What is an M&S expert? Clarifying Competency Expectations in the DAF's Modeling and Simulations Workforce: A Case Study

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ABSTRACT

The United States Department of the Air Force (DAF) is at a pivotal juncture in enhancing its operational and strategic capabilities through advanced modeling and simulation (M&S) technologies. However, the lack of a formalized career trajectory for M&S professionals threatens to undermine the potential gains from these technologies. While a formalized career trajectory can be seen as an administrative issue, the ramifications are far reaching. M&S professionals in the DAF have disparate and uneven skill sets, even as they are performing critical functions. This current lack of a policy-driven M&S workforce path risks effectiveness and efficiency of M&S initiatives within the DAF through inconsistencies in project outcomes and hampered interoperability across units and missions. This ultimately diminishes the strategic advantage that could be achieved through optimized M&S applications.

The DAF must delineate and mandate specific competencies for its M&S workforce to harness the full spectrum of benefits offered by M&S tools and methodologies as well as to ensure the workforce is equipped to meet the demands of modern warfare and decision-making processes. Accomplishing this objective demands a deep understanding of M&S expertise.

The present paper will explore the ramifications of the current oversight and identify actions needed to develop the structure for an M&S workforce in the DAF. The authors conducted a case study using the development of a M&S fundamentals course. The case study provides examples of knowledge limitations that, if extrapolated across additional DAF efforts, present opportunities for improvement. The aim is to clarify the problem space and identify actions that would support current efforts to aimed at improving the DAF's M&S capabilities.

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BACKGROUND

Importance of M&S in DAF Applications

Modeling and simulation (M&S) play a pivotal role in modern military operations, spanning objectives and integrated within every MAJCOM. They enhance training by providing safe and controlled environments for skill development. M&S aids strategic decision-making by allowing commanders to explore scenarios and evaluate outcomes. Additionally, it informs system optimization and acquisition, ensuring cost-effective choices. These enablers are organized within the DAF across three primary "pillars": Live, Virtual, and Constructive Operational Training (LVC-OT) led by AF/A3, Integrated Life Cycle Management (ILCM) led by SAF/AQ, and Decision Support led by AF/A9 (SAF/SA). From these three pillars, M&S permeates all DAF work. The DAF has made strides to support M&S talent sourcing and development. For example, the Workforce Development Cross Functional Team (CFT) within the DAF M&S Council was established to support the Chief Modeling and Simulation Office (CMSO; Gooden, 2023).

Modeling and simulation serve as the foundation for modern testing, tactics, and training. However, the criteria for what makes an "expert" in this field can be inconsistent and occasionally counterproductive. While multiple factors may be contributing to this situation spanning policy and practice, the present work focuses on the symptoms and consequences faced when experts have significantly divergent understanding of the important concepts within their field. This paper aims to demonstrate how inconsistent competency requirements impacted the design of an M&S foundations course and present a case for how future M&S workforce development can develop reliable M&S experts.

Identification of the Problem: Lack of Standardized Competencies in DAF M&S Workforce

As essential and ubiquitous as M&S expertise is, DAF does not have M&S-specific career field specialties. Without the articulation of the M&S career, personnel assigned to various M&S related work come from disparate academic and experiential backgrounds, which presents strength through diversity. It also introduces vulnerabilities. Without the career path, there has not been clarified competency-based training, which sets in motion a series of vulnerabilities across simulation systems. AFI 16-1005 acknowledges this gap and seeks to rectify it by stating, "M&S has a unique core body of knowledge that needs an appropriate mix of professional M&S personnel including officers and government civilian employees in diverse organizations. There is no separate M&S career field, so tracking and management of this expertise is achieved through special experience identifiers (SEI) in accordance with AFI 36-2101, Classifying Military Personnel (Officer and Enlisted)" (pp. 10).

In 2023, the Air Force Agency for Modeling and Simulation (AFAMS) and CMSO endeavored to answer part of that call by contracting an M&S Fundamentals Course. The target audience for the course included Officers, Enlisted, Civilians, contractors or those who wanted to gain what the project requirements referred to as "general understanding" of modern M&S practices. The course was deployed on the AF myLearning learning management system (LMS) in September 2023.

The purpose of this paper is to offer the development of a Fundamentals in M&S course as a case study that provides examples of inconsistencies and obfuscations that, when applied to the broader state of DAF M&S workforce, reveal the problem as immediate and requiring specific solutions.

