A New Reality

How the Marine Corps can leverage technologies like mixed reality to meet future training, sustainment, and operational requirements

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Prepare to put down your controllers and step into the game—there is a new reality coming. The tectonic shift in naval warfare thinking stemming from 38th *Commandant's Planning Guidance* (Washington, DC: HQMC, July 2019) released a year ago should only hasten its arrival. To outpace near-peer competitors, the Marine Corps acquisition community is rapidly developing and advocating for new paradigms in technology, including mixed reality, to deliver advanced capabilities that equip Marines for joint force operating concepts like *Expeditionary Advance Based Operations*.

As the Marine Corps' acquisition workforce drives forward, its adversaries are not standing still—the moment new capabilities are introduced, counter-capabilities are developed. In a tit-for-tat, equipment-fielding battle, the acquisition community has to maintain its advantage. It must be capable of building open, modular systems for rapid reconfiguration in new and unimagined ways. It needs speed and agility to ready the Marine Corps for conflict and postured to adjust fire at a moment's notice—especially when one's hand is tipped to the adversary before the point of conflict.

In parallel to shifts in strategic thinking, the complexity of Marine Corps systems has also increased. Marines are quickly moving into a futuristic era in which once mechanically based instruments of war are being replaced with complex electrical- and software-based systems that can lead to more advanced warfighting but also introduce the potential for data and sensory overload.

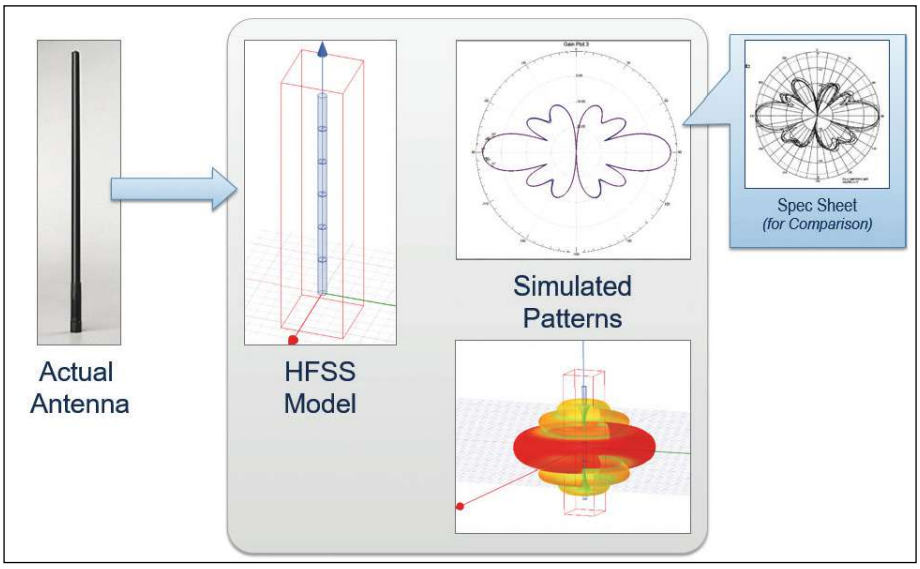
Meanwhile, program managers, technologists, and engineers see this and are stepping out to develop and field equipment that give Marines the advantage in scenarios germane to the *Commandant's Planning Guidance*. That means that today's generation of gear will be overcome by the next generation. For instance, today's tactical vehicles—the JLTV and LAV now, the amphibious combat vehicle and amphibious reconnaissance vehicle eventually—will become smarter vehicles, designed with autonomous systems, advanced electronic warfare/signals intelligence sensors and payloads, artificial intelligence cognitive aids, conditions-based maintenance, and more.

All of this illustrates how the pace of new technologies and capability requirements far exceeds that of new vehicle platforms, creating ever-evolving challenges in the world of land systems integration. Yet, acquisition professionals know failure is not an option in satisfying mission requirements within the allowable constraints of size, weight, and power. Fortunately, the tools coming out of the DOD's digital transformation are offering solutions for the acquisition community and operational Marines to leverage in overcoming these challenges and maintaining battlefield superiority.

This article explains how the Marine Corps acquisition community, supported by innovative engineering professionals, is leveraging digital engineering tools and methodologies to streamline the development and integration of new technologies. The DOD's *Digital Engineering Strategy,* (Washington, DC: June 2018) highlights the importance of enabling stakeholders to not only interact with digital technologies but also "solve problems in new and groundbreaking ways." Going forward, it will be critical to continue implementing recently proven and efficient practices like model based systems engineering (MBSE) while also embracing other ones now emerging, in particular, mixed reality: a powerful and promising technology that encompasses the continuum from virtual reality (VR) to augmented reality (AR) and could significantly improve the daily functions of Marines in the training, sustainment, and operational domains.

Over the past five years, the Digital Integration Facility at Naval Information Warfare Center (NIWC) Atlantic has been leveraging digital technologies to improve the efficiency and effectiveness of integrating and fielding vehicular capability packages. By leveraging digital engineering tools like physical modeling and simulation while also employing MBSE practices, the systems become smarter, as do the Marines.

