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The Profession of Modeling and Simulations: Unifying the Organization

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THE PROFESSION OF MODELING AND SIMULATION: UNIFYING THE ORGANIZATION

by

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ABSTRACT

The organization of Modeling and Simulation (M&S) as a profession started in the early twenty-first century spurred by the advent of computers and the vast networking capabilities of contemporary computing. M&S is still in its infancy when compared to other disciplines, such as engineering, computer science and mathematics. However, the profession has experienced significant growth in part due to the varied use of M&S techniques and tools within almost every discipline.

Professional organizations and academic programs supporting M&S across the country have started to materialize. In a short timeframe, the growth of these supporting organizations has outpaced their ability to stay unified as a discipline, aligned with standardized Knowledge, Skills, and Abilities (KSAs) and with growing stakeholder needs.

Consequently, there appear to be gaps in the M&S professional organization. Such as a lack of synchronization between the three primary stakeholder groups of the M&S profession: academia, government, and industry. The discipline's professional organization fails to recognize a single body of knowledge as an authoritative reference for M&S KSAs. Academic institutions do not have unanimity regarding targeted KSAs. Industry lacks the confidence to hire M&S professionals who have a core understanding of KSAs directly associated with the version of M&S used by each separate industry.

This research study attempts to take a coordinated step forward in unifying the M&S discipline by assessing and prioritizing the current competencies and standards required of M&S professionals and identifying the needs and competencies valued by primary stakeholders. A survey instrument was developed in conjunction with Rebecca Leis' doctorate research. The instrument was distributed to M&S stakeholders to ascertain the breadth of the needed, valued,

and required KSAs within the domain. The survey was evaluated by cross-referencing questions and tabulating responses. Results from this research suggest ways in which stakeholders can coordinate efforts in advancing the M&S professional organization and support a uniformed set of KSAs needed in academia, government, and industry now and in the future.

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LIST OF ACRONYMS (or) ABBREVIATIONS

ABET – Accreditation Board for Engineering and Technology

AMSO – Army Modeling and Simulation Office

AT&L – Acquisition, Technology, and Logistics

BoK – Body of Knowledge

CCIE – Cisco Certified Internetwork Expert

CITI – Collaborative Institution Training Initiative

CMSP – Certified Modeling and Simulation Professional

CP36 – Army Modeling and Simulation civilian

CPA – Certified Public Accountant

DoD – Department of Defense

DARPA – Defense Advanced Research Project Agency

ECPC – Economic Classification Policy Committee

Eng – Engineer

FA57 – Army Modeling and Simulation uniformed Officers

HR – Human Resource

I/ITSEC – Interservice/Industry Training, Simulation, and Education Conference

IRB – Institutional Review Board

IST – Institute for Simulation and Training

JCATS – Joint Conflict and Tactical Simulation

JLVC – Joint Live-Virtual-Constructive

JTLS – Joint Theater Level Simulation

KSA – Knowledge, Skills, and Abilities

LVC – Live, Virtual, and Constructive

M&S – Modeling and Simulation

MaSK – Modeling and Simulation Knights

MOVES – Modeling, Virtual Environments, and Simulation

MSCO – Defense Modeling and Simulation Coordination Office

MSMS – Master of Science Medical and Healthcare Simulation

MSPCC – Modeling and Simulation Professional Certification Commission

MSVE – Modeling and Simulation Visualization Engineering

NAICS – North American Industry Classification System

NCS – National Center for Simulation

NMSC – National Modeling and Simulation Coalition

NPS – Naval Post Graduate School

NTSA – National Training and Simulation Association

ODU – Old Dominion University

PII – Personal Identifiable Information

PMP – Project Management Professional

RQ – Research Question

RU – Recertification Units

SAIC – Science Applications International Corporation

SCS – Society for Modeling and Simulation International

SIMNET – Simulator Networking

SISO – Simulation Interoperability and Standards Organization

SMST – School of Modeling, Simulation, and Training

SME – Subject Matter Expert

STEM – Science, Technology, Engineering, and Mathematics

SQ – Survey Question

UCF – University of Central Florida

US – United States

VV&A – Verification, Validation, and Accreditation

CHAPTER ONE:
INTRODUCTION

Imagine starting an advanced degree in the academic discipline of Modeling and Simulation (M&S) at any number of universities across the United States (US). Individuals chose the degree because it sounded interesting, fit with career aspirations and employment opportunities, or perhaps it was a program suggested by an employer.