REVIEW OF PRINCIPLE THEORIES

To understand how the development of one course revealed gaps across an enterprise's M&S workforce, it helps to consider theories of learning and performance and its relationship to expertise. While the course developers leveraged many theories, there are two that are specifically relevant as we examine workforce-relevant gaps: **constructivism** and **expertise** theories. Constructivist learning opportunities are designed to help learners internalize and transform the new information. Under the constructivist paradigm, learners should be presented with opportunities where the delivery of new information prompts the learner to enhance "cognitive structures that enable us to rethink prior ideas" (Brooks & Brooks, 1993, p.15). The authors also drew from research in expertise that states expertise goes beyond *what* is known by an expert and considers *types* of knowledge that impact successful performance. Bereiter and Scardamalia (1993) proposed that both experts and nonexperts rely on different types of knowledge, including procedural or formal which refer to skills and 'book learning'. But it is the integration of tacit knowledge linked to performance; as performers develop expertise, they can solve problems more efficiently.

By applying these two theories via iterative design and development, course developers revealed gaps in the experts' shared knowledge, their understanding of M&S examples for problem-solving, and the ways they prioritized specific M&S roles. The following section highlights the methods used that framed the approach.

APPROACH

Because the researchers ask the question "*what does it mean to be an M&S expert*?", particularly within the DAF, the investigation justifies the need for qualitative data. In terms of research structure, the researchers acknowledge the possible ambiguity of the definition of *case* and/or *case study*. The researchers identify their methodology as a case study under the definition that it is bounded in terms of time and focused on an in-depth exploration of specific individuals (Creswell, 2005). The results and conclusions generated in this paper are supported by the data collected during the course development project sponsored by AFAMS. The course developers employed the successive approximation model (SAM; Allen & Sites, 2012; Jung, Kim, Lee, & Shin, 2019), which is an agile instructional design model that emphasizes iterative prototyping and refinement to create engaging online courses, allowing for flexibility throughout the development process. Because the course developers used SAM there was opportunity to collect the qualitative data during the development to not only influence the next iteration of the product but additionally draw conclusions about the needs of the DAF M&S workforce.

AFAMS provided volumes of instructional material that had been used in various formats and venues for over a decade. As part of the project, the researchers were asked to review an existing 18 module eLearning M&S course to determine if 1) the course could be modified technically to play on the myLearning LMS and 2) the course required content or other instructional updates/modifications to the content before migrating the course to myLearning.

Given this as the task, the Authors used the following methodology to assess the validity of the existing materials:

1. Target audience: does the existing training's target audience match the intended audience for the new course?
2. Content references and authoritative sources: are the reference cited up-to-date and complete?
3. Is the instructional sequencing and format appropriate to support the intended learning outcomes?

The researchers began with an examination of the reference and sources cited within the course and discovered there were several cases of material that appeared to have been taken from an authoritative source, but no reference could be found. In cases where citations were included, most were obsolete. The most notable examples were the citations to the DoD M&S Glossary (last updated in 1998) which set old foundations for understanding of terms. But even more concerning were statements about M&S and its uses based on obsolete implementations. For example, the previously-used courses begin by stating the purpose of M&S as being solely focused on ***imitation*** of real-world processes, facilities, systems, humans, environments, and activities. The instructional material immediately following stated that all models and simulations are "wrong" because they were always simpler than reality. The fundamental flaws of these positions have spawned substantial discourse beyond the scope of the present analysis, but a few key considerations are warranted to understand the problems that they introduce to M&S instruction. For instance:

- While modeling is inherently *simplification*, it does not mean it is inherently *wrong.* The real world is often too complex for useful examination; models enable study and examination. These models intentionally omit certain details to make them manageable and useful. For example, in tactical simulators, it is absurd to think that every blade of grass need be modeled. Simplicity in models is a trade-off— researchers often start with

simple models and iteratively refine them based on experience to strike a balance between realism and computational feasibility. Most importantly, assuming that a simplification is wrong is a fallacy. Simpler models can sometimes be epistemically better for informing decisions. They allow for uncertainty assessment because they require less computational resources. Idealized models help us gain insights even if they do not perfectly mirror reality (Helgeson, Srikrishnan, Keller, & Tuana, 2021).

- Not only was the role of imitation in M&S misrepresented in the original coursework, it also fell short of current understanding of the field. The 2023 BoK (Body of Knowledge) explains M&S in terms of more than just imitation and includes ***experimentation*** and ***experience*** applications. The foundation also shifts M&S as a computational tool to M&S as a multi- and inter-disciplinary field. Furthermore, the BoK stresses the need to place the model at the center (not the simulation). The model is a curated artifact of knowledge that must be maintained, enhanced, and reused over time (Ören, et al., 2023).

Teaching an M&S workforce that "all models are wrong" and focusing on its role for imitation to the neglect of experimentation and experience contributes to workforce problems. Learners may lose confidence in the systems they are tasked with developing or supporting. They may become risk adverse, knowing that anything they build is already being labeled as "wrong". Perhaps most problematic for the DoD especially— if models are considered universally "wrong," there might be less emphasis on validating and improving them. Rigorous validation is essential to ensure models are fit for their intended purpose, however it becomes quickly nonsensical to ask someone to validate something that has been pre-determined as "wrong".

