The role of the Metaverse in the military domain

Andrei-Alexandru NEDELCU, Ionuț PETRE

National Institute for Research and Development in Informatics – ICI Bucharest, Romania

andrei.nedelcu@ici.ro, ionuț.petre@ici.ro

Abstract: This article explores the transformative impact of the Metaverse on military operations, focusing on how Virtual Reality (VR) and Augmented reality (AR) technologies are revolutionizing training, communication and technological development within the defense sector. The Metaverse enables realistic simulations of combat scenarios and military operations in a risk-free virtual environment, enhancing decision-making capabilities and operational efficiency. It facilitates real-time communication and coordination among geographically dispersed personnel and offers detailed terrain and resource analysis for informed strategic planning. Additionally, the Metaverse serves as a testing ground for advanced military technologies, allowing pre-deployment adjustments. Case studies, such as VR pilot training and command system simulations, highlight its effectiveness in improving training outcomes and reducing costs.

Keywords: Metaverse in Military Research, Virtual Reality and Weapons, Optimization of Design and Testing Processes, Operational Efficiency in Armed Forces, Digital Integration in Military Systems Development.

Rolul Metaversului în domeniul militar

Rezumat: Acest articol explorează impactul transformator al Metaversului asupra operațiunilor militare, concentrându-se pe modul în care tehnologiile realitatea virtuală (VR) și realitate augmentată (AR) revoluționează instruirea, comunicarea și dezvoltarea tehnologică în sectorul apărării. Metaversul permite simulări realiste ale scenariilor de luptă și operațiunilor militare într-un mediu virtual fără riscuri, îmbunătățind capacitățile de luare a deciziilor și eficiența operațională. Acesta facilitează comunicarea și coordonarea în timp real între personalul dispersat geografic și oferă analize detaliate ale terenului și resurselor pentru o planificare strategică informată. De asemenea, Metaversul funcționează ca un teren de testare pentru tehnologii militare avansate, permițând ajustări înainte de desfășurare. Studiile de caz, precum antrenamentul piloților în realitate virtuală și simulările sistemelor de comandă, subliniază eficiența sa în îmbunătățirea rezultatelor instruirii și reducerea costurilor.

Cuvinte cheie: Metavers în cercetarea militară, realitate virtuală și arme, optimizarea proceselor de proiectare și testare, eficiența operațională în forțele armate, integrarea digitală în dezvoltarea sistemelor militare.

1. Introduction

The Metaverse, a wide virtual environment integrating Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), is reshaping the military sector by addressing key challenges in training, communication and technology development. This immersive technology provides a secure, interactive space for realistic simulations, allowing military personnel to practice and refine their skills without the risks and costs associated with traditional methods. A proper security level is essential, since a higher-than-necessary security level translates into additional operational costs and/or reduced functionality, while a lower-than-necessary security level leads to users not trusting and not using the system (Dumitrache & Sandu, 2020). In training, the Metaverse enables the creation of detailed combat scenarios where soldiers and commanders can safely rehearse maneuvers and decision-making. It enhances communication and collaboration by facilitating real-time interaction among geographically dispersed units, improving coordination and decision-making. Additionally, the Metaverse serves as a platform for testing and developing new military technologies, accelerating their evaluation and refinement before real-world deployment. This chapter explores the transformative impact of the Metaverse on military practices, highlighting its potential to improve efficiency, reduce costs and enhance operational effectiveness.

The Metaverse, this extended and interactive virtual reality, has become a widely discussed and researched topic in numerous fields in recent years. This innovation has captured attention in the IT industry, video games, education, medicine, art, socialization, and also in the military domain. A key moment in the evolution of the Metaverse was the founding of the first academic program in virtual reality (VR) by Michael Zyda at the University of California, Los Angeles

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(UCLA) in the early 2000s. This program played a pioneering role in preparing students to engage in the field of virtual reality and simulation (Zyda, 2005a). Concurrently, Albert Rizzo became known for his research on the use of virtual reality in the treatment of post-traumatic stress disorders (PTSD) in the military (Rizzo et al., 2017). Belinda Lange made significant contributions to the research and development of VR applications for training and therapy in the military, focusing particularly on stress and anxiety management (Rizzo et al., 2011). In the same context, Sheryl Brahnam conducted notable research in the field of human-machine interaction and virtual reality, with relevant applications in military context (Brahnam & Lakhmi, 2011).

