Modeling and Simulation Professionals – Meeting the Demand

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ABSTRACT

The development and appropriate use of modeling and simulation (M&S) technology relies on professionals with a skill sets that run the gamut from computational science, software engineering, and analysis to domain knowledge found in instructional design, physics, engineering, health sciences, military sciences and more. To support the needs for developing the skilled workforce required to grow the M&S industry, which provides well-paying jobs and bolsters the economy, universities have developed curricula, certificate, and degree programs to meet this niche. However, fulfilling these M&S skill sets is not the exclusive domain of M&S programs. Furthermore, time constraints may require specialization among the many M&S-related topics for a Certified Modeling and Simulation Professional (CMSP). It may not be possible for a new graduate to develop proficiency sufficient to meet workforce demands. This paper builds upon earlier work surveying Domains, Skills, Knowledge, and Applications of the M&S Professional. Assuming the stated restrictions exist, we survey professionals, program managers, and academics and examine areas of emphasis in the various M&S programs available. We evaluate the degree to which M&S specific programs are able to meet industry demands and assess whether those demands are being met by M&S graduates or graduates with other specialties. We end with observations about the M&S workforce with recommendations for the M&S Community at large.

ABOUT THE AUTHORS

Lisa Jean Bair is a Solutions Architect for SAIC's training and simulation service line, serving as its Training Enterprise Market Initiative lead. She has over 19 years of experience in operations analysis, with over 20 peer-reviewed publications and a 2013 I/ITSEC best paper nomination. She has led research and development, analysis and support tasks completed by project teams consisting from individual contributors to small teams containing a wide range of expertise levels, from entry-level research assistant to PhD qualified subject matter experts. She has engaged in all aspects of company management, including technical and programmatic management, customer engagement, and business development and is active in the M&S community, currently serving as chair of the Communications, Outreach, and Public Affairs committee for the NMSC. Ms Bair's areas of expertise include M&S validation, simulation supported analysis, agent-based simulation, multiple objective decision analysis, multi-attribute utility theory, and analysis. Her experience includes concept development and experimentation; analyses of alternatives; complex decision problems; M&S planning use; test and evaluation; and validation. Her original research established a comprehensive multi-agent system taxonomy and foundational principals and a framework for M&S validation. Her current research interests lie in developing multi-modal education media. Ms. Bair earned an MS in Operations Research from The College of William and Mary and a BS in Applied Mathematics from ODU.

James J. Jackson is leading SAIC's training and simulation service line. Mr. Jackson has supported a variety of programs ranging from the TIMED satellite, to the VIRGINIA Class Submarine and clients ranging from the US Joint Forces Command to the National Institute of Health. While at the Johns Hopkins University Applied Physics Lab, Mr. Jackson studied the shock and vibration effects on the Standard missile's IR guidance system. Mr. Jackson developed a novel concept for shock and acoustic isolation for the VIRGINIA Class Submarine using a simulation based design approach. At SAIC Mr. Jackson led several training and simulation programs ranging from experimentation to collective training. Mr. Jackson has authored more than 16 technical papers and current research interests are the integration and application of disparate analytical, modeling, and simulation tools to solve complex warfighting issues. He is a member of the industry advisory board for the Virginia Modeling, Analysis, and Simulation Center (VMASC). Mr Jackson holds a BS Degree in Mechanical Engineering from Virginia Tech and an MBA from William and Mary. He is a member of Tau Beta Pi, the national engineering honor society.

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INTRODUCTION AND BACKGROUND

The end of the twentieth century saw the rise of computational modeling begin with the use of computers to solve problems in mathematical physics and expand into using computer simulations for manufacturing and process analysis (Goldsman, Nance, & Wilson, 2009). Its last decades, pushing into now, saw the development of large-scale modeling and simulation (M&S) applications across multiple industries, such as healthcare, transportation, defense, biology, and meteorology, and spanning applications from analysis and experimentation to prediction and training. The increasing importance of M&S to the United States, prompted the U.S. House of Representatives to pass House Resolution 487, 16 July 2007, establishing M&S as a national critical technology. However, complexity in development and application of M&S rose along with its rise in national importance as a critical technology creating a dilemma in education, professionalization, and industrialization of the practice of M&S.

M&S Industry

Although having high-level recognition within a growing marketplace, the M&S industry is not recognized as such by the North American Industry Classification System (NAICS). Every five years, the Economic Classification Policy Committee (ECPC) reviews NAICS codes for potential revisions necessary to reflect changes in the economy. While they recognized the impact of M&S technology on the economy, they denied a 2010 proposal that the M&S industry be granted a NAICS code for not being sufficiently differentiated from customer computer programming services (NAICS 541511) and from the manufacturing of simulators (found under NAICS 333319). Further, they found that creating an M&S-specific NAICS code would create problems with mutual-exclusivity requirements because of the breadth of activities, uses, and disciplines associated with M&S (US Census Bureau Special Projects Staff, 2010). That is, the ECPC explicitly avoids a market-focus stretching across industries (e.g., tourism touches airlines, hotels, and restaurants proving the same services irrespective of whether their patrons are tourists, businessmen, or neither) when assigning NAICS codes.[1]

Understanding the rationale but believing that M&S requires specialized skills obscured by seemingly surface-level assessments and the M&S has an economic impact currently hidden by existing NAICS categorizations, the National Modeling and Simulation Coalition (NMSC) submitted a new NAICS code proposal (2014 NAICS Proposal) to address and counter the ECPC's original findings. A key part of this thesis is production of M&S is sufficiently complex and sophisticated to require highly-trained professionals versed in an M&S-specific body of knowledge. These activities are informed by application domains, but separate from them, and while other use and development of M&S may exist alongside it, but M&S is separate and distinct unto itself[2] (NMSC, 2014).