These gaps in articulating *what M&S is* create real problems in the DoD, as were demonstrated during the creation of the updated course. During their interactions with subject matter experts the course designers observed 1) ambiguity of terms resulting in communication challenges, 2) over-emphasis of constructs that have minimal impact on M&S DoD talent, and 3) lack of understanding about the depth of possibilities of M&S which leads to missed opportunities. The following sections provide observations of those challenges and implications for future workforce development.

RESULTS

As described above, the course was developed using a modified SAM. The approach supports rapid development for computer-based instruction but requires high levels of engagement from the customer and subject matter experts throughout the process (Figure 1).

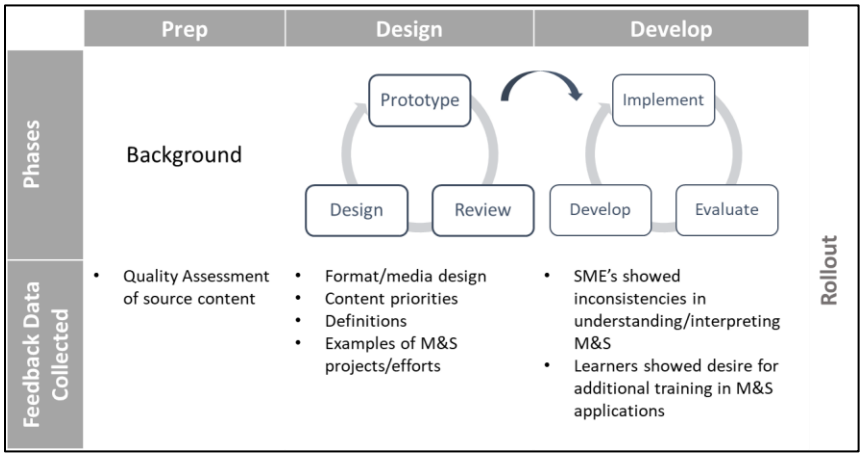

Figure 1. SAM used for rapid courseware development and data collected.

The feedback collected was intended to inform ongoing course creation, however, other insights emerged from this project that are relevant to the M&S community. So, while the project was not a research activity, feedback results presented herein provide examples of M&S workforce readiness that warrant further examination through formal methods. The feedback and data collected within each phase are described in brief below.

Preparation

Whereas an Analysis, Design, Develop, Implement, Evaluate (ADDIE) model front-loads an analysis phase into the design process, SAM has a rapid background phase. This distinction is significant, as the ADDIE approach may have a lengthy effort aimed at assuring all content is correct before designing (a very valuable approach in traditional formats such as textbooks). However, SAM's preparation aims to collect source information rapidly.

It is at this initial phase that some of the concerns arose. The source material provided included DVD lectures with computer-based tests and some material was 30 years old. The run-time of the information was over 15 hours and was considered the basic information that every DAF person entering M&S work would need to know. The instructional design team was asked to transfer the course to myLearning with the assumption most of the information was reusable. While assessing the quality of the source material, the instructional designers observed four quality concerns:

1. Age of source material. As M&S is part of a myriad of rapidly evolving fields (e.g., AI, data-science, digital engineering, materials development), no expert in the field should assume that the content of decades-old source material is accurate enough to meet the foundational needs of today's M&S workforce.
2. Authoritative sources. The original course material *attempted* to cite authoritative definitions and official guidance from either government or industry sources. As the designers investigated, they found both failures to cite authoritative sources, as well as a lack of authoritative standards which to cite in other cases.
3. Identification of "foundational" knowledge. There was no alignment of the original course lectures with job-performance criteria. This is an understandable oversite given that the course was developed prior to the DAF's investments in competency modeling.
4. Andragogical design. The original course presented all information as equally important and without applied contexts. Furthermore, the assessments depended on recalling definitions (from the course, not necessarily from authoritative sources), and did not evaluate application of information. This is not uncommon to observe in older computer-based training materials. However, modern instructional design emphasizes respecting that adult learners in the workplace need information that is relevant to their work and providing flexibility for interaction with the information (Knowles, 1968; Brooks & Brooks, 1993; Wozniak, 2020).

Ultimately, this request to transfer older source material directly into an online format with minimal updating made by people who are highly engaged in M&S work suggests a couple of things. First, a misunderstanding of what provides a good return on investment for instruction, which is common among those who are not instructional designers. The second and more relevant suggestion is that decision-makers involved in directing resources required to build the next generation of M&S experts may not be adequately supported to stay abreast of what is "foundational" knowledge in their field today. To bridge the gap caused by the problematic source material and outdated instructional practices, the contractor team collaborated with AFAMS to develop an entirely new course. It relied on an interaction-based approach specifically suited for online learning which is described in the following section.