The aim of this paper is to examine the impact of the Metaverse on military research and development, focusing on how VR and AR technologies contribute to optimizing design and testing processes, enhancing operational efficiency, and reducing costs. By investigating these aspects, the paper seeks to highlight the transformative benefits of the Metaverse in military contexts and provide a comprehensive understanding of its applications.

To guide the reader, this paper is structured as follows: Section 2 explores the applications of the Metaverse in the military domain, including its role in training, communication, analysis, and technology development. Section 3 examines virtual training and simulations on military ranges, detailing their evolution and practical applications. Section 4 assesses the impact of VR and AR technologies on military training, focusing on performance evaluation, efficiency, and cost reduction. Section 5 discusses the Metaverse's role in battlefield analysis and decision-making, emphasizing its contributions to tactical and strategic planning. Section 6 delves into research and development efforts within the Metaverse, analyzing how the virtual environment supports military innovation and technology testing. Finally, Section 7 summarizes the key findings and reflects on the future potential of the Metaverse in military research and development.

This structured approach aims to provide a thorough analysis of the Metaverse's influence on military practices and its future implications.

2. The Metaverse in the military domain

The Metaverse represents a promising perspective in a military context, providing an extended and interactive virtual environment that can transform how military personnel and commanders interact, train, and make real-time decisions. Below are highlighted some key aspects of the impact of the Metaverse in the military domain (Fawkes & Cheshire, 2019):

1. **Training and Simulation:** The Metaverse allows realistic simulation of combat scenarios and military operations. This secure virtual environment provides soldiers and commanders with the opportunity to train and make critical decisions without risks to lives or costly equipment (Easley, 2022; Hajjami & Park, 2023).
2. **Communication and Collaboration:** By facilitating real-time communication and collaboration among geographically dispersed military personnel and commanders, the Metaverse optimizes the rapid exchange of information, coordination of operations, and efficient decision-making in critical situations. Access to updated information and coordinated actions becomes more effective (Zhang et al., 2023).
3. **Analysis and Planning:** Using the Metaverse for a detailed analysis of terrain, objectives, and resources before a military operation enhances commanders' ability to assess scenarios, develop strategies, and anticipate operation outcomes. It provides a comprehensive perspective for informed decisions (Kenny, 2022).
4. **Testing and Technology Development:** The Metaverse becomes a conducive ground for testing and developing military technologies, such as weapon systems, surveillance equipment, or autonomous vehicles. Evaluating the effectiveness of these technologies in a virtual environment allows adjustments before their real-world implementation (Wired, 2022).

Through these applications, the Metaverse emerges as a versatile tool with significant potential in transforming military practices and enhancing operational efficiency.

3. Virtual training and simulations on military ranges

3.1. Virtual training on the military range

Military training has become an increasingly technology-driven field, mainly due to the desire to minimize exposure to hazards and preserve the confidentiality of military tactics and technologies (Herrero & De Antonio, 2005). The need for simulating reality among military personnel is crucial, as conducting "on-field training" in the context of warfare is not always possible. Sometimes, it's extremely challenging to expose military personnel to the real, both mental and physical, challenges of military life. In such situations, it becomes essential to retreat into some form of unreality, and this is where specially designed VR applications for the military come into play.

A significant aspect of VR-based simulation is that it provides an environment where risky and complex maneuvers can be carried out, which might be difficult to achieve in real life on actual equipment. VR's ability to simulate equipment malfunctions, unfavorable weather conditions, or any unexpected scenario becomes possible without endangering lives or damaging expensive equipment. This represents the most apparent application of virtual reality in a military context.

The scope of combat simulators is vast, covering airplanes, helicopters, frigates, submarines, tanks and many more, with all defense departments benefiting from virtual reality simulators. The use of the metaverse in military ranges opens new perspectives and enhances the training capabilities of the armed forces. Simulations and virtual training are essential components of the metaverse in the military domain, providing an opportunity to replicate and practice complex military scenarios in a safe and controlled environment.