Through the use of multi-physics modeling tools combined with additive



High Frequency Structure Simulator (HFSS) used to model a vehicle antenna, showing a near identical match to the manufacturer's specification sheet. *(Image provided by author.)*

manufacturing, engineers are able to more quickly run through lower-cost prototype iterations, ensuring the final design is a near guarantee in form, fit, and function once it is fabricated. Coupled with finite element analysis, simulations check performance under various shock and vibration conditions, thus enabling engineers to have a ruggedized design that reduces surprises during testing. In the electrical domain, these tools are used to characterize and analyze antenna propagation and co-site interference, ensuring optimum antenna placement and awareness of the electromagnetic signature.

These modeling and simulation tools of the physical hardware are crucial to understanding the physical limitations of the systems. Depending on the complexity of an antenna and quality of its model, radio frequency pattern/gain, and co-site interference, these simulations are typically 80 to 90 percent accurate when compared with physical test results. This level of accuracy is more than adequate to make an engineering decision with the option to be verified by testing. This robust radio frequency modeling and simulation capability leads to a significant reduction in cost and schedule by not having to test and retest multiple antenna configurations during vehicle integration. In order to realize these same benefits in streamlined delivery, MBSE can be leveraged to optimize the systems engineering workforce.

By taking a model-based systems engineering approach to system design, engineers can spend less time managing documentation-based artifacts and more time solving technical challenges. While a model-based approach requires a certain level of initial investment, once established, the results and efficiencies gained can be significant. One noteworthy payoff is the reusability of models that enables programs to reuse parts or whole models from prior programs rather than starting with a blank slate. Just as a picture is worth a thousand words, engineers will no longer be digesting endless documents to understand the systems. Instead, they will be on the same page, speaking the same language, and viewing a familiar model of systems. Using MBSE allows systems engineers to not only model the physical architecture of a system (or system of systems) but includes the behavioral characteristics as well. This allows for greater understanding and traceability of requirements as well as identifying interoperability issues through the modeling of various mission thread scenarios. Additionally, acquisition professionals may simulate various mission threads through behavioral diagrams, such as use case, activity, sequence, and state machine. Doing this provides a quick way to identify interoperability issues or gain an awareness of unintended behaviors of the system.

To demonstrate the impact of MBSE, NIWC Atlantic engineers modeled several systems that were part of a digital call for fire of a HIMARS firing unit using variable message format communication protocols. An activity diagram was used to simulate the sequence of events as part of this mission thread for Island Marauder 2019. Additionally, block definition diagrams and internal block diagrams were used to model interoperability requirements. Doing this assessment automatically revealed a previously verified communications issue which required no

One step in the AR demo guide for installing a VRC radio using a JLTV model. *(Photo by author.)*

hardware setup. While the problems could have been identified, the legacy documentation-based systems engineering approach requires a lot more effort and is prone to easily missing small pieces of information. The MBSE approach helps solve some of these challenges and enables more analysis earlier in the design cycle to catch these types of interoperability errors. Prior to having the ability to model this system of systems and its mission threads, the systems engineers and operators could not tell from the mission-level documentation if the proposed messages had all the necessary information. Now, with the integrated model, message contents can be tested and easily validated for a given situation.

As the adoption of MBSE matures so will the tools advancing the practice. An example includes a recent effort to develop a tool capable of automatically converting a system model to software code and vice versa. This capability will generate synergy between the systems and software engineers, creating the ability to maintain traceability and the integrity of data between the systems and software developers. When software engineers advance their code, updates will be made to the system model and provide visibility into the impact on the requirements. Likewise, as requirements change and the system model is updated, these updates will be transferred into the software code. With all the data and information that comes through physical- and system-level modeling, new technologies are constantly emerging to support this digital transformation. As alluded to earlier, the DOD's *Digital Engineering Strategy* acknowledges that systems engineering complexities require a new way of doing acquisition, and that digital engineering will enable the use of models throughout the lifecycle to digitally represent the system of interest in the virtual world, whether that is a system of systems, a process, a piece of equipment, or a part. Consequently, there may be no better way to expand horizons in the virtual world than with mixed reality.

Mixed reality has the potential to not only completely transform much of how capabilities are fielded in tactical vehicles but also how the Marines will train and operate. As mentioned, mixed reality covers the spectrum from VR to AR, whereas VR is the technology in which a user can be completely immersed in a simulated virtual environment and AR displays holographic virtual content within the user's field of view, without occluding them from seeing their physical surroundings. Mixed reality will transition the user from being a spectator playing games with a controller to stepping inside the game and living it. Likewise, acquisition community members will put down their manuals and documents to become hands-free and fully absorbed in the tasks at hand. By combining VR and AR, mixed reality stands to be a key enabler throughout the acquisition community and operational Marine forces.