Once one initiates the core classes, one discovers the significant diversity among the student population studying this specialized field. Of the students sitting in a typical M&S class, one may count undergraduate degrees and experience from a menagerie of fields: engineering, computer science, healthcare, mathematics, psychology, fashion design, criminal justice, military training, and sociology. One may wonder, what are all these people doing here? Why did they choose to obtain a degree in M&S? Are there such varied M&S related jobs available? If so, what are they?

A quick internet search in October 2018, on the popular job search site Indeed.com, yields insight into the differing jobs related to M&S with over 2,094 related hits. The electronic search was conducted using no location indicator.

The preponderance of job titles for the first three pages of results includes systems analyst, M&S analyst, M&S engineer, analyst, statistician, M&S support, M&S research, M&S operator/trainer and M&S operations. Education requirements listed from jobs posted on the first three pages include related degrees: engineering, computer science, operations research, mathematics, science, and related degrees.

General searches for “modeling and simulation” and “M&S” resulted in a similar number of hits, all with similar job titles and education requirements as the previous. Only one job, of

the over two thousand, titled "Modeling & Simulation Analyst," required an M&S or related degree.

Rebecca Leis, the 2016 President of Modeling and Simulation Knights (MaSK) at the University of Central Florida (UCF) discussed the bleak prospect of jobs for the many non-science, technology, engineering and mathematics (STEM) related graduates (Leis, 2017). Leis stated, "There is a large, diverse population of students gaining advanced degrees in M&S. The equivalent demand from industry, requiring higher level education related to M&S is lacking" (p. 1). Additionally, Leis indicated, MaSK students' most-pressing question for a visiting member of The Society for Modeling and Simulation International (SCS) continues to be, "what jobs are available to M&S graduates (p. 1)?"

The critical questions for all stakeholders in the M&S field remain, as they have for the past 15 plus years, "What Knowledge, Skills, and Abilities (KSAs) are essential to employers hiring M&S qualified candidates or 'simulationists'?" and "Do academic institutions offering advanced M&S degrees teach the KSAs required for employment within the M&S field?"

Supporting and in conjunction with the above questions, stakeholders are asking "Are there M&S related KSAs unique to an individual employment field?" "Is M&S a secondary specialization related to STEM or a primary employment field?" and "What is the advantage of gaining an advanced degree in M&S?"

As students exit the educational pipeline and enter the workforce, it is critically important, for mental wellbeing and future security, to understand the M&S discipline and profession as a whole, its historical path, and future direction.

History of Modeling and Simulation

The profession of simulations has an exponentially progressive history. M&S is, in comparison, a very young discipline in regards to the fields of study related to mathematics, physics and astronomy, engineering, physical science, computer science (Ören, 2014). Models were used many hundreds of years ago (Little, 2006) as early as 2,500 BC when Egyptian sculptures modeled terracotta warriors to simulate battlefield exercises. These early models were developed to teach techniques and tactics used in battle from a relatively safe home environment. The idea of "train as you fight" continued throughout humanity.

Simulation techniques have a long history. In 1824, Prussian Baron von Reisswitz published "Wargame" a work detailing how to utilize models over time and space to practice war. In 1877, the simulation method later called, "Monte Carlo" was first used by Comte De Buffon in his famous needle experiment. In 1908, William Sealy Gosset published his famous documents on t-distribution (Goldsman, Nance, & Wilson, 2009). Gossett used a simulation to conduct his experiments.

The use of simulations, for various reasons, has been in existence since the early fourteenth century and has changed little over the years (Ören, Mittal, & Durak, 2017). Modeling the complex environment and conducting simulations is and appears to have always been a cost-effective way to do experiments, develop new products, and coordinate training.

In the US, a formal policy was created by the Department of Defense (DoD) in the 1980s establishing the acquisition of M&S technology (Little, 2006). The establishment of the Defense Advanced Research Project Agency (DARPA) in 1958 by President Eisenhower played a role in the advancement of computers and the DoD's use of computer simulations. The development of Simulator Networking (SIMNET) merged the use of computer graphic technology and network

capability (Sokolowski & Mielke, 2017). As the DoD acquired technology related to M&S, there also existed the need for trained individuals to understand, operate, and utilize the technology; even if they were not officially called M&S professionals. These early simulationists and their contributions to our global society can be attributed to M&S because of the use of physical modeling and the application of those models over time.

Today the rapid increase in the use of computers and network related technology have made the use of M&S vital to many professional disciplines (Ören et al., 2017). Consequently, the field of M&S is rapidly growing and advancing. M&S is used in many "conventional and unconventional areas as a powerful infrastructure" (Ören, 2011a).