3.2. Advanced simulators for military forces

Military training can be perilous and fraught with risks, with many soldiers succumbing to non-combat causes or accidents every year (Mann & Fischer, 2019). Technologies have enabled us to simulate different environmental conditions, such as day and night, various weather types, and other scenarios (Rushmeier et al., 2019). Armies have begun to use simulation software or serious games as training tools. Hussain (2009) developed the Flooding Control Trainer (FTC) to train new recruits in various skills in the U.S. Navy. The U.S. Air Force has started experimenting with VR training to complement traditional hands-on training through the Aviator Training Next (ATN) program. Preliminary results suggested that VR training produced pilots of the same quality and competence as those trained in an actual aircraft (Dalladaku et al., 2019).

Traditional training methods are often limited by the real training environment and specific devices or equipment. VR training provides a safe and controlled virtual environment at a relatively low cost for armies to practice technical skills and enhance cognitive functions (Zyda M.,2005b). Many traditional training methods require specific locations or equipment sets.

In 2016, Siu created a specialized VR surgical training system for healthcare personnel transitioning from operations to civilian activities (Siu et al., 2016). The training system addresses the needs and essential skills for military personnel and dynamically generates optimal training tasks for healthcare workers to enhance their efficiency in requalification.

Another similar scenario where VR has significantly improved the quality and conditions of training compared to the traditional method was presented by Taupiac (Taupiac et al., 2019). The authors created a virtual reality training software that helps French Army infantry learn the procedure for calibrating IR sighting devices on a combat system called FELIN. To practice on the actual FELIN system, soldiers must repeatedly practice on traditional software until they make no mistakes. The traditional system provides only a 2D program to practice the calibration procedure, while the new VR method allows them to practice in a virtual environment using the 3D-printed rifle model, providing control and a usage feel similar to the real counterpart. An ad hoc study was conducted on a group of French soldiers to compare the two methods. The result indicated that the VR method significantly improved the soldiers' learning efficiency and intrinsic motivation to perform training tasks (Taupiac et al., 2019).

The study led by Greunke and Sadagic, have validated that VR training yields comparable results to real-world training (Greunke & Sadagic, 2016). Overall, VR technologies make significant contributions to technical military training, reducing costs by partially replacing traditional equipment with more affordable VR devices. While they don't completely replace traditional equipment, they represent an efficient and more economical alternative for training.

3.2.1. Advanced simulators for air forces

The 2H111 Landing Signal Officer Trainer is situated in Oceana, Virginia, and is utilized to train all air traffic directors (DTAs) over time. To create an immersive environment, the room comprises multiple large screens and physical representations of real instructions. Due to these constraints, each DTA must share the equipment housing room, leaving gaps between training periods.

Figure 1. DTA VR (Greunke & Sadagic, 2016)

Greunke and Sadagic devised a lightweight DTA VR training system, as depicted in Figure 1 and Figure 2, utilizing commercially available devices to support the capabilities of the 2H111 Device (Greunke & Sadagic, 2016). In addition to the basic capabilities of the 2H111, the DTA VR training system included extra features not offered by 2H111, such as voice recognition and visual cues to aid trainees in virtual environments. This approach was presented to real-world DTAs at a DTA school, where a side-by-side comparison was conducted.

Figure 2. Comparison of 2H111 System and VR System (Greunke & Sadagic, 2016)

Feedback was positive. Following a similar model, Doneda and de Oliveira created the Helicopter Visual Signal Simulator (HVSS) to further enhance DTA trainees' skills after theoretical studies (Doneda & Oliveira, 2020). A user study was conducted with 15 DTAs, where a VR simulator was created for the Brazilian army, allowing the instructor to train observers at minimal cost and without space limitations. The simulator was validated with 13 experienced artillery officers. Results indicated that the simulator met expectations in terms of both presence and effectiveness.

