutting-edge technologies in many areas. The presence of mass information exchange possibilities has an impact on everyday events. At present, the true effectiveness of extending physical space with virtual space remains to be discovered. The development of immersive technologies is still in its infancy, but many people in the world are looking forward to sharing experiences and demonstrating results. Virtual reality is well known, but only few professional writings summarise the topic with all the associated terms and technologies. So let us take a look at what the whole world is talking about, what virtual reality is and its related segments. Nowadays, it is useful to talk about military applications alongside civilian life, and the following will explain why.

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