In 2007, the US House enacted House Resolution 487 which formally established M&S as a "national critical technology" (Forbes, 2007). The DoD, the manufacturing industry, the research and development industry, the health care industry, the entertainment industry, academia, and many more use M&S as an imperative solution to accomplish goals and make decisions. If M&S simply disappeared, so would the progress made in associated disciplines.

Modeling and Simulation Today

M&S can be considered as a summation of its parts. Concomitantly, when considering any individual component, simulation or modeling, the whole must also be considered. Thus, simulations are used everywhere in today's complex and ever-changing global society considering its vast uses. Over the last ten years, significant advancements in space travel, national defense, healthcare, weather predictions, and many others have incorporated the use of M&S (Bair & Jackson, 2013). M&S is needed to help solve increasingly complex problems in all industries and fields of study. Few areas of modern society do not use M&S in some form or fashion. M&S facilitates experimentation which are too dangerous, expensive, or would take too

long for results (Ören, 2014). M&S enables scientific domains such as computers, engineering, mathematics, physics, cosmology, and space exploration to explore and analyze complex and indeterminate problems. Simulation is used for prediction and understanding of phenomenon/system by replication. M&S allows for the intense study of complex systems, such as meteorology, economics and climate change, that would otherwise be prohibitively expensive, unethical or dangerous (Padilla, Diallo, & Tolk, 2011). With the continued progression of the computer processing speeds, memory, and network technology, the M&S related domain will continue to expand and progress. For example, M&S is being used in particle physics to conduct virtual simulations of dark matter trying to provide an increased understanding of related issues in cosmology. The medical field is using M&S to model internal human organs to ascertain natural function and to one day build artificial organs (Yilmaz, 2017).

The US Army is using simulations to progress individual and unit skill advancement in troops training for combat. Live, Virtual, and Constructive (LVC) simulations are used to replicate real-world wartime scenarios (Nolan et al., 2017). Many industries use simulated training including healthcare, education, and manufacturing. Simulations are a cost-effective and acceptable way to teach and train vital skills and abilities. Students can replicate actual conditions in a training environment with far higher frequency and far less induced risk than traditional training conducted using actual equipment in a field or live scenario.

The use and practice of simulation are spreading to every conceivable discipline. M&S is widely and readily accepted and utilized. Figure 1 provides a glimpse of the different domains and applications across the professional arena incorporating simulations. The figure depicts a non-exhaustive list of M&S domains applied to M&S applications.

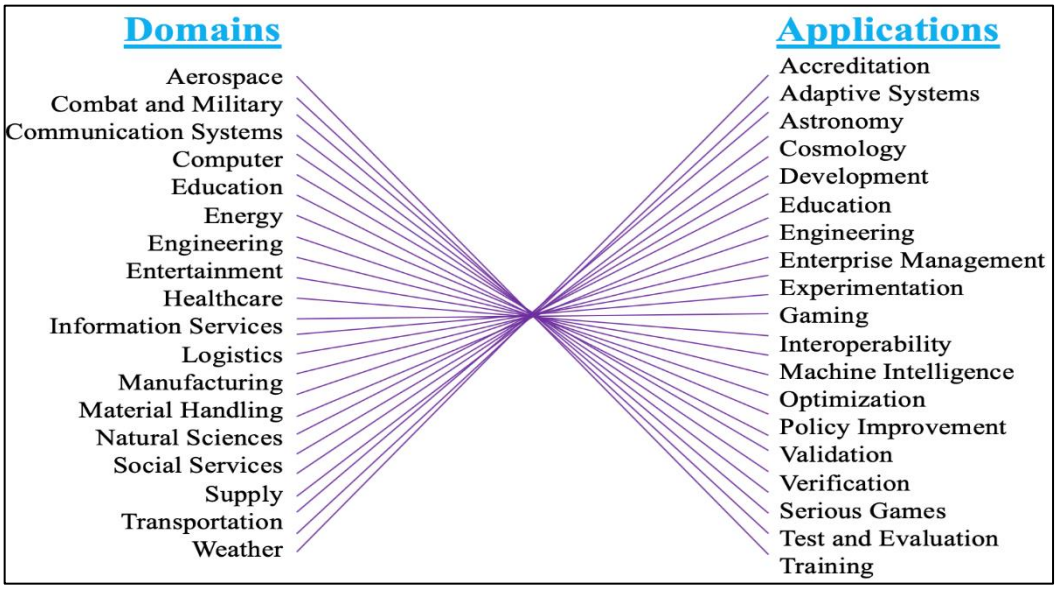


Figure 1: M&S Domains and Applications

Simulation has become more than an individual component. Review of the list of domains and applications suggests that simulation is used by developers, experimenters, trainers, and those seeking personal entertainment (Ören et al., 2017; Petty, Reed, & Tucker, 2012). Therefore, a simulationist might be someone who both uses and develops simulation related applications over a vast spectrum of disciplines.