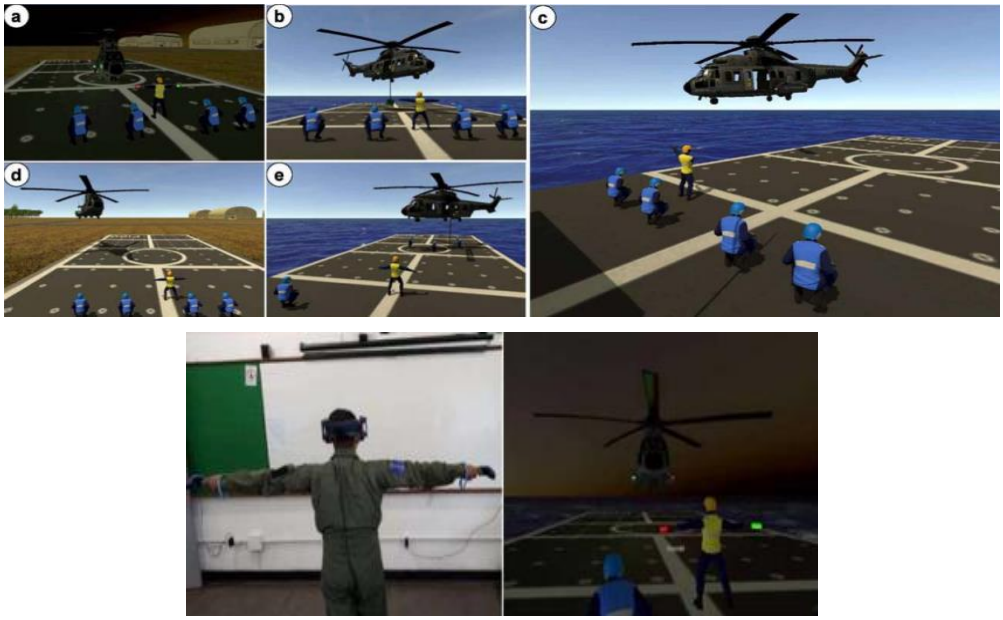

Figure 3. HVSS Simulator (Doneda & Oliveira, 2020)

The Aviation Combined Arms Tactical Trainer-Aviation (AVCATT-A) is a helicopter combat training system that employs virtual reality simulation, as depicted in Figure 3. The system can simulate five types of helicopters - AH-64A Apache, AH-64D Longbow Apache, OH 58D Kiowa Warrior, UH-60 Black Hawk, and CH-47D Chinook. AVCATT-A is exclusively a helicopter combat training simulator and is not a flight simulator. There is no degree of motion, and it does not provide trainees with the sensation of piloting a helicopter. Only instruments specific to combat operations are usable. The system's purpose is to train fighters to enhance their skills rather than assist novice pilots. AVCATT-A provides realistic training conditions by generating a virtual environment with combat smoke, snow or dust, as well as changes in wind, visibility, temperature, and cloud conditions. The system uses a Head-Mounted Display (HMD) device on which the VR combat simulation visuals are created. When the trainee moves their head, the VR world is automatically redrawn. Developers have created so-called masks that provide a representation of the cockpit.

3.2.2. Advanced Simulators for Ground Vehicles

Virtual Reality (VR) technologies open new horizons in military training, especially in the simulation of vehicles. These simulators, developed by researchers and specialists, provide a sophisticated platform that accurately reproduces the appearance, sensations and maneuverability of various military vehicles. Through the use of VR devices, soldiers can experience an unprecedented level of immersion and reality, surpassing traditional methods with a mouse and keyboard or a car simulator wheel.

The VR vehicle simulator can faithfully recreate diverse terrains and various weather conditions, thus providing an extremely realistic training environment, as depicted in Figure 4. Soldiers can navigate specific environments, from reconstructed urban settlements to specific terrain areas from any part of the world. This is not limited to simulating the appearance and maneuverability of vehicles but can also include various roles that a soldier might have in that vehicle, such as a driver, gunner, or member of a rescue team. From light reconnaissance tanks to Non-Line-of-Sight (NLOS) unmanned mortars, all of these can be detailed in the simulation, providing a comprehensive framework for military training. By simulating every aspect of the vehicle and battle scenarios, soldiers can refine their skills in a virtual environment without the risks associated with real-field training.

