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ACCELERATING THE DELIVERY OF TECHNOLOGY TO THE WARFIGHTER USING COLLABORATIVE IMMERSIVE XR TECHNOLOGY ENVIRONMENTS & TOOLS

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ABSTRACT

As technology continues to improve at a rapid pace, many organizations are attempting to define their place within this modern age and the Department of Defense (DoD) is no exception. The DoD's primary focus on modernization ensures that its design, development, and sustainment of systems demonstrate unparalleled strength that outpaces our adversaries and continue to solidify our position quickly and efficiently as the world's mightiest through fundamental change.

Digital Engineering (DE) is the foundation of that fundamental change. Speed-to-Warfighter, reliability, maintainability, resiliency, and performance are all improved through DE techniques. Accelerating technical integration by connecting once isolated data to a digital thread encompassing all domains, and further facilitating the evolution of the traditional approach/processes into an effective DE strategy. DE's goal supports a reduction of inefficient process/procedures/communications that traditionally can yield slow iteration, inconsistent resource management, limited participation, and more while promoting mitigating efficiencies.

This document explores a DE approach that allows for stakeholder/user collaboration daily using a model centric environment connected through the digital thread and supports the DoD's 2018 DE strategy implementation. It provides easy and efficient information sharing with one input informing and directly impacting the inputs/outputs of the connected model; creating one authoritative source of truth. Demonstrations and support can readily be provided using existing tools and enabling the ability to complete iterations in minutes or hours instead of weeks or months. It also supports early collaboration, evaluations, and reviews using immersive and XR (augmented/virtual/mixed reality) technologies utilizing both concepts of augmented reality to virtual reality to improve overall efficiency and decision making throughout the product lifecycle. Additionally, the utilization of XR provides many other benefits that allow for a variety of more in-depth applications involving human in the loop practices promoting efficiency, consistency, validation, verification, and facilitates *performance and knowledge boost of processes, procedures, and end-user applications. Through the use of XR immersive technologies the technological landscape is quickly shifting and evolving in how data is consumed in many areas including industry, government, commercial, and academics. This document demonstrates actual proofs of concept of this evolutionary change in conjunction with DE practices to demonstrate military adoption and processes that support collaboration, evaluation, and opportunities for quicker project completion or stage progression with XR.*

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1. INTRODUCTION

Evolutionary technologies are seen throughout history and have managed to have a significant impact on life or quality of life from the creations of the pulley to the computer and other highly technological advances. It is also known that the production of new more efficient and beneficial technologies or processes provide a foundation to build upon for the next greatest technological improvement providing us with the new state-of-the-art approaches and technology. Although all approaches of evolutionary concepts of technological change may vary, the end result based on the improvement and changes in technology to promote efficient solutions producing new technology supporting this continual change and growth towards the ultimate solution [1] [2]. One of the newer technological changes focuses on digital environments that provide quick iteration capabilities with constant change, fast improvements and fixes, various user interactions, and complex solutions that were not possible a decade ago.

To accommodate this change there needs to be a solution to allow for the proper adoption of the technology and digital engineering helps facilitate methods of channeling this rapid digital growth, and the use of immersive technology is assisting in the further evolution of this technological solution [2]. A subset of immersive technology known as XR denoting augmented, virtual, and mixed reality technology will be the primary focus of this document and its ability to improve approaches in digital engineering supporting the digital thread. Proofs of concept in conjunction with DE practices to demonstrate military adoption and processes that support collaboration, evaluation, and opportunities for quicker project completion or stage progression with XR will be shown throughout this document.

1.1 Traditional and Digital Engineering Approaches

Although technology has progressed throughout the years, there will always be a difference between the old and new. Here the traditional and digital engineering approaches provide an idealization of that transition in human efforts to prioritize improvement in many domains.

Traditional methods and processes have promoted work environments where engineers and designers work independently, are document centric, models and documents are standalone, provides a disjoint set of artifacts, where manual effort is required to maintain and update, are labor intensive and time consuming to commit changes, slow iteration, with formal reviews obstructing engineer productive time, and it is difficult to get stakeholder participation.

Digital engineering, on the other hand, allows for stakeholder collaboration daily, a model centric environment, digital thread model connections, easy and efficient information sharing, one input informs and directly impacts inputs/outputs of connected models and applications creating one authoritative source of truth, the ability to support and regularly provide customer demos, works with existing tools, enables the ability to complete iterations in minutes or hours instead of weeks or months, and early collaborative evaluations using immersive and XR technology to improve overall efficiency and decision making.