Design

Because the course was intended to be delivered asynchronously, the approach used a layout of small sections of new content immediately followed by a series of short examples of the concept and its use within the DAF (wherever possible). The developers included only examples that were unclassified and publicly releasable, so the course could be shared with the broadest possible audience.

The instructional designers used the agreed-upon outline as a guide to collect examples of M&S constructs as they are applied in the DAF and DoD. The assumption was that if the SMEs unanimously agreed that a construct is essential for every M&S professional to know, then they should be able to indicate how that knowledge is applied in DAF M&S work. The process was straightforward: For each construct, provide an example of how you use it.

This is where the disconnect between DoD frameworks of M&S constructs and industry M&S constructs became evident. For example, when asked *why* M&S is helpful, the project stakeholders who support DAF M&S efforts speak of its use primarily in high-end advanced testing, tactics, and training (HEAT3). That question from a M&S theory standpoint outside the DoD garners a more nuanced industry taxonomy: imitation, experience, and experimentation (Ören, Zeigler, & Tolk, 2023). This matters because the industry-wide taxonomy for the utility of M&S is based on *what one can do with M&S*. The DoD focus on M&S for HEAT3 solutions inherently *limits* to those kinds of products. None of the SMEs assigned to this project were familiar with the imitation, experience, and experimentation framework. This introduced an opportunity to work with the SMEs to see how testing, tactics, and training can each apply imitation, experience, and experimentation tools and techniques. This gap in M&S expert knowledge was uncovered when the instructional designer requested examples of why M&S is useful.

The design process challenged the instructional designers and SMEs to consider the relationships between points of critical information. That is, it is one thing to design the course content, it is another to design its presentation order

in a fashion that helps learners rapidly acquire new knowledge. The following section explores the development process and provides examples of expert gaps that were revealed through building instructional presentation.

Development

The approach that was used included the layout of small sections, with each section built to present concepts with their definitions, contexts, and examples. During the development phase, it became clear that the learner audiences who have been working in M&S but may not have had formal training in M&S would need "unlearning" in some specific cases as well. This was discovered when SMEs provided conflicting feedback which required adjudication to address the inconsistencies. Inconsistences were also uncovered when instructional designers requested examples (to show learners what the concept may include) and context (to show learners how they may be expected to apply this concept in the DAF). Finally, in instances where multiple SMEs used incorrect or outdated information, the instructional designers sought to offer brief statements to address any unlearning, assuming that these misunderstandings may be pervasive. Figure 2 shows how the feedback framework was structured to help adjudicate SME insights to glean examples, context, and promote any re-learning that might be needed.

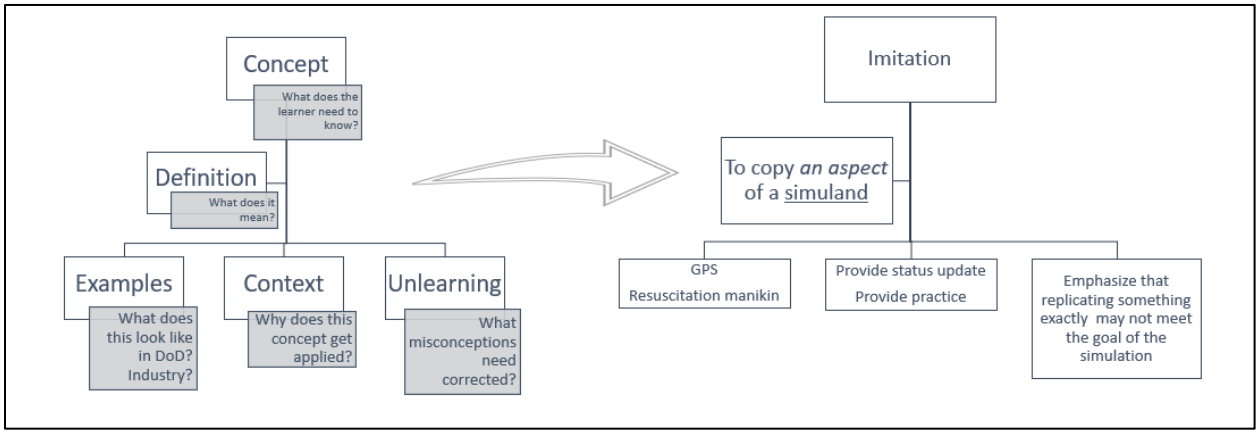

Figure 2. General information structure (left) with "Imitation" example.

By providing context-based examples, learners could immediately see that imitation should not be conflated with fidelity. **Figure 3** shows a training manikin and a navigation GPS app that imitate without requiring replication.