NIWC Atlantic is adopting the use of AR and VR technologies both in the process of engineering design, simulation, testing, and installation, as well as into the systems undergoing development themselves. With a team of engineers skilled in the development of mixed reality, more affordable training is possible by removing the physical and logistical constraints dealing with physical hardware. In addition, virtualized environments are capable of creating highly realistic training, such as simulating battlefield conditions. As identified in the Training and Education Command's "Vision & Strategy For 21st Century Learning" (Quantico, VA: 2020-2030) document,

> Commanders and unit leaders must have the ability to augment in real time the traditional live training events with simulation, augmented and virtual realities, and enhanced war-gaming in order to better train as they expect and intend to fight.

NIWC Atlantic is employing mixed reality to enhance the tasks of installations and maintenance by providing AR instructional overlays or even live remote-guided support. AR allows the Marines to improve readiness on tactical vehicles and accentuate survivability by training on real equipment with holographic aides displayed as needed. Marines can learn how to operate new systems in either garrison or combat settings that aid learning or push them to greater limits in assessing performance under various scenarios. Mixed reality stands to open a door of endless possibilities, which will allow the Marines to be better equipped and more prepared for the challenges they face.

At the cutting edge of wearable computing, the recently released head-mounted Microsoft HoloLens 2 display is a game-changing mixed reality device. To help explore such new and exciting opportunities, NIWC Atlantic is working with PM LTV to develop an AR installation guide. With the AR headset, the Marines will see 3D models of the JLTV along with a step-by-step guide directing them through the required procedures overlaid on the vehicle in front of them. This is the future of how this work will be done.

NIWC Atlantic engineers are looking to expand this even further by developing a fully detailed vehicle maintenance guide that could be accessed with the flick of a finger or voice command rather than sifting through an old dirty Haynes manual with hard to read black and white images. Meanwhile, the environmental cameras of the AR device can recognize the user's location and identify what they are looking at while displaying information, even interactive content, relative to that context. Another feature encompasses remote maintenance support, where subject matter experts can view on their monitor what a Marine sees and then annotate with text or graphics appearing as holograms in front of the Marine, walking them through their repair. In addition to advancing capabilities in field support, mixed reality can enhance the Marine's situational awareness.

Working on a project to provide new capabilities to the LAV operators, NIWC Atlantic is also using VR to improve in-vehicle visibility from securely within the vehicle. Because of limited visibility from inside, vehicle commanders resort to standing on their seat for improved situational awareness. But this can expose them to enemy fire or result in unsafe conditions. That is why mixed reality technologies have been developed

View in the VR headset showing the 360-degree camera and secondary interrogation camera displayed as a picture in picture. *(Photo by author.)*

View in the VR space allowing for any data to be displayed. This could be a map background with PiP. *(Photo by author.)*

to offer close-range 360-degree imagery around the vehicle and picture-in-picture features for longer range target interrogation, giving the LAV operators a view of their surroundings without having to exit the vehicle. In addition to VR camera feeds and many other features, there is also the ability to present maps and map data of the area, or to compare recently captured imagery with known historical images, view electromagnetic signature information, or perhaps review training material. While in the virtual space, the operators can see this assortment of secondary data while also maintaining awareness of activity outside of the vehicle.

Considering the enormous potential, one's imagination can run wild with ideas for solving real-world problems with mixed reality. For example, imagine AR technology running a command post, altogether eliminating the need for the traditional setup and breakdown of workstations, monitors, and other equipment by making all critical tasks digitally operational. Picture Marines pulling up a virtual monitor to process data like GPS coordinates, intelligence, or 3D models of buildings from any place at any time, unencumbered by wires, hardware, and office fixtures, all while collaborating with analysts in secure virtual spaces.

Marines in the field are quickly becoming oversaturated with data. Rather than taking their eyes off what is in front of them, this data can now be presented in their field of view for rapid assessment and action. Whether they acknowledge and dismiss it, call it up for more information, or it requires a physical response, the aim is to make accessing and processing data easier and less of a chore. As an example of this, NIWC Atlantic mixed reality engineers built a prototype signal detection system that used a HoloLens AR headset to retrieve data from a direction-finding antenna. For the given frequency, the antenna captured the angle of arrival of any detected radio frequency emissions, and the headset displayed the direction and other information about the signal to the wearer. This can help operators maintain situational awareness of their physical environment while signals of interest are displayed using holographic imagery in their field of view, alleviating their need to constantly toggle between a system screen and the world around them.

Clearly, digital engineering is not only rapidly transforming the way acquisitions is tackled but also, coupled with mixed reality, the acquisition professionals of the Navy and Marine Corps will take the operational Marines into a new reality. This technology will transform the way engineers and program managers look at and interact with their system's data, providing accelerated prototype development as well as a greater and faster understanding of system functionality and operation. An equal impact that mixed reality brings is in empowering Marines to train more effectively; have greater hands-free, realtime support during maintenance, repair, and installation; and adding advanced capabilities that non-intrusively alert front-line Marines of danger. Ultimately, smarter systems engineering approaches and mixed reality, in particular, will impact DOD just like other major innovations of the past 40 years, such as GPS. The transformative potential of these technologies will increasingly make them promising enterprise realities worth pursuing.

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