2. IMMERSIVE TECHNOLOGY AND XR – AUGMENTED, VIRTUAL, AND MIXED REALITIES

XR is defined in this case as the use of augmented, virtual, and mixed reality, while immersive technology can encompass many other technologies that may be used to provide an absorbing immersive environment for users, XR represents a subset of that domain [3]. Immersive technology has also been described as a computer-generated simulation of reality with physical, spatial, and visual dimensions that allows for the creation of interactive technology utilized by architects, science, engineering researchers, the arts, entertainment, and the video game industry [4]. XR provides the conduit to bridge the gap between realities with a focus on integrating the concepts into a digital engineering process essentially providing a unique perspective to consuming and understanding data. Depicted in figure 1, the Reality – Virtuality Continuum illustration shows various immersion types along a continuum charting the transition from the real-world environment to fully virtual immersion that governs the user's experience and use of XR immersive technologies.

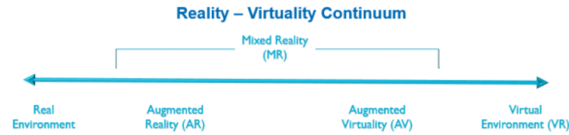

Figure 1: Reality – Virtuality Continuum

XR technology use also has had multiple hurdles that it has encounter throughout history, from its early limited computation resources and capabilities demonstrated by Ivan Sutherland in the 1960s such as the Sword of Damocles showcasing the use of head mounted displays CRT lens representing one of its initial beginnings [4] [5]. As time progresses, resources and hurdles are being surmounted that now present capabilities demonstrating the maturation of the technology enabling it for use in everyday communication and other applicable experiences that warrants its use [6] [7]. XR's transcendence of being known as only a gaming technology places it in a state to support digital engineering efforts in a more serious form that can yield real world applicable results in various areas including industry, military, government, and education; this document will be used to demonstrate some of those virtual reality use cases [8]. Although the approaches used can be easily transferred into both augmented and mixed reality environments as well [9].

3. XR ENABLING DIGITAL ENGINEERING

Digital engineering in this context references an integrated digital approach that uses systems data and models across disciplines to support lifecycle activities from concept through disposal. Models are used to digitally represent the systems of interest (i.e., systems of systems, systems, processes, equipment, products, and parts). It also enables stakeholders to interact with digital technologies and solve problems in new and ground-breaking ways providing a more agile and responsive development environment. Additional benefits of using digital engineering include informed decision making, greater insight through increased transparency, enhanced communication and collaboration, greater flexibility and adaptability in design, improved performance and mission assurance, increased acquisition efficiency, risk management, and a reduction in execution cost.

There are many benefits to gain from this digital engineering approach, and the use of XR further expands on those benefits and allows for a higher degree of transparency in addition to bringing the human into the digital loop essentially optimizing the digital thread even more. This supports the evolution of the environment and operational capabilities using an emerging technology. Typically, the user is limited to representative material such as computer aided design (CAD) or other architectural/equipment modeling content. Utilizing XR significantly boosters the visualization and interaction processes supporting participants' ability to be able to visually see, interact, discover, and understand the product or components [10]. As a result of incorporating XR into digital engineering many other benefits arise that allow for a variety of more in-depth applications involving human in the loop practices promoting efficiency, consistency, validation, verification, and facilitates performance and knowledge boost of processes, procedures, and end-user applications [3] [11]. Examples of the XR content combined with digital engineering will be shown within this text as proofs of concept providing final representations on CAD to XR Ready Objects, a proprietary XR application, collaboration, evaluation, and military project adoption and uses. Although these examples are specific to the work conducted, it is important to understand that this approach is not limited to these specific applications and can be adapted to represent multiple environments in industry, commercial, military, and academics [8]. Modeling or immersive experience results also can support augmented, virtual, and mixed reality objectives. Additionally, this XR approach has also been applied to multiple entities including U.S. Army, Navy, and Air Force, NASA, industrial, and other commercial applications.