M&S Workforce

While the M&S workforce commands above average salaries and benefits, requiring high levels of training and education (National Training and Simulation Association [NTSA], n.d.) and the M&S industry continues to grow in importance, developing a qualified M&S workforce has been a challenge for industry, government, and academia—due, in part, to the range of skills required by the discipline's practitioners, which include mathematics, engineering, and computer science (Kincaid & Westerlund, 2009). This is a multidiscipline work-force, requiring understanding of the physical sciences, programming skills, game design, human factors, current computer technology, and more, with hands-on experience critical (Mymic LLC & The Asta Group, 2013).

Workforce Certification

The Certified Modeling and Simulation Professional (CMSP) certification supplements this growing educational base in M&S, identifying individuals who have attained significant knowledge and experience in M&S. The primary purpose behind its development is to provide a definitive description of the M&S profession, establish core

knowledge required by practitioners, and distinguish those competent to practice (Lewis & Rowe, 2010). The exam topic index reflects diverse areas of application, domain, and methods. It includes M&S history, implementation, business practices, and related fields. As the CMSP matured, two tracks have evolved: the first, a technical track suitable for engineers and developers; the second, a management track suitable for users or managers (Petty, Reed, & Tucker, 2012). This evolution explicitly acknowledges the variety and diversity of work by M&S professionals.

Question of Interest

Five years ago, the Department of Defense (DOD) M&S Human Capital Strategy (HCS) found the need to "[establish] standardized M&S educational / training competencies and associated instructional programs that foster clear communication within and across Services and M&S functional areas" (DOD, 2010, p. 17). Although dated, this finding is intriguing given the many academic programs and the CMSP, existing then and now. Additionally, the Analysis of Modeling and Simulation in Virginia, a report prepared for the Virginia Department of Emergency Management (VDEM Report), could not recommend the better major (e.g., computer science, engineering, M&S) for entrants into the M&S workforce, with some study participants suggesting studying this question (Mymic LLC & The Asta Group, 2013). Findings such as these and informal conversations, workshops, and panels suggesting that a common understanding of the M&S Professional only exists as a gestalt—*I'll know it when I see it*—inspired this effort. This paper builds upon earlier work surveying the domains, skills, knowledge, and applications of the M&S Professional (Bair & Jackson, 2013). It reflects our interest in understanding the relationships between the industry demand, or need, for M&S Professionals and the market's ability to meet it. Professional certifications, education programs, and an M&S-industry esprit de corps exist. We wanted to understand how well they aligned. Our investigations into this question are informal. Rather than provide detailed statistical and market analysis to bear on this problem, we consider our analysis to be back-of-the-envelope. We wanted to collect enough objective data to stress our assumptions formed from our personal experiences, assess viewpoints across domains and roles, identify hidden biases and potential sources of miscommunication, and assess the need for more rigorous analyses.

POINTS OF VIEW: PROFESSIONAL, ACADEMIC, AND INDUSTRY

In 2010, The DOD M&S HCS estimated that its M&S workforce has approximately 30,000 military, government civilians, and contractors costing $2.25B in labor alone, remarking that results thus far creating an effective M&S workforce to support acquisition, analysis, experimentation, planning, training and test and evaluation were mixed, with inefficiencies driven in part to the diversity of M&S use (DOD, 2010). Three years later, the VDEM Report suggests that the M&S workforce lacks harmony, noting a lack of consensus on whether M&S exists as a separate industry and suggestions within industry that computer science and engineering degrees provided a broader and better skill set. It found that M&S educational programs need better unification toward workforce needs and provide more hands-on experience. To shed light on these dichotomies, we first examine the underpinnings behind the development of the CMSP. Next, we look closer at educational programs available for the would-be M&S Professional and their areas of emphasis and relationships to CMSP requirements. Then, we investigate the M&S Professional community's perception of required skills.

The CMSP

Established in 2002, observations of self-ascribed M&S Professionals inspired the CMSP was born observations of. Taking this as a given state—*M&S Professionals exist*—Bill Tucker and others hunted what differentiated this group from other professions. One striking difference was the lack of a meaningful professional certificate—project managers: Project Management Professional (PMP); engineers: Professional Engineer (PE); software specialists: Certified Software Quality Analyst (CSQA); network engineers: Cisco Certified Design Professional (CCDP); and many more. These certifications provide surety to employers that employees have needed skills and knowledge and provide a knowledgebase standard and a set of ethics for practitioners to follow. (Tucker, 2015) The American Society of Heating, Refrigerating and Air-Conditioning Engineers echoes this value through its Building Energy Modeling Professional certification (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2012). Starting with 27 pioneers, forming the initial CMSP implementation group, and 134 charter members, nominated by their peers (Modeling and Simulation Professional Certification Commission, 2012), NTSA receives from 20-30 CMSP applications a year and the CMSP ranks have grown to approximately 500 (Rowe, 2015).