Figure 4. Military Vehicle Simulator
(photo courtesy of the U.S. army, photo by Jason Kaye)

4. The Impact of VR and AR technology in military trening

Virtual Reality (VR) and Augmented Reality (AR): Through the use of VR technology, military personnel can immerse themselves in a virtual environment, making them feel as if they are in a real-life scenario, as depicted in Figure 5. This could involve simulating a battlefield, tactical missions, or command and control operations. Using virtual reality headsets and specialized controllers, soldiers can interact with the virtual environment, practicing different skills and strategies. This provides an opportunity to test and develop skills and tactics in a safe and controlled manner. Augmented reality is the process in which the user simultaneously sees the physical world and the virtual world, where virtual information is overlaid and aligned with the visuals of the physical world (Azuma, 1997). The defense sector is interested in the possibilities of interconnecting VR and AR systems for simultaneous collaboration. The VR system consists of a three-dimensional database that maps the outdoor environment where the AR user is. The AR user, a soldier, is displayed as a 3D avatar. The AR user wears a portable computer that transmits GPS signals to the VR system, which, in turn creates an avatar for the user in that location. The VR user can create a new object in the virtual world, which is visible to the AR user in the external environment.

Figure 5. Simulating Reality Using VR (Azuma, 1997)

There is an application of this technology in the military domain, where it enhances the **effectiveness of combat soldiers**. This way, the soldier can be aware of nearby friendly and enemy troops. This means that cues regarding threats, locations of friendly forces and positions of aircraft are visible to the AR user. The AR user can communicate with the base station and is alerted to the environmental situation. On the other hand, the base station receives information about the current situation on the battlefield and can update the status of the three-dimensional model. As mentioned, there are mutual benefits for the soldier and the command center through the exchange of information, which is useful in real-time training or battle/combat simulations. It is possible to generate large battle environments where fictional entities can be placed, such as soldiers, vehicles

and aircraft. Additionally, real entities can be added to the environment where both can participate in an exercise. With this application, simulating combat training becomes possible at lower costs (Piekarski et al., 1999).

The assessment of performance within simulated environments is a critical aspect of using Virtual Reality (VR) in military training. By collecting and analyzing data generated during virtual exercises, VR provides a rich source of information for the meticulous evaluation of both individual and collective soldier performance. The collection of data during virtual training allows the recording of soldiers' actions and reactions, providing a detailed overview of their behavior in different simulated combat scenarios. This information serves to identify the strengths and weaknesses of each individual, facilitating the process of improving their training. The VR system also enables soldiers to connect in the same virtual environment, allowing real-time collaboration to solve complex missions. This makes team performance assessment possible, analyzing their ability to coordinate actions, communicate effectively, and achieve set objectives. Beyond assessing human performance, VR can be utilized for evaluating and testing military equipment. Virtual simulations allow the analysis of equipment characteristics and performance in various simulated combat scenarios. This contributes to identifying necessary improvements and making informed decisions regarding the acquisition and implementation of military equipment. In conclusion, the use of VR in military training provides a comprehensive approach to performance evaluation. It allows a detailed understanding of individual and collective behavior, facilitates improvement processes, and extends to the evaluation of military equipment. The insights gained through this process contribute to informed decision-making regarding the acquisition and implementation of military technologies.

The optimization of efficiency and reduction of costs associated with military training represent a significant advantage offered by Virtual Reality (VR) technology. This technology eliminates the need for massive consumption of material and human resources in traditional field exercises. In a virtual environment, soldiers can undergo repeated and focused training without the logistical challenges of transporting and managing real equipment and ammunition. This results in a substantial reduction in costs related to the acquisition, maintenance of equipment, and the consumption of ammunition and fuel Furthermore, VR technology eliminates or minimizes the risks associated with traditional training exercises. In field exercises, there is always the possibility of accidents, injuries, or even fatalities. Through the use of VR technology, soldiers can practice and simulate hazardous combat situations in a safe and controlled environment, thereby reducing risks to their lives and physical integrity. The increased flexibility in scheduling and conducting exercises is another benefit of VR technology. Soldiers can train at any time and in any location, eliminating restrictions imposed by weather conditions or the availability of physical training grounds. This facilitates better planning and efficient utilization of time and resources.

Virtual simulations and training through VR and Augmented Reality (AR) technologies represent an efficient and innovative way to prepare and enhance soldiers in various aspects of military activities. These technologies provide a safe, repeatable and adaptable environment for honing skills, developing strategies, and evaluating performance. Through these technologies, soldiers can gain experience and confidence before facing real-life situations, contributing to the overall increase in military efficiency and capabilities.