Figure 3. Imitation with limited fidelity examples from course.

Unlearning and expertise

By developing meaningful scenarios, the SMEs were also challenged to unlearn assumptions counter to contemporary M&S theory. For example, the imitation discussions emphasized a conflation of the terms *imitation* and *fidelity*. That, in turn, illuminated an over-simplified understanding of fidelity (that is, one that represents "the real world" as accurately as possible). Consequently, the course design included more nuanced discussion, including the information provided in Table 1.

Table 1: Fidelity examples (partial list)

Type of Fidelity	Explanation	Fidelity Type Examples
Physical fidelity	The degree to which the model looks, sounds, and feels like the simuland.	A virtual simulation used for ***practicing repair on motor vehicles***: The knobs on the equipment could respond to touch the same way they do when the human interacts with the actual equipment. *Note:* This type of virtual simulation would likely not need to include physical fidelity for every aspect of the equipment. It might not be important for all elements to be operational.
Equipment fidelity	The degree to which the equipment (hardware and software) replicates the simuland	A virtual simulation of ***night vision goggles designed to provide the same experience of using goggles in a dark area***: The display needs to move the way that it would move if the person was moving their head while wearing the googles
Motion fidelity	The degree to which the motion cues in the simulation replicate those felt in the real environment	A virtual simulation for ***G-force training***: The simulation should provide the same effects on the body as a person would get while in flight.
Psychological-cognitive fidelity	The degree to which the simulation replicates the psychological and cognitive factors of the real environment (e.g., situational awareness, interpersonal engagements)	A virtual simulation of ***working with an interpreter in an adversarial situation***: The simulation should be designed to elicit the same sorts of emotional responses in the user as would happen in the real environment. *Note*: This type of fidelity is quite different from the others as there are specific challenges in designing activities and interactions that will elicit the types of emotional responses that occur in real-world contexts.
Task fidelity	The degree to which the tasks and maneuvers required of the user replicate the tasks and maneuvers in the real environment	A virtual simulation designed for ***CBRN experimentation***: The simulation of the radios and other equipment should be designed to require the same level of physical interaction as the actual device so that users can discover whether those systems can be used when wearing a HAZMAT suit. *Note:* It can be difficult to determine to what extent the tasks and maneuvers need to be realistic. One way to think about this is whether the purpose of the M&S activity is designed to build skills, experience, or knowledge specifically related to those interactions.

The crux of this is that M&S professionals currently engaged in DAF M&S work and assigned to M&S projects had typically relied on the 1998 M&S Glossary, which defines fidelity as, “the accuracy of the representation when compared to the real world.” (DoD Publication 5000.59-P, (reference. (g)). This is not aligned to model fidelity in other industries, which assumes that a high-fidelity model may represent something that does not exist yet. It is not the “real world” that needs modeled but perhaps a reasonable aspect, such as a decision process, potential contagion, or predicted behaviors. The result is a potential M&S workforce that has been taught that they must have high-fidelity simulators and therefore, requirements are written in a fashion that emphasizes replicating visual and tactile reality. This problem can be illustrated by training systems that very accurately reflect intel regarding red agent behaviors; the requirements demand they reflect reality, which means that the agents are not designed until there is evidence of the red features. However, a simulation that was designed for task fidelity may have requirements that address how a pilot responds to red aircrafts behaving in certain ways, prioritizing the behaviors that the pilot will most likely confront.

Examples of government M&S SME engagements reflecting expertise gaps

The development phase allowed DAF SMEs to revisit content at a more detailed level. This phase also introduced SMEs who were not regularly engaged in the design phase to provide content feedback while reviewing the developed material. Feedback collected during this phase included the following:

- The use of the term "simuland". In one case a high-ranking reviewer indicated that it was a typo.
- Disagreement among SMEs and conflicting documentation to distinguish between "blended" and "hybrid" simulation systems, although these terms were considered foundational.
- Ambiguous and inconsistent application of LVC construct while adhering to the notion that it is "very important". LVC is a distinctly military conceptualization; it has varying use within DoD and lacks widespread use outside DoD.
- Difficulty locating recent (within 10 years) DAF or DoD examples of topics that were deemed essential for every M&S expert to know.