Initially developed through a series of workshops and later refined with the help of leading practitioners, educators, and researchers, the Modeling and Simulation Professional Certification Commission (M&SCPP) selected CMSP-

exam topic-areas covering what M&S does, where it is used, and how it is used. A core tenet underlying all of this was the understanding that *model-builders simplify and extract to obtain useful representations for the decision making process, making model-builders professional liars* (Tucker, 2015). This is an interesting corollary to the first half of "all models are wrong; the practical question is how wrong do they have to be to not be useful," and an answer to the second (Box & Draper, 1987, p. 74). Described in Bair and Jackson (2013), Table 1 summarizes CMSP-examination topic-areas. Key to understanding this taxonomy is the recognition that simulation science requires an understanding of architecture design, data management, computational complexity, modeling methods, statistics, and more with the ability to apply that knowledge to both the domain of use and the application.

Table 1. CMSP Exam Topic Areas (Petty et al., 2012)

M&S-Domain Specific Knowledge	**Areas of Specialized Expertise**	
1. Concepts and context 1.1. Fundamental terms and concepts 1.2. Categories and paradigms 1.3. History of M&S	**2. Applications of M&S** 2.1. Training 2.3. Experimentation 2.5. Engineering 2.2. Analysis 2.4. Acquisition 2.6. Test and evaluation	
6. Supporting tools, techniques, and resources 6.1. Major simulation infrastructures 6.2. M&S resource repositories 6.3. M&S organizations	**4. Modeling methods** 4.1. Stochastic modeling 4.2. Physics-based modeling 4.3. Structural modeling 4.4. Finite element modeling and computational fluid dynamics 4.5. Monte Carlo simulation 4.6. Discrete event simulation 4.7. Continuous simulation 4.8. Human behavior modeling 4.9. Multi-resolution simulation 4.10. Other modeling methods	**5. Domains of use of M&S** 5.1. Combat and military 5.2. Aerospace 5.3. Medicine and healthcare 5.4. Manufacturing and material handling 5.5. Logistics and supply chain 5.6. Transportation 5.7. Computer and communications systems 5.8. Environment and ecology 5.9. Business 5.10. Social science 5.11. Energy 5.12. Other domains of use
7. Business and management of M&S 7.1. Ethics and principles for M&S practitioners 7.2. Management of M&S projects and processes 7.3. M&S workforce development 7.4. M&S business practice and economics 7.5. M&S industrial development		
M&S-Specific Software-Engineering-Related Expertise		
6. **Simulation implementation** 6.1. Modeling and simulation lifecycle 6.2. Modeling and simulation standards 6.3. Development processes 6.4. Conceptual modeling 6.5. Specialized modeling and simulation languages 6.6. Verification, validation, and accreditation 6.7. Distributed simulation and interoperability 6.8. Virtual environments and virtual reality 6.9. Human-computer interaction and virtual environments 6.10. Semi-automated forces (SAF) / computer generated forces (CGF) 6.11. Stimulation		
Domain Knowledge in Related Fields of Practice		
8. Related communities of practice and disciplines 8.1. Statistics and probability 8.2. Mathematics 8.3. Software engineering and development 8.4. Systems science and engineering		

Workforce Education

During the first decade of the twenty-first century, the need for a well-educated M&S workforce prompted the founding of university degree programs at all levels. During this period, the DOD (2010) identified the need for systematic M&S education focusing on core concepts common to all application areas, providing a common M&S vocabulary, concept and principles base, and understanding of accepted methods and procedures. It found that its workforce requires technical competencies in M&S-related engineering and scientific principles and the ability to objectively monitor and evaluate emerging technologies, articulate technology needs and requirements, and develop programs to advance the M&S state-of-the-art. Moving forward, it will identify required unique skill-competencies for M&S technical capability, functional application, and management. To help understand the breadth of education and training offerings currently available, we did an internet keyword-search to find M&S degree and certification programs offered online and in residence, matching their courses to CMSP-topics to assess their coverage of the CMSP knowledgebase. Starting with programs hitting the keywords "Modeling" AND "Simulation," we broadened the result to include programs mentioned in the DOD M&S HCS and the VDEM Report. The resulting list covered recognized leaders in the M&S industry, biased to the M&S economic-base in Virginia. That list poorly represented schools offering game design and visualization courses. To address this, we added programs that did not offer M&S-

specific degrees but had classes with at least one match to CMSP knowledge areas. Nevertheless, this list has a bias toward M&S degrees, if only due to the large number of program-offerings across the country that could suffice, such as in the fields of computer science, engineering, or operations research. The resources for this effort did not permit a review of them all. We based all results on public information found on university webpages. We excluded commercial CMSP-preparatory offerings. Our programs list overlaps but differs from that provided in the 2014 NAICS Proposal, but we believe it sufficient to honestly illustrate observations of M&S education opportunities.

Course CMSP-Topic Coverage

Although some courses in their description and instruction could cover more than one, we matched each program-offering course to a single CMSP-topic to give a general, initial sense topic coverage. We scrubbed the data to give as fair a representation as we could without overcomplicating the data or the analysis. Overall our review showed good coverage across the CMSP topics, with the largest gaps in ***M&S-Domain Specific Knowledge*** and ***M&S-Specific Software-Engineering-Related Expertise*** (Table 2). There were many topics related to computers and networks that fit poorly into the taxonomy, neither relating to simulation infrastructures nor virtual environments nor fitting into another obvious related-discipline. For this analysis, we considered those classes within the simulation infrastructures subtopic, overwhelming it, and we could have easily made another choice. Likewise, game-design courses provide the vast majority of matches to the virtual-worlds subtopic.