4. XR IMMERSIVE CAPABILITIES AND PROCESSES

4.1. CAD to XR Ready Objects

To begin this approach there is a need to gather digital engineering model data to initiate the conversion process into something usable for an XR immersive experience. Some digitally stored or created content may be originally designed in unfavorable formats suitable for XR usage. Figure 2 illustrates an example of the final CAD output of the CAD to XR Ready Object process that initially began with 40,576 polygons that was reduced to a more optimized version containing only 5,870 polygons. The left image indicates the original CAD, while the right image represents a processed model with a lower polycount. In order to mold the data into more favorable content a combination of modeling and CAD tools and processes are used to process, visualize, and provide immersive experiences that are reflective of project goals and objectives. These tools may consist of 3D geometrical applications that allow for augmenting the model's geometrical structures used to define the piece of geometry into a final product feasible for XR consumption. The reduction provides a better model that is suitable for mobile devices, such as the Quest 2 virtual reality headset without compromising the original design of the CAD model. This approach ensures that any models generated are suitable for mobile platforms, and also supports devices or equipment that have more computational power than today's cell phones including desktop applications.

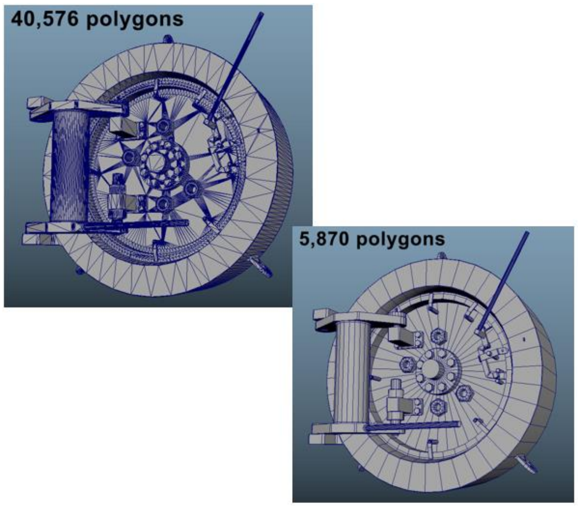

Figure 2: Initial CAD Conversion for XR Ready Objects

Additional steps involve the verification and validation of the model data, as well as preparations and understanding the required parameters to generate this content in a meaningful immersive context.

4.2 Proprietary XR One App Application Solution

The One App is an innovative software application within the tech stack that is used to support the development and usage of multiple applications in one convenient location. The application itself is able to host various immersive experiences from 3D desktop applications to fully immersive experiences for its users. In real time, the user can choose to experience a multitude of environments made available to them through administrative control.

Administrative controls provide an additional level of content security only allowing users to see and interact with content associated with their level of authorization. Additionally, the application lowers the technical skill required for operation, essentially eliminating the need for a high-level of technical knowledge. By significantly reducing the level of skill required to operate the application the user base is immediately broadened. The One App supports the alleviation of the user's requirement to navigate the complex process of generating immersive content and the challenges associated with it.

This tool provides an essential component to the approach of providing immersive XR experiences of various types while also providing direct procedural control, collaboration, and situational awareness between administrators and users. It also supports additional collaboration functionality including voice, multiplayer capabilities providing a sense of presence, user location negligibility, and can be directly tied into the digital thread's operations. Figure 3 below demonstrates the One App process powered by an accelerated development program for quick and efficient immersive environment production known as XRXL and the consumption of generated XR Ready Objects through content to create an immersive experience.

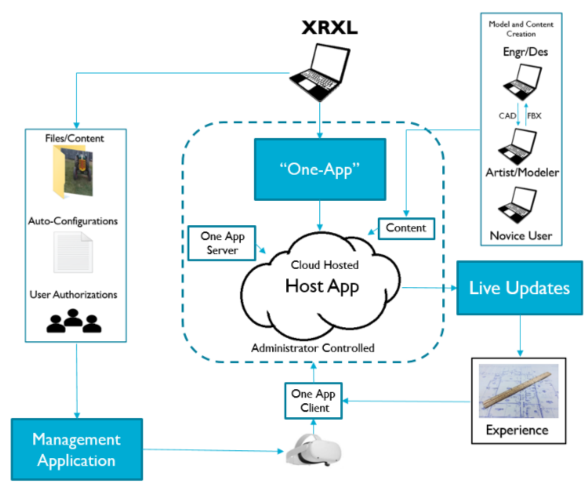

Figure 3: The One App Process

4.3 Virtual Rapid Prototyping Military Application

This project was commissioned under the Army National Guard (ARNG) G-2 Military Intelligence Services and Support (MISS)