Modeling and Simulation Organization as a Professional Body

Due to the increased importance placed on M&S throughout history and the overwhelming interconnectedness of M&S with all disciplines, scholars have advocated for M&S to become a recognized profession in order to set M&S apart from other disciplines as an independent and unique organization. Some of the contributors who have placed significant effort into the process of making M&S a profession include, Louis Birta (University of Ottawa), Tuncer Ören (University of Ottawa), Andreas Tolk (Old Dominion University), Jose Padilla (Old Dominion University), Roland Mielke (Old Dominion University), William Waite (AEgis), Lisa Bair (SAIC), and James Jackson (SAIC). These contributors, among many others following

professional organization models, have introduced much to the furtherance and development of M&S as a professional body.

Unfortunately, even with all the varied work being conducted, simulation as a professional entity is not unified. Some stakeholders of M&S, see M&S as a unique discipline that serves the needs of other disciplines and draws life by helping diverse scientific fields of study (Yilmaz, 2017). Because M&S is used in such a multi-disciplined manner, the overall creation of M&S as a professional organization has suffered. Each discipline claims M&S as part of their own. Authors, such as those mentioned above, have tried to unify popular opinion in an effort to assist in the overall creation of the profession of M&S. Their efforts have yet to result in a unified foundation for the M&S professional organization.

In the early 2000s, DeVin, Kincade, Crosbie, and others recognized the need for M&S higher level education in order to train the professional creation and use of M&S applications (Crosbie, 2000; DeVin, 2001; Kincaid, Hamilton, Tarr, & Sangani, 2003; Szczerbicka et al., 2000). In 2002, the National Training and Simulation Association (NTSA) created the Certified Modeling and Simulation Professional (CMSP) certification in order to engender industry confidence in the quality and level of education among M&S professionals (Bair & Jackson, 2015; Lewis & Rowe, 2010; Ören, 2005b; Petty, Reed, & Tucker, 2017). In 2003, Birta and Ören introduced an outline of an M&S body of knowledge (Birta, 2003; Ören, 2005c). This action may have been the official beginning of M&S as a professional organization.

Consequently, many discuss the creation of M&S professional organizations starting somewhere in the early 2000s in order to unify M&S professionals, provide support, and assist in the dissemination of M&S knowledge (Garrett, Robb, Severinghaus, & Fujimoto, 2017; Ören, 2005a, 2005b; Sokolowski & Mielke, 2017; Tolk, 2017; Yilmaz et al., 2008). All of these

authors and their efforts were committed to unify the M&S professional and create a unique and professional simulationist.

As time progressed, it became evident that additional help was needed to solidify M&S as a unique academic discipline and professional organization. Continuing to engender support from the vast associated disciplines, M&S proponents modified their ideas and asked probing questions intended to further M&S professional unification. Authors attempted to identify the popular KSAs that ensured stakeholders unequivocally understood what defined a qualified M&S professional (Bair & Jackson, 2013; Kölsch, 2011).

In 2008, the DoD published a joint Body of Knowledge (BoK) in an attempt to amalgamate the M&S knowledge amongst the four military services and secure a sole repository of knowledge (Office, 2008).

In 2010, Ören attempted to solicit general public support by updating his definition of simulation to be more expansive. Ören also initiated efforts to create a list of common simulation terms that would be universally recognized (Ören, 2011b; Ören & Waite, 2010). Around the same time, the NTSA updated the CMSP testing to include individual certifications for users, developers and managers of M&S (Lewis & Rowe, 2010; Petty et al., 2017). Even the DoD showed particular interest in understanding what KSAs constitute a well-qualified M&S professional and unifying M&S knowledge (Darken & Blais, 2017; Nolan et al., 2017; Paulo & Few, 2009).

As of this publication, efforts continue to progress with the purpose of solidifying M&S as a unique and independent professional discipline. However, with all of the advances made to progress the M&S profession as a whole, much is still unknown. For example, “Why is there not greater support for an M&S BoK?”, “Why don’t stakeholders using M&S or involved in M&S

require M&S certified or degreed professional employees?" and "Why isn't there more unification among the academic community offering M&S education?"