The sub-topics under ***M&S-Domain Specific Knowledge*** cover those determined as fundamental to the field of M&S, and thus, every M&S practitioner should have familiarity and understanding of them. Sub-topic 6. Supporting tools, techniques, and resources only had course title matches to *6.1 Major simulation infrastructures* with most of those coming from certificate programs. While programs may cover information about *6.2. M&S resource repositories* and *6.3 M&S organizations* in other classes, these topics are probably those learned through networking or from within the workforce. However, this lack may be a hidden driver for some of the VDEM Report findings. No courses were dedicated to *1.3 M&S history* in any of the degree[3] programs, although courses matched to *1.1 Fundamental terms and concepts* and *1.2 Categories and paradigms* could cover this material. We identified no classes for these topics in the Naval Postgraduate School (NPS) courses we reviewed, but we suspect that courses we matched to DOD-related certificate programs and NPS's modeling methods courses cover this material. These topics matched to introductory and survey; data structures and algorithms; mathematical modeling, systems modeling, simulation techniques, and computational modeling; and formalisms among other courses in M&S degree-programs. Still, courses attached to certificate programs and other majors were more than a third of the matches. This reinforces the observation in the VDEM Report and the DOD M&S HCS that the M&S workforce needs a common lexicon for and understanding of M&S—differences in topics of instruction may make for an unaware workforce. Two other subtopics had no coverage: *7.3 M&S workforce development* and *7.5 M&S industrial development*. While these relate to the topic area 7. Business and management of M&S and one would not necessarily expect a student at the undergraduate level to have direct instruction in these topics, they do cover areas of interest to the DOD for understanding, evaluating, and producing simulation at the edge of the state-of-the-art.

Course coverage for ***M&S-Specific Software-Engineering Related Experience*** (i.e., 5. Simulation Implementation) was uneven. Although we assigned over one-fifth of the courses to this area, they covered only four out of the eleven course topic areas. No courses were clear and obvious matches to *5.1. Modeling and simulation lifecycle, 5.2. Modeling and simulation standards, 5.3. Development processes, 5.4. Conceptual modeling, 5.5. Specialized modeling and simulation languages, 5.10. Semi-automated forces (SAF) / computer generated forces (CGF*), and *5.11. Stimulation*. Although the software engineering courses likely cover the topics in 5.1-5.3, equally likely, they do not take an M&S-specific point of view. Moreover, unique characteristics within topics 5.4 and 5.5 arguably require specific attention in M&S programs. The bulk of the remaining courses address *5.8. Virtual environments and virtual reality* and *5.9. Human-computer interaction and virtual environments* with only four courses splitting the balance for *5.6. Verification, validation, and accreditation* and *5.7. Distributed simulation and interoperability*. The 2014 NAICS Proposal asserts that topics 5.1-5.9 form the cornerstone for what separates M&S from other disciplines. Our observation that coursework neglects these topics reinforces needs identified in the DOD M&S HCS and underscores the VDEM Report finding that M&S workforce applicants often lack experience developing new products. Both these topics provide the foundation for M&S development.

The content category of ***Areas of Specialized Expertise*** are those areas that an M&S Professional might specialize, their experiential and expertise niche, and students usually cover these specializations at the graduate and certification levels of study. In the topic of 2. Applications of M&S, we matched courses to all topics except for *2.5 Test and*

TABLE 2. AREAS OF WEAK COURSE COVERAGE OF CMSP TOPICS

	Tools, techniques, and resources							Simulation implementation						
	6.1	**6.2**	**6.3**	**5.1**	**5.2**	**5.3**	**5.4**	**5.5**	**5.6**	**5.7**	**5.8**	**5.9**	**5.10**	**5.11**
ASU														
Columbus SU											2	1		
ECPI											5			
Full Sail	4								1		5			
GMU	2								2					
GTI	1									1				
Indian Rvr SC										1	4			
JMU														
NPS	1										3	2		
ODU	3										5			
Portland SU														
Purdue	1										1			
Stevens IT	2										3	1		
TCC	2													
Th. Nelson CC														
TNCC														
U of Richmond	5										1	1		
UAH	2										5	2		
UCF												3		
UVA														
VA Cmwlth U	1													
VA Tech														
W&M														
Coverage	24	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**2**	**34**	**10**	**0**	**0**
Certificate	5								2	1	6	2		
Associate	2													
Bachelors	4								1	1	10			
Masters	6										9	6		
PhD	1										3	1		
Undergraduate	5										26	1		
Graduate	1										5.8			

Evaluation and *2.6 Engineering*, with clustering around *2.4 Acquisition* through certificate programs and *2.2 Analysis* through coursework at all levels dedicated to the analysis related topics. The absence of matches to the engineering topic is most likely a function of the programs in our review, although there were some courses in certificate programs that we could have easily applied either here or to physics-based modeling. In the case of topic area 3. Domains of use of M&S, 44% of the courses came from degree programs outside of the M&S specialty and 29% from certificate programs. The M&S regular degree-program courses only matched to *3.1 Combat modeling and military* and *3.6 Transportation*, with the additions two topic not listed: environmental and maritime. Subtopic 4. Modeling methods fared much better having coverage on all topics, other than *4.9 Multi-resolution modeling*, with *4.6 Discrete event simulation* nearly 40% of the matches.