5. The Role of the Metaverse in battlefield analysis and decision-making

Through the Metaverse, military personnel can gain a more comprehensive perspective on tactical and strategic situations. They can visualize the terrain in detail, obtain real-time information about identified objectives and threats, as well as the movements and positions of both friendly and adversarial forces. This three-dimensional and interactive visualization facilitates analysis and understanding of the situation, aiding in the identification of optimal courses of action. The Metaverse also allows the simulation and testing of various scenarios and strategies, enabling military personnel to assess the effectiveness of different actions and plans, anticipate decision consequences, and identify the best options to achieve set objectives. This simulation and testing capability contribute to risk reduction and operational efficiency.

In the realm of command and decision-making in battle, the application of the Metaverse and associated technologies (VR/AR) primarily involves two aspects. Firstly, by synthesizing realistic three-dimensional battlefield scenarios based on acquired information data, command personnel can comprehend the entire battlefield situation in a more visual and intuitive manner. Secondly, the use of VR-based tactical analysis technology is employed to conduct simulation analyses on the decision-making plan proposed by command personnel, aiming to provide better reference information for decision-making.

During the battle phase, the simulation system based on analysis and VR technology can repeatedly simulate and analyze the decision-making plan established by the commander, offering the best choice for the battle plan. The analytical simulation system can provide not only a realistic three-dimensional battlefield environment but also visualize the outcome of the commander's decision-making plan execution. This enables the commander to understand at a glance a series of possible consequences of the decision-making plan. Commanders can select and propose high-quality decision-making programs, using them as reference.

Firstly, commanders must understand the current and future battle situation in order to make good strategic decisions, known as command and control. Secondly, commanders need to plan and evaluate possible force movements, termed planning and modeling. Currently, command and control, as well as planning and modeling, are primarily carried out using paper maps and acetate overlays. Some data is input into a computer system where it can be analyzed and utilized by a battlefield visualization system. New developments allow the use of digitized information without the need for direct human effort in a battlefield visualization system.

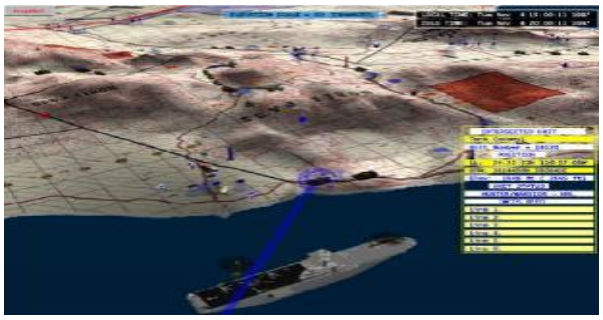

Figure 6. Battlefield Simulation through Augmented Reality (Girardi et al., 2019)

The battlefield visualization system uses an interactive virtual workspace platform, as depicted in Figure 6. This platform provides a 3D display in a workstation-like environment, where information about the battlefield can be utilized. This information includes a topographic map, entities representing various units (eg., friendly, hostile, unknown and neutral), obstacles, key points on the battlefield, and other features. Virtual reality receives updated information about the current state of the battlefield, such as the number of units, their position, direction, speed and damage, ensuring real-time situational updates. Users can view the map from different angles and query and manipulate entities within the virtual environment (Girardi et al., 2019).

Another advantage of the Metaverse in analysis and decision-making is the ability to access and integrate a variety of information sources. Military personnel can benefit from data and information from different systems and sensors, such as satellite images, information reports, weather data and more. By integrating this information into a virtual environment, military personnel can obtain a completer and more up-to-date picture of the situation and make more informed and well-founded decisions.

6. Military research and development in metaverse

Research and Development (R&D) constitute a fundamental element of military progress, and the integration of the metaverse brings an innovative dimension that supports activities in this field. An adequate cyber defense makes threats manageable, to the extent that residual risks seem largely acceptable, similar to those speciffic to the classic threats (Vevera, 2016). The Metaverse

provides a virtual and interactive environment where researchers and developers can experiment with and test various military concepts and technologies.