Task Order (TO) and demonstrates a real world application of using virtual reality for rapid environment prototyping. The purpose of this work was to provide the Army National Guard (ARNG) G-2 and its strategic partners with intelligence services and support. Including integrated training, program business operations and consulting, engineering, logistics, and ancillary information technology products and services to enable ARNG G-2 to provide efficient and dynamic Military Intelligence (MI) training support and increase readiness for the Warfighter. The initial challenge was to develop an efficient operational space within an ISO container that can be transported and deployed at various locations using virtual reality shown in figures 4 through 11.

The solution integrated an immersive virtual environment representative of the three-dimensional CAD model and provides a sense of scale to support critical decision making and configuration efforts. Immersive technology was utilized to produce a virtual environment that supports a single or multi-user experience and collaboration via a virtual space to provide a digital immersive solution to gain an immersive sense of scale, spatial awareness, and a unique perspective to evaluate the configuration of the environment before committing to a final design.

Figures 4 and 5 illustrates the gathering of data from the original source provided through digital engineering practices that support the conversion process into accurate XR Ready Objects.

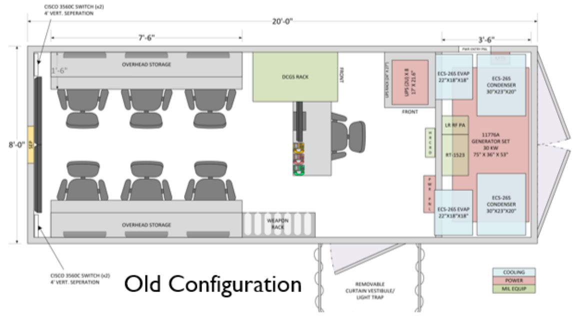

Figure 4: Demonstrates the Original 2D CAD Layout

Figure 5: ISO Container 3D CAD

Figure 6 represents a quick turn-around within days to generate an alpha version composed of the immersive environment to initiate the quick feedback loop provided by the XR experience generation procedures that focus on collaboration, communication, and verification and validation. This ensures that the end goal remains in focus as repeatable quick iterations are completed to generate the final immersive environment.

Figure 6: CAD Conversion to XR Ready Content – Alpha Proof of Concept

The content represented by figure 7 shows revision one demonstrating the quick transition from the alpha phase of the XR immersive experience into a phase that introduces the transportation ground vehicle that transports the container, voice integration, generic avatars supporting the sense of presence and control, and other interactive components. The first revision provided an environment that supported spatial awareness for the user, and generated multiple changes due to the ability of being virtually informed and gaining a perspective of situational awareness that cannot be obtained through the use of CAD or other similar desktop related applications. The application of the XRXL development tool allowed for this seamless transition to take place in a matter of days.

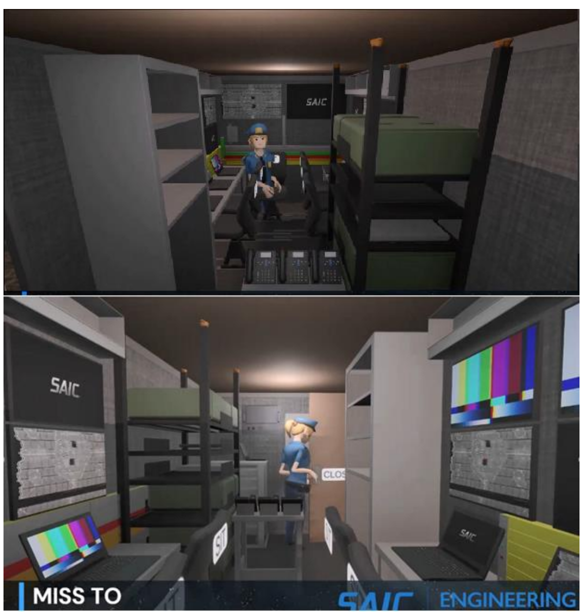

Figure 7: XR Fast Feedback Loop Revision One – ISO Container's Interior Operations Environment

Figure 8 reflects added changes that directly impact both functionality and environmental concepts of the immersive environment with the addition of a black lighting feature that activated and deactivated upon entering and exiting the container. This feature was requested as a result of revision one feedback, and it provided greater fidelity to the immersive environment.