Another challenge encountered while engaging with SMEs during the development phase was to get examples of the concepts – especially used in DAF contexts. The developers uncovered examples of foundational terms being used in conflicting ways. At times, the terms "model" and "simulation" were used incorrectly or interchangeably. Additionally, the SMEs were most accustomed to using LVC as a *framework* as opposed to a construct. Unfortunately, this leads to confusion within the practice. For example, upon review of Module 2, one SME responded to the phrase "live simulation",

> *Live is Live. As in Live aircraft on a range. Where else is the term "Live Simulation" used? I have been doing Distributed training since it was called DMT. I have never heard this term used while conducting AF LVC.*

This remark is anchored in experience using AF simulations and working with an LVC schema. The problem is not so much that this expert has this opinion but that this opinion illustrates how adherence to the schema introduces limited thinking. Outside of the DoD, where LVC is not the primary framework for classifying simulations, a live simulation includes any run-through of a scenario. In healthcare, standardized patients have been used to conduct low-cost live simulations for decades. Consider surgeons who practice on animals or cadavers. These are live surgeons using the equipment that they will use in the field. Yet, the critical scenario element (the recipient of the surgical procedure) is not *a live human*. However, it is not virtual in the sense of a computer-based human nor constructive either. In modern mission practice, the lines between each are blurred to the point that it becomes clear that the goal is not to define what "kind" of simulation it is in terms of L, V, or C, but rather to determine which aspects of the simuland should be imitated, experienced, or experimented so that the best tools to do so can be identified. The above quote shows how SMEs with decades of experience are using LVC language in ways that demonstrate the shortcomings of LVC language itself.

There were also several cases where the SMEs directed the team to examples that didn't illustrate the concept at all or in a manner that would be confusing. One example the developers were directed to were *Virtual Flag* events as an example of virtual simulations. Given that "virtual" was in the name of the event and so many PAO-released write-ups were available online, the developers thought this would be a good fit. Unfortunately, from a learner's perspective, this example didn't work very well. This complex event uses virtual A-10, Airborne Warning and Control System (AWACS), Control and Reporting Center (CRC) simulators, constructive blue, red and white forces, and live crew members. Unpacking the virtual part of this exercise is difficult to do in a manner that would be beneficial for the learner. In a later draft, the developers considered using the United States Air Forces in Europe and Air Forces Africa Warfare Center's (UAWC) Effects Based Simulator as a virtual example but ran into the same issues. The CRC virtually replicates C2 operations for a training environment, but the crews use the system to control constructive and virtual aircraft during each training event.

In cases such as this, the developers selected non-DAF examples that allowed the concepts to be more easily separated. One example was ChronoPoints, a research lab that employs laser scanning technology to create virtual artifacts of physical spaces, preserving them for perpetuity. For example, the Glass Bank at Cocoa Beach was a local landmark that fell into significant disrepair after the bank's closure. It was eventually demolished in 2015. However, the research team recreated the space virtually. That virtual space became a place where people could walk through spaces together even though they no longer exist in the real world. Similar efforts at ChronoPoints have captured the Saturn V and the Douglas C-4 as well as significant places in aviation, including the TWA flight center and Mercury Control Center. The careful selection of examples can help prevent learning traps (as opposed to providing excessive narrative or repetitive definitions). Table 2 summarizes some of the challenging examples the instructional designers encountered.

Table 2: Information that would need to be explained with design and workforce considerations.

Need to explain:	Learning goal or topic	Learning Trap	Example selected	Implications for workforce development and expertise
Using M&S for imitation	Representing with precision	Must always be an "exact copy"	GPS receiver & mapping app	M&S professionals who do not understand the basic purpose of imitation and its associated constraints risk modeling the wrong simuland.
Using M&S for experimentation	Discovery Hypothesis testing Demonstration	Context can be complicated	Pharmaceutical simulated clinical trials	Those without adequate preparation in experimental design and methods are unable to interpret simulation outcomes— particularly in respect to issues of generalizability and reliability.
MOP, MOE	Application to acquisitions	• Applying within the context of "operates" vs. "addresses the problem" • Realism conflated with training effectiveness	ChatBot with high MOP, low MOE	Those who author requirements or conduct verification, validation, and accreditation (VV&A) but lack training to design simulation MOPs and MOEs risk approving systems without assurance the system is addressing the problems it is intended to address.

User feedback reflecting workforce development

As of 24 June 2024, the *Introduction to DAF Modeling & Simulation (M&S) Fundamentals* Course had 553 students currently in progress and 155 students who successfully completed the end-of-course exam. The feedback suggests the course content is relevant to Learners' current work and the course introduced topics that are relevant to future work:

- Feedback from the myLearning survey shows that 31% of learners use the terms provided in the course "nearly every day" and 47% use them "sometimes", 22% of the respondents use the terms "never or almost never". It is unclear whether the respondents answering that question are currently tasked in M&S work.
- When asked to self-describe their experience with M&S, 14% said "Very High" and 38% indicated "High", with 38% saying, "Low" and 10% indicating that they had no experience in the area.
- Looking to the future, the respondents indicated, "If given the opportunity, I would like to pursue a career that includes at least some of the work cited in the courses as examples:" Respondents indicated 55% "Absolutely", 37% "Possibly" and 7% said "Not at all" or were unsure.