The virtual production of weapons becomes a crucial application area for virtual reality technology. In the design and development of weapons, this technology offers advanced demonstration capabilities, allowing developers and users to immerse themselves in the virtual environment of combat to operate weapon systems authentically. This process enables the testing of design schemes, the evaluation of tactical and technical performance indicators, and the integration of innovative ideas throughout the weapons development process, accelerating the development cycle and assessing their operational effectiveness.

Concrete examples, such as the US Air Force's F-22 and JSF fighter planes, have benefited significantly from the integration of VR technology into their development process. The adoption of 3D digital design and manufacturing has reduced the development cycle by 50% and lowered costs by over 93%. Additionally, the CVN21 aircraft carrier became the first carrier entirely designed in a virtual environment, shown in Figure 7, with VR technology bringing significant benefits in reducing the development cycle and associated costs (Zhang et al., 2023).

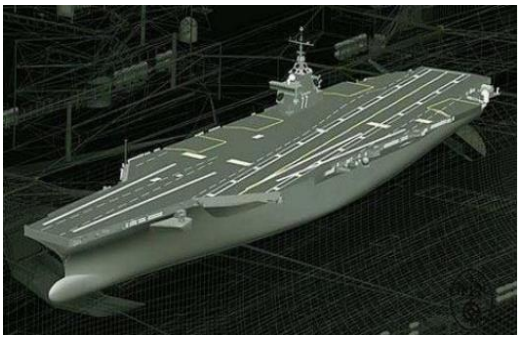

Figure 7. CVN21 Aircraft Carrier Prototype in Augmented Reality (Zhang et al., 2023)

7. Conclusions

The Metaverse is reshaping the military sector by revolutionizing training, communicatio, and technology development through immersive VR, AR and MR technologies. It provides a secure and interactive environment for realistic simulations, enabling military personnel to practice and refine their skills without the risks and costs associated with traditional methods. This innovative technology facilitates realistic combat scenarios for training, enhances real-time communication and collaboration among geographically dispersed units, and supports detailed analysis and planning of military operations. The application of the Metaverse in military training allows complex maneuvers and scenarios to be simulated safely and effectively. VR and AR technologies contribute significantly to performance evaluation, operational efficiency and cost reduction, offering a controlled environment for testing and developing military equipment. The ability to visualize and simulate battlefield scenarios provides military personnel with a comprehensive perspective, enhancing decision-making and strategy development.

Overall, the Metaverse proves to be a transformative tool in military research and development, optimizing training processes, improving collaboration, and advancing technology testing. Its integration into military practices promises to redefine standards, increase efficiency, and enhance the preparedness of armed forces, reflecting its substantial potential and future impact on the sector.

In light of the transformative impact of the Metaverse on the military sector, future research will focus on several key areas to further explore its potential. One significant direction will be the development of advanced mixed reality (MR) simulators that integrate elements of augmented reality (AR) and virtual reality (VR) for tactical training. For example, designing and testing MR simulators that replicate complex scenarios, such as reconnaissance missions and crisis management, will provide immersive and interactive experiences for military personnel. Additionally, research will deepen the use of VR technologies for the evaluation and optimization

of military equipment, including virtual simulations of vehicles that allow adjustments before physical production. Another avenue of exploration will be the application of AR platforms for enhancing coordination among geographically dispersed units, enabling real-time visualization and interaction with tactical data. Furthermore, the impact of virtual simulations on strategic planning will be analyzed to provide detailed insights into potential outcomes of various operational scenarios. These research directions are poised to advance the understanding and application of the Metaverse in the military field, optimizing current practices and reflecting a continued commitment to innovation and modernization in military operations.