Figure 8: Sample of Black Lighting Addition and Change via Quick Feedback Loop

Some additional interactive capabilities were added such as maintenance laptop interactivity, more realistic avatar representations with animations, and other functionality that focused on security, storage, representation of the actual environment, and the proper utilization of space and equipment to benefit the warfighter in figure 9.

Figure 9: Accelerated Changes in Revisions Two and Three

After the completion of revisions two and three the XR immersive process identified multiple deficiencies in the original CAD design which resulted in a complete reconfiguration of the environment to optimize soldier environment operation and performance. The CAD designed presented an adequate design initially, but through the ability to gain spatial awareness and scale in a collaborative multi-user immersive experience changes were made, shown in figure 10 and 11, to reflect a more optimized environment. This process demonstrated that the spatial validation could be shown within the CAD environment adequately, but the verification within the XR immersive environment did not reflect that same validity prompting an immediate design change.

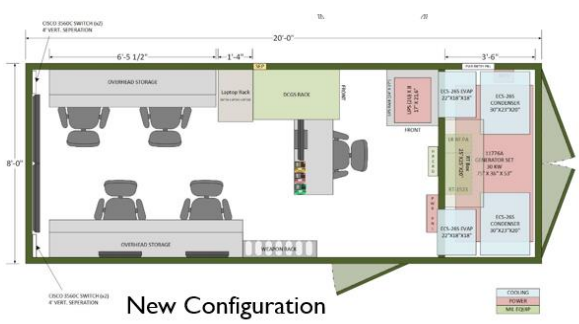

Figure 10: Virtually Informed Optimized New CAD Layout

MISS TO combine multiple design factors including transport, deployment, HSI, and the development of a functional design, in addition to the use of virtual reality for rapid environment prototyping and configuration to evaluate a transportable command and control environment while utilizing the limited space of a 20-foot ISO container. MISS TO demonstrated SAIC's ability to keep stakeholders readily informed and involved through virtual rapid prototyping, virtually informed decision making, faster iteration, immediate feedback and team collaboration, and quick configuration updates for changes or additions to the proposed project. As a result, the immersive impact led to substantial changes to the original design to boost functionality and the ability to perform, as well as generating the consideration of other factors that may influence the productiveness of the environment such as engine room configuration, noise pollution, container access and storage, etc. This serves as a primary example of combining both CAD to XR Ready Objects and One App application deployment of XR solutions into a final result that allowed for evaluation and collaboration between essential personnel to design and agree upon a final design before ever actually procuring materials and constructing the unit. This approach provided a significant reduction in time and cost saving by utilizing virtual reality within our XR immersive experience creation to identify and solve prototyping challenges early.

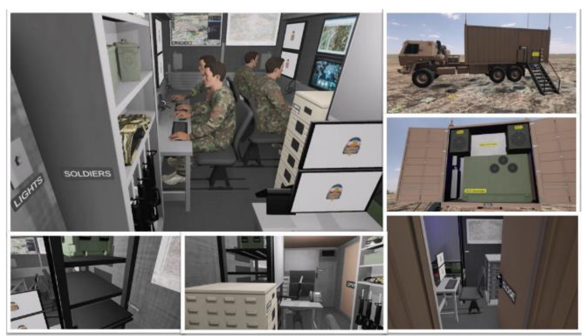

Figure 11: Virtual Rapid Prototyping of the MISS TO Warfighter Environment

5. SUMMARY

When using immersive technologies in various combinations with digital engineering including capturing the content to be modeled and reproduced properly, and whether in the context of CAD or other methods the information has to be converted into three-dimensional, virtual reality, or augmented reality ready immersive content [12]. That process may vary depending on the nature of the process, hardware, and software solutions used. Another challenge relates to the environment and functional development of an immersive environment that may include but is not limited to world generation, accurate simulation development, user interface design, and user interaction functionality. Additionally, there will be a need to develop collaborative functionality in relation to the tools that teams may require to collaborate within an immersive virtual space including concepts related to security and content distribution [13] [14] [15].

The examples demonstrated within this text addresses those challenges and has the flexibility to make many more adjustments to properly support digital engineering and the digital thread. The ability to directly operate from content contained within the source of truth solidifies this approach in using XR to enable digital engineering to ensure the delivery of meaningful content in multiple areas including military, production, facility management, training, and other applications.

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