The VDEM Report provides an interesting insight into the effects of education-gaps related to all CMSP-topic areas, particularly in the areas of ***M&S-Domain Specific Knowledge*** and ***Areas of Specialized Expertise***. The report suggests that programs of study should provide a better pairing in computer science and engineering programs with other disciplines such as physics, bioengineering, and graphic design. It goes on to suggest that educational programs should focus on advanced physics, current computer technology, engineering, math and specific technical science capabilities, stronger math and science to understand models, and systems dynamics thinking (Mymic LLC & The Asta Group, 2013, p. 52). Elsewhere, the report found uneven availability of qualified applicants having systems engineering capabilities, with those applicants often lacking M&S experience in development and within their domain field (i.e., 3. Domains of use of M&S), and expressed regional interests in a workforce with more software programming and development skills; science, technology, engineering, and mathematics degrees and professional certifications.[4] This list underscores the need for M&S Professionals to have a strong background in the fundamentals of applied mathematics; the sciences and scientific thinking; and modern computation, computer technology,

and programming. It highlights a potential disconnect on the importance of computer technology across M&S communities—a topic missing from the CMSP except as it relates to software engineering and simulation infrastructure.

Degrees and Certificates

Figure 2 and Table 1 show the degree distribution for the courses we reviewed. Unsurprisingly, Associates programs comprise the smallest portion of the collected program-offerings. These programs are relatively new, and we only represented two in our data review. Overall, M&S undergraduate-programs represented just less than 25% of the total. By contrast, Masters and certificate programs comprise 60% of the total M&S-programs reviewed. This supports the VA Report call for more M&S-programs in lower leveled degree programs. Many of our courses came from program-offerings in other related disciplines. Those of and related to computer science, engineering, and operations research comprise the bulk of these majors, with computer science degrees at both the undergraduate and graduate levels. These undergraduate programs provided most of the course coverage for an introduction to modeling and simulation, game design, and data structures. Conversely, engineering and operations research programs were at the graduate level, with engineering programs addressing modeling applications for systems and transportation and operation research providing in depth coverage of topics such as stochastic simulation. The other degrees only address M&S-topics as a subject overview. This provides insight into VDEM Report recommendations to pair computer science and engineering disciplines with other academic disciplines, including subjects such as art and graphics design. This analysis also may underlie the inability for the VDEM Report to recommend preferred degrees for the M&S workforce, either by degree-type or major. Despite this, it does identify many capabilities needed within the M&S workforce, including graphics artists, hybrid modeling and gaming, software engineering and coding, and multidisciplinary analysis. It also included findings that M&S-workforce education needs to include communication skills. These skills form the foundation for effective design, development, use, and interpretation of M&S, and M&S Professionals require them across the entire M&S-lifecycle (Sargent, Nance, Overstreet, Robinson, & Talbot, 2006). Courses explicitly dedicated to the M&S lifecycle (5.1), conceptual modeling (5.4), systems engineering (8.4), and statistical analysis (2.2, 8.1) as it relates to M&S application domains would help support this need by incorporating within them frameworks to help communicate models between teams, users, and managers.

Industry Perceptions

The 2014 NAICS Proposal identifies M&S as a discipline distinct from others (natural sciences, computer sciences, software engineering, high performance computing)—more than a general method used in science and engineering, not just a tool used in many industries, nor only a specialized skill set—setting to prove that M&S practices are independent of application domain and use. By contrast, the multidisciplinary M&S workforce is a theme in the DOD M&S HCS, but it links the workforce to its Computer Engineering 0854 Series. The VDEM Report goes further, recognizing that M&S occupations include civil, industrial, and mechanical engineers; chemists; computer programmers and network engineers; information security analysts; and web developers and network architects. To help understand these apparently conflicting viewpoints and M&S Industry's views of itself, we developed an informal survey using SurveyMonkey® and disseminated it with help from NTSA, who distributed it by email via its regular communications, resulting in 24 respondents by the initial cutoff date. We gave an extension for responses, with a dedicated email sent to NTSA's mailing list and personal requests sent to our personal networks. The final result includes data collected from 146 responses from 16 April to 9 June 2015.

From its inception, we never planned that these results would undergo rigorous statistical analysis. Its distribution method, alone, both reduces the scientific weight that could append to any results and biases them to M&S training.