The myLearning survey also asked participants to indicate which (from a list of topics) they are most interested in studying further, if future courses were offered. The survey limited the selection to one of the following: discrete event simulation, modeling continuous systems, modeling human behavior, analysis and operations research using M&S, and distributed simulation. A summary of the responses is shown in Figure 4.

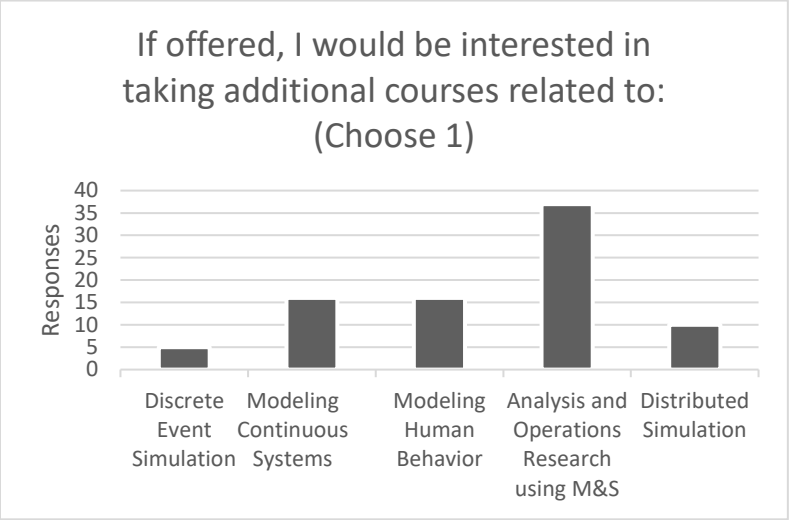

Figure 4. Student-requested M&S Topics.

Finally, the respondents were asked in open text format to indicate other topics of interest (that were not options offered and noted in the Figure above). The responses included:

- Advanced theory for determining, crafting, selecting, and documenting M&S requirements
- User experiences and requirements
- VV&A
- Developing M&S systems for training
- IT support, Marketing
- AFSIM
- The use of artificial intelligence in modeling and simulation for decision making.

These responses suggest that the M&S workforce who is participating in this foundational course see a need for future courses primarily in areas of ***applied*** M&S and less in M&S technical development. This aligns with the understanding that most DAF M&S billets are filled by users of M&S solutions and development of those solutions is typically contracted out.

There are 2 key takeaways that the course designers observed:

1. Highly experienced and thoughtful SMEs supporting the course development came from diverse M&S related backgrounds. Most are not creators of models and simulations, but are responsible for the management of M&S. Those with technical experience creating models and simulations had limited or no formal work preparation in human performance as it relates to M&S.
2. Learners, who to date are typically assigned to course by their supervisor or have volunteered to take the course to provide feedback, have indicated a desire for more M&S instruction. The topics they are seeking overwhelmingly address the human side of M&S more than the technical side.

These observations must be contextualized within the limitations of the present approach. First, this effort was to build a course, not conduct a formal examination of the M&S workforce. Consequently, the risk of bias is high and the ability to generalize the results is low. That said, these observations provide insight into a probable state: the informality of M&S career pathing within the DAF may be contributing to long-term workforce challenges which affect or even mirror DoD and Joint efforts. The discussion section outlines a path to examine the gaps and potential next steps.

DISCUSSION

Defining "M&S expertise" is not merely a philosophical consideration, but a very real defense workforce development concern. To determine what kinds of M&S experts need to be developed, we need to understand what jobs must be performed and what competencies are required to accomplish them. While data collected during the development of the M&S Foundations course and following its launch suggests that there are gaps across DAF M&S competencies,

these gaps are far from insurmountable. To bridge these gaps, it is essential that DoD generates a common position of what it means to be an M&S expert within the DoD. The answers may vary, but there are many other similar complex fields where there are specialties upon which niche competencies are layered (e.g., medicine). Next, any M&S workforce development actions should be built upon current M&S initiatives, leveraging common resources. Capturing a picture of current DoD-wide M&S initiatives would involve identifying operationally relevant projects that develop and/or use models and/or simulations. This distinction between the creators and users of M&S solutions across DoD helps us to clarify where workforce competencies should focus.

The case presented herein is drawn from DAF-generated insights. However, the longstanding differences in how the services tackle M&S professional readiness would suggest that there may be robust pockets of excellence that could be recreated across services. **Error! Reference source not found.** provides examples of the kinds of tasking and work that M&S experts do within the DoD.