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Andrei-Alexandru NEDELCU is a computer science engineer specializing in cybersecurity, with an extensive academic background, including a Bachelor's degree in Computer Science and a Master's degree in Information Technology Security, both obtained from the Military Technical Academy "Ferdinand I." His undergraduate and master's theses focused on evaluating files using SandBox technologies, as well as implementing proactive security methods based on Zero Trust architecture. Currently, he works as a scientific research assistant at the National Institute for Research and Development in Informatics (ICI) in Bucharest, within the Cybersecurity and Critical Infrastructures Department. Previously, he held positions as a cyber security engineer, network configurator, and application developer. Among the significant projects in which Andrei-Alexandru Nedelcu has participated are the Workshop SCADA VM Windows Privilege, where he explored SCADA system security and privilege management in Windows, CURS SCADA SECURITY Cyber Security, an in-depth course dedicated to SCADA system security, and Cyber Range for Industrial Control Systems – ROCYRAN, where he contributed to developing a simulation environment for testing industrial control systems. He has also been involved in Metaverse Advanced Research and Emerging Technologies for the Digital Transformation of Society, where he investigates the impact of emerging technologies and the Metaverse on the digital

transformation of society. Recently, Andrei-Alexandru Nedelcu was admitted to the PhD program in Computer Science and Information Technology at the Doctoral School of Automation and Computers, emphasizing his ongoing commitment to research and innovation.

Andrei-Alexandru NEDELCU este inginer în informatică, specializat în securitatea cibernetică, cu o pregătire academică extensivă, incluzând o diplomă de licență în Computer Science și o diplomă de master în Securitatea Tehnologiilor Informației, ambele obținute la Academia Tehnică Militară „Ferdinand I". Lucrările sale de licență și masterat s-au concentrat pe evaluarea fișierelor utilizând tehnologii de tip SandBox, precum și pe implementarea metodelor proactive de securitate bazate pe arhitectura Zero Trust. În prezent, lucrează ca asistent de cercetare științifică la Institutul Național de Cercetare-Dezvoltare în Informatică -ICI București, în cadrul Departamentului de Securitate Cibernetică și Infrastructuri Critice. Anterior, a ocupat funcții de inginer în securitate cibernetică, configurator de rețele și dezvoltator de aplicații. Printre proiectele importante la care Andrei-Alexandru Nedelcu a participat se numără Workshop SCADA VM Windows Privilege, în cadrul căruia a explorat securitatea sistemelor SCADA și gestionarea privilegiilor în Windows, CURS SCADA SECURITY Cyber Security, un curs aprofundat dedicat securității sistemelor SCADA și Cyber Range for Industrial Control Systems – ROCYRAN, unde a avut o contribuție în dezvoltarea unui mediu de simulare pentru testarea sistemelor de control industrial. De asemenea, a fost implicat în Metaverse Advanced Research and Emerging Technologies for the Digital Transformation of Society, unde investighează impactul tehnologiilor emergente și al Metaverse asupra transformării digitale a societății. Recent, Andrei-Alexandru Nedelcu a fost admis la programul de doctorat în Calculatoare și Tehnologia Informației al Școlii Doctorale de Automatică și Calculatoare, subliniind angajamentul său continuu față de cercetare și inovație.

Ionuț PETRE graduated from the Faculty of Electronics, Telecommunications, and Information Technology at the National University of Science and Technology POLITEHNICA Bucharest in 2005. He is currently a Grade II Scientific Researcher and leads the Department of Transformation and Governance at the National Institute for Research and Development in Informatics - ICI Bucharest. He also oversees the XR Innolab innovation lab. His research interests include Smart City, XR technologies, Machine Learning, Big Data, resource management, data processing, software development, and integration. With over 15 years of experience in research and development projects, Ionuț Petre has published articles as author and co-author in prestigious journals and has delivered scientific presentations at national and international conferences in the field.

Ionuț PETRE a absolvit Facultatea de Electronică, Telecomunicații și Tehnologia Informației, Universitatea Națională de Știință și Tehnologie POLITEHNICA București, în 2005. În prezent, este cercetător științific gradul II și conduce Departamentul de Transformare și Guvernanță, din cadrul Institutului Național de Cercetare-Dezvoltare în Informatică - ICI București. De asemenea, coordonează laboratorul de inovare XR Innolab. Interesele sale de cercetare includ Smart City, tehnologii XR, Machine Learning, Big Data, managementul resurselor, procesarea datelor, dezvoltare și integrare software. Cu o experiență de peste 15 ani în proiecte de cercetare-dezvoltare, Ionuț Petre a publicat, în calitate de autor și coautor, articole în jurnale de prestigiu și a susținut prezentări științifice la conferințe naționale și internaționale în domeniu.