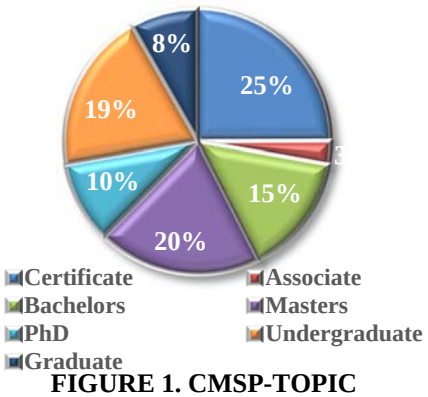

FIGURE 1. CMSP-TOPIC COVERAGE BY DEGREE TYPE

TABLE 3. DEGREE TYPES AND MAJORS

Modeling and Simulation Degree				Related Degree	
Associates	2	Masters	7	Undergraduate	6
Bachelors	4	PhD	4	Graduate	3
Certificate	8				
Related Majors					
Analytics (Business, Decision, Supply Chain Management & Analytics), Architecture, Computer & Information Science, Computer Science, Engineering (Biomedical, Chemical, Civil, Electronics, Mechanical Engineering. Technology), Game Design & Development, Intelligence Analysis, Integrated Science & Technology, Marine Science, Mathematics, Operations Research. Psychology, Systems & Information Engineering, Urban Studies & Planning					

Further, the discipline of creating good survey questions has its own testing validity procedures. Nonetheless, we felt that a survey would help to identify trends within and perceptions across M&S communities, and our results provide a qualitative view of the M&S industry less subject to the vagrancies of opinion and personal memory. Figure 2 shows the respondent pool demographics. The CMSP topics provided the scope for the questions, with free text available to respondents to add information or elaborate on their response. We asked the same questions of everyone, irrespective of their potential domain of application, domain of use, or role as an M&S Professional. Rather than proscribe differences between these groups through the questions we asked, we wanted to assess the degree of unanimity the respondents had with respect to these topics—the de facto M&S Body of Knowledge. Most of our questions allowed for multiple selections and respondent comments. Recognizing that many in our industry perform many roles, we wanted to assess the effect this might have on how respondents viewed our profession. Likewise, we wanted a broad perspective of the CMSP topics as viewed by our industry, so we avoided arbitrary rating schemas that could be misinterpreted as giving weight or emphasis to one topic area over another.

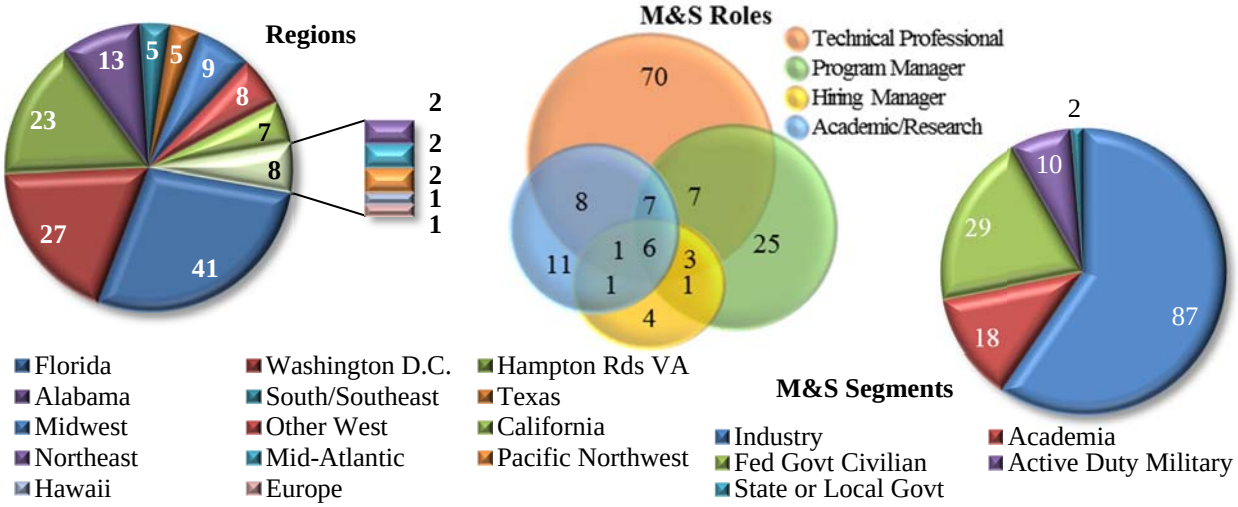

FIGURE 2. DEMOGRAPHICS FOR M&S PROFESSIONALS SURVEY

The desire to understand the perception the various M&S Professionals have of themselves, their profession, and across the M&S Industry and the alignment of those perceptions with those of the M&S customer-base and education-opportunities drove this effort. This made it critical the M&S community's perception of available M&S certifications—especially the CMSP. Responses to direct questions regarding their value are telling. Of all of the groupings and subgroupings of our respondents by M&S-role only those only within the academic/research (73%) or the program manager (79%) groups rated certifications as valuable.[5] However, those fulfilling hiring manager roles were evenly split, either agreeing that certifications were valuable or seeing them as not valuable at all. This indicates that either hiring managers may not understand the level of expertise demonstrated by the CMSP, may not agree that the CMSP demonstrates needed expertise, or see no requirement necessitating the hiring of those that hold it. More troubling is that our survey respondents having a technical professional role were nearly evenly split in seeing these certifications as either valuable and neutral or irrelevant. Regional effects from California, the south/southeast, the Pacific Northwest, and other west regions likely drove these results, with responses bimodal and nearly evenly split. Only Alabama, the Midwest, and Texas saw these certifications as very valuable. This suggests that while management and academia see intrinsic worth to them from what the CMSP conveys, there are insufficient external pressures forcing its attainment by the workforce. The regional differences, M&S-role variances, the VDEM Report, and DOD M&S HCS suggest the M&S community and its customers lack awareness of these certifications or do not accept them as a sufficient demonstration of relevant and necessary expertise.