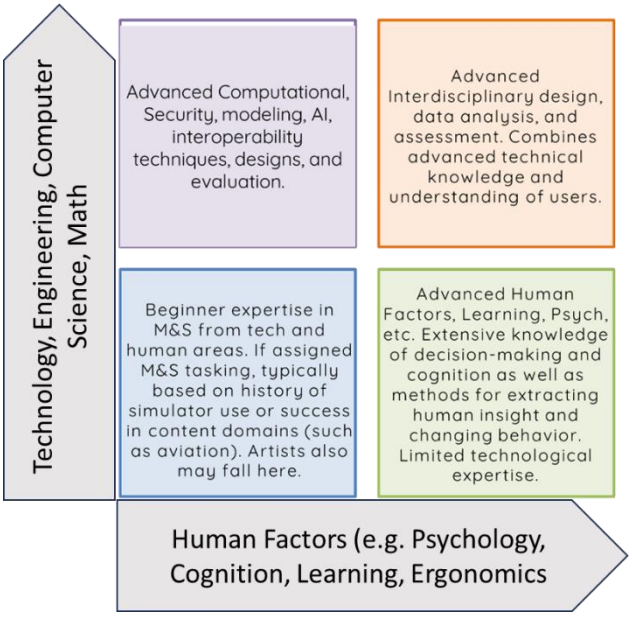

Figure 5. DAF M&S tasking mapped across STEM topics.

The crux is, that there are different kinds of M&S work, from policy and requirements authoring, to project management, to simulation development, and trainers. Figure 5 illustrates these broad categories of M&S work framed by the STEM (Science, Technology, Engineering Math) and Human Factors perspectives. Career paths should accommodate this variety of expertise, while acknowledging that many of our high STEM/low Human Factors personnel are contracted and not internally hired. It will behoove DAF and DoD efforts to develop robust M&S career and ascension paths, building off successes from some services in specialty careers. However, the replication of successes demands DoD-wide acknowledgment that Defense M&S is a more inclusive expertise field than what is used in other industries because of its dependence on psychology, training, and human performance.

To build on these findings, future work should include comprehensive coding and tracking of M&S expert types and the ways those experts contribute to DoD missions. Specifically, the DAF should continue workforce development investments that assure expert competencies are clarified and promoted prior to recruitment into DAF employment. Finally, M&S experts who write requirements and policies should be highly skilled in both the “technical” and “human” sides of M&S work. While this is most obviously needed for training simulation work, it is arguably imperative for testing and tactics as well, keeping in mind that all models and simulations are ultimately used by humans who will be impacted by the quality of design and quality demands consideration of the human user and the mission objectives.

CONCLUSION

The present paper describes the creation of a modernized course in M&S Fundamentals, a project which illustrated an important gap. M&S expertise is ill-defined, not only within the DAF, as the information presented herein highlights, but across the DoD, as the lack of cross-service competency expectations would suggest. In the context of M&S work within DAF, the application of basic M&S language is lax. The present analysis suggests that while it may suffice to broadly say an M&S expert applies M&S tools and techniques, this definition risks over-generalizing the field. It is useful to clarify that M&S experts fall into categories of users, makers, managers, and policy authors/assessors and each of these categories relies on varying degrees of technical and human factor knowledge. The absence of mandatory expertise standards reflecting this nuance for M&S personnel poses additional risks, such as a failure to grasp performance requirements, unrealistic solution expectations, and inadequate measures of effectiveness. Addressing this gap necessitates a robust workforce strategy.

Future work should examine the benefits and drawbacks of including M&S within AFMAN36-2100, thereby classifying military personnel who work to create M&S tools distinctly from those who use M&S tools. Such an analysis should be cautious to avoid taxonomic overlaps with contributing fields (e.g., engineering, computer science, human factors) and inadvertently creating more disciplinary confusion. However, the importance of M&S expertise extends beyond the DAF if the Great Power Competition is to be taken seriously. The challenge will be to accommodate Night One readiness while preparing for the full spectrum of mission success, which may extend far beyond Night One. Combining a long-term vision with the near-term priorities can help large scale M&S projects improve effectiveness and sustainability.

Examination of current DAF and DoD M&S workforce needs should quantify personnel in M&S related roles, categorizing them as creators, users, policy makers, and system evaluators. These should be mapped against anticipated needs as well as the required human and technical competencies needed to execute those jobs. This mapping must also include sustainable career advancement paths, not merely training and instructional paths. To assure a sustainable workforce in the DAF and DoD broadly, there must be a culture within each service that reflects a high value for M&S work as mission essential. A feasible path towards general and admiral ranks through M&S service must be acknowledged and socialized.

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The opinions stated herein are solely the authors and do not represent official positions of the DAF or any associated agency. Access the CAC-enabled *Introductions to DAF Modeling & Simulation Foundations* course described in this paper on myLearning at: https://lms-jets.cce.af.mil/moodle/enrol/index.php?id=13976 .

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