Our survey asked respondents to rank the importance of each major CMSP-topic area, and they clearly viewed modeling methods and M&S-domain topic areas as the two most important M&S topics, with modeling methods the clear winner. Answers to the other survey responses are consistent with this finding. There were distinct differences in emphasis placed on the expertise M&S professionals should have with the modeling methods.[6] Since available work varies regionally, it makes sense that the workforce would select necessary expertise accordingly. The responses across all regions suggest broad agreement that M&S professionals should have some familiarity in physics-based, discrete-event, human-behavior, and stochastic modeling methods. Most indicated the importance of familiar-

ity with multi-resolution and continuous simulation. Interestingly, when taking an industry-segment view of the data, state and local government responses noted the importance of human computer interfaces, generally having less emphasis across the other segments. Answers to more detailed topic-area questions bore out these observations.[7]

We saw no substantive disagreement on the importance of the CMSP topic-areas to the M&S workforce. There was resounding agreement of the value brought from understanding conceptual modeling, simulation paradigms, virtual environments, and the fundamentals of computation topics, but the history of M&S, SAF/CGF, and HCI all scored low across most groupings. Although standards appeared in the top five list for the academic, military, and federal government groupings, the ranking accrued from the technical M&S-role group meant that it did not average that high overall. This indicates a mismatch between the technical workforce, academia, and the federal government customer base on M&S standards, an area of potential concern. Our data also suggest disconnects within the workforce with respect to model development, with the military and state and local governments ranking this low, where and the industry, academia and federal groups ranking this need high. Responses to the survey question asking which duties an M&S Professional could expect to perform appear to contradict these findings, though. Here, our survey pool placed designing M&S-supported studies, designing M&S-supported test and evaluation studies, and perform a validation study appeared in the top tier of responses; assess human-computer interfaces and develop physics or engineering studies in the second tier; and develop wargaming or campaign models, develop other types of models, and develop professional code in the last tier. Our survey lacked sufficient fidelity to draw strong conclusions on this topic. This requires a larger, broad-spectrum, well-designed study to better discover the M&S workforce's understanding, experience, and beliefs in this area. A suggestion also found in the VDEM Report.

Only 15% respondents listed an M&S-degree as a top degree-field within the M&S workforce. By contrast, nearly 80% of our respondents identified the computer science, software development, systems engineering, industrial engineering, systems engineering, and applied mathematics majors as appropriate. While many identified the domain of use as the best major (e.g., aerospace, physics, engineering), there were only nine who indicated a domain without also including one or more of these other majors. It is difficult from the data to determine this variance is due to an actual preference or a general lack of awareness of available M&S-degree options. However, our survey overwhelmingly responded with a preference for an M&S workforce holding Masters Degrees. The responses to the duties of an M&S Professional can help explain this observation. We apply M&S to solve inherently complex problems. The math required for both development and use pushes beyond that which Bachelors programs usually cover. This is proven out by the high number of M&S related masters programs and only a few Bachelors programs in M&S—having a Bachelors and domain experience in a fields tend equates to Masters level experience over time.

CLOSING THOUGHTS AND RECOMMENDATIONS

The CMSP topic-areas provided the basis for our examination. Although we recognized that there could be, and were, reasoned, reasonable arguments against this, one must select an examination framework. In our previous paper, we argued that as a field of study, M&S is a nascent science. The factors drove our argument 1) the definition of a mature science posited by Kuhn (Kuhn, 1970 p. 5); 2) observations from and Szczerbicka et al. (2000) in Kincaid and Wusterland (2009 p. 277) that M&S lacks a "firm pedagogical foundation;" and 3) our own investigations (Bair & Jackson, 2013). However, one could counter that the existence of the CMSP, its peer-reviewed test bank, and the supporting body of knowledge provide the perfect rebuttal to our claims. In fact, the 2014 NAICS Proposal does just that. Nonetheless, observations made from within the M&S community and by their customers indicate that the CMSP has not been successful in uniting the M&S workforce under a common body of knowledge, technical understanding, and skill set nor have existing educational programs been able to do so. If we are to avoid lost opportunity, then it bears asking, "Where and what is the disconnect?"

Although there are differences in focus and emphasis, M&S-focused programs cover CMSP-topics, generally aligning with industry demands. However, the 2014 NAIC Proposal asserts that conceptual modeling, simulation standards, validation, and the production practices that link the three into a coherent whole comprise the defining characteristics of M&S, separate and distinct from software development and beyond the application of M&S within a scientific or other discipline. However, our investigations suggest these core-M&S areas have the widest gap. Most of the M&S-specific programs had few courses dedicated to the theory of computation, software engineering, and systems engineering, topics found traditionally in other majors. Similarly, modeling methods have good coverage, but to meet the demands exposed, these courses need to provide a firm underpinning in the M&S-core and a practical understanding of real-world use. The M&S workforce needs courses that go beyond survey courses exposing students to multiple methods and provide more depth than "textbook" examinations into individual methods. *Academia*

needs to develop and provide courses giving a holistic grounding across methods, using a common lexicon for each, bolstered by practical project-based applications to provide the M&S workforce a consistent technical and theoretical understanding of M&S and its implications for use. Modeling methods and applications provide a vehicle to explore the core of M&S but are only tools and not the core themselves.

Our research shows that the demand signal for M&S-development and its domains of application vary by field of use, dynamic in response to industry's reaction to the demands from customer sectors. Differences in our data probably reflect perceived needs within sectors. For instance, state and local governments may be unaware of or do not see the need for distributed simulation, or perhaps, do not want to solicit simulation development. One interpretation of our data is that this group prefers to obtain already-developed, easy-to-use simulations based in solid fundamentals. While without doubt this simplifies this sector's needs, the data suggest that our customer sectors differ in their need from the M&S workforce, having implications for the posturing appropriate by both academia and industry to meet them. While M&S education programs and the CMSP cannot, and should not, regularly alter the M&S curriculum; if it desires to meet industry demand, the M&SCPP may want to consider the weight given these topics in future CMSP improvements. *We believe that NTSA and other application- and use-focused organizations can advise the M&SCPP and M&S education community on industry's demand-priorities with regular periodicity, maximizing the utility and skills-relevancy of fresh graduates.*

The VDEM Report resoundingly called for an M&S workforce with more practical skills and experience. The open-ended responses in our survey highlight these and other areas that may not have much emphasis in either the formal M&S education programs or the CMSP program—pure business skills, team management, skills, communication skills, and practical application coupled with domain understanding—all necessary to the successful use of M&S. *We recommend M&S degree-programs investigate using team-based learning to develop team leadership and management skills in their graduates, expanding their use if already in place*. Industry clearly has a demand for these skills "not directly M&S" and views them as necessary for the M&S Professional *We further recommend that the M&SCPP look to include these not-directly-M&S skills within the CMSP course of study.* It is difficult to obtain experience and gain domain understanding without spending time performing the job—a fact the M&SCPP recognizes. *Therefore, we recommend that government agencies support and service providers more robust M&S internship and CO-OP programs to increase the effectiveness of new entrants to the M&S workforce*.

The M&SCPP predicated its work upon the premise that *M&S Professionals exist*. It is difficult to argue against this opening gambit. Yet, the entering assumption of this prime facie argument occurs earlier than initially presented: *I and my colleagues self-identify as a professional working with M&S, therefore M&S Professionals exist*. This is a fundamental premise upon which we must observe and reflect. The CMSP adds value, stature, and prestige to our profession. It gives notice to our colleagues, management, and customers that we have the skills, knowledge, repertoire, and understanding to meet the requirements of the *Professional Liar*. This title is not pejorative, rather it precisely recognizes that creating, selecting, and using models is more than programming, choosing software, loading data, and hitting "start." The entry-level analyst often may hear, "To someone with a hammer, every problem looks like a nail." For role of the M&S Professional, this analogy should be likened to that of a master carpenter. The selection of tool is not, "Should I use a chisel?" but rather, "Which chisel should I use?" while considering the hardness and grain of the wood in terms of the desired final product. This analogy fails, though, when one considers the potential outcomes from M&S use. To say that lives hang in the balance is not hyperbole, at least not in defense and healthcare. In this case, recalling the "your best weapon is between your ears and under your scalp—provided it's loaded," is more apropos (2005, p. 8).

M&S Professionals cannot afford to work by rote, unaware of the potential implications of their work—nor can the customers they support. For the CMSP to realize its goals, the M&S Professionals that practice and their customers must value this certification as necessary—not optional—as should the institutions educating them. The evidence, albeit scant and informal, suggests that the M&S industry lacks this impetus. If those self-identifying as M&S Professionals do not see value in and seek the CMSP, then they cannot grow as a workforce, and it is those hiring and their customer-base who create that value. M&S can provide solutions to meet the needs for military training in a cost-, resource-, and time-constrained environment, but coupling these requirements with the technical, research, and theoretical understanding required to manage the complexity issues inherent in developing and delivering simulation-based training necessitates a merged understanding of these skill sets by academia, consumers, and providers. Each must recognize that the differentiated M&S-expertise declared by the CMSP is important or accede to a technician's role.

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[1] US Census Bureau issue papers (Special Projects Staff, n.d.) discuss benefits and limitations of this approach.

[2] NAICS Proposal 2014 suggests a metaphor: a scientist, can develop software without being a software engineer, but the existence of these activities within the marketplace does not obviate software development as an industry. Note the ECPC denied the application in July 2015.

[3] Throughout this paper we will use degree to expressly include certificates, unless specifically excluded.

[4] The report makes no mention the CMSP anywhere in its report nor does it specify the types of certifications desired, leaving open the possibility that they could refer to computer, network, engineering, or other certifications.

[5] Respondents rated certificates on a scale of 1 (not important) to 5 (very important). We considered ratings of either a 4 or 5 as “valuable”, 3 as “neutral” or possibly unaware, and a 2 or 1 as “irrelevant” or “not valuable.”

[6] We asked respondents to identify which CMSP Modeling Methods qualified candidates in the M&S workforce should be familiar. The distribution of these responses provided the pool ranking for the topic.

[7] We asked respondents to select areas of primary expertise and skills sets, selected from M&S Domain-Specific Knowledge and M&S-Specific Software Engineering areas of the CMSP topic list, that qualified candidates in the M&S workforce should be familiar. The distribution of these responses provided the pool ranking for the topic.