As the profession organizes, it continues to be imperative that a common understanding of what M&S is across all domains and disciplines is needed (Padilla et al., 2011). Specific ideas need to be identified to create the profession of M&S. For example, concepts such as standardization, a well-organized body of knowledge, a standard of ethics, and professional community (Sarjoughian & Zeigler, 2001). Developing such a wide range of uniquely skilled individuals into a cohesive, unified M&S professional organization has constituted and still constitutes a significant challenge.

This research study intends to present the critical need for in-depth polling of M&S professionals involved in academia, government, and industry. It is of paramount importance to the future of the profession to have a clear understanding of, "Who is using M&S?" and "What KSAs are required by employers of M&S professionals?" The M&S profession, as an organization, must have a unified influence going forward to alleviate confusion from inside and outside the profession regarding what constitutes M&S as an academic discipline and a professional organization.

The outcome of this study is to provide insight into which KSAs M&S stakeholders deem essential for the field, as well as those critical to employment attainment and retention. The study utilizes a survey component that will yield insight into the need for a clearer understanding of what M&S does, what M&S opportunities are available, and what skills are brought to bear by an M&S professional with a higher-level degree.

The following sections support the current study. The literature review section documents an in-depth evaluation of the M&S gaps associated with the professional

organization. The methods section details the research questions and the survey used to explore the perceived gaps. The results section verifies the methods section by providing the respondent answers to the survey questions posed in the methods section. Finally, the discussion section provides evidence of the perceived gaps by discussing the gaps in relation to the research questions.

CHAPTER TWO:
LITERATURE REVIEW

What is a Profession?

From the onset, M&S professionals have attempted to solidify M&S as a professional organization. Many have determined to create coalitions of like-minded academic and professional individuals in order to understand and remedy the problems associated with creating a new and unique professional structure (Ören & Waite, 2010; Rogers, 1997).

Researchers and authors from many different professions have postulated what is necessary in order to create and maintain a professional organization. Interestingly, what constitutes a profession has not changed much over the years. In 2000, an Australian organization published a website promoting the standardization of professional organizations. In their view a profession is comprised of the following:

> A disciplined group of individuals who adhere to high ethical standards and uphold themselves to, and are accepted by, the public as possessing special knowledge and skills in a widely recognized, organized body of learning derived from education and training at a high level, and who are prepared to exercise this knowledge and these skills in the interests of others. (Professions, 2018, p. 1)

Greenwood, an organizational theorist, writing on the attributes of a profession, discussed the importance of organization within the profession. He indicated that each professional group needs: a body of knowledge that codifies the skills required, authority /credibility – includes examinations and certifications documenting the expertise of individuals, code of ethics which create a culture of values and norms, and community sanction/regulation and control of members (Greenwood, 2010).

Tolk, in his 2017 paper, indicated in order for M&S to become a solidified professional organization, key stakeholders such as academia, government, and industry must partner. With

everyone involved in M&S working together, clear boundaries can become evident (p. 5). Bair and Jackson (2013) indicated the wide range of disciplines related to M&S make it difficult to accurately describe the education, training, and employment of an M&S professional (p. 9). It is likely only through the expression and involvement of all professionals within the many different disciplines directly involved with M&S that the eventual profession of M&S will emerge as a uniquely different organization (p. 9, 10).

Collectively, M&S researchers knew from early research that clearly defined boundaries related to the model of a professional organization must be made if the M&S profession was ever going to assure the public and associated academic, government, and industry stakeholders that M&S is a unique and qualified professional organization capable of producing skilled products, services, and knowledge dissemination (p. 9).

Boundaries may take the form of KSA which are gathered as foundational expertise and codified in professional knowledge form in a BoK (Wu, Mayo, McCuen, Issa, & Smith, 2018). KSAs are developed using various expert sources including organized panels, subject matter expert (SME) opinion, and review of previously produced research (Salas et al., 1999). For the purposes of this research, KSAs are defined: "knowledge – a body of information needed to perform a task, skill – the proficiency to perform a learned task, ability – a basic capacity for performing a wide range of different tasks, acquiring knowledge, or developing a skill" (Aamodt, 2012, p. 53).

As Ören suggests, it is necessary to detail the attributes of the M&S professional body using the indicated model of a professional organization and then confess the preserved gaps associated with each attribute (2005). The BoK is a central repository of knowledge and information regarding the profession. The professional organization's BoK provides specific

knowledge to unify the individuals and provide a mutual understanding of standard practices (Ören, 2005c; Tolk, 2010).

Tolk indicated, that authority and credibility are provided through education and certification, and that academic instruction must be centered on the knowledge of the profession (Tolk, 2017). He suggested that a profession should clearly communicate the academic requirements and the continued education requirements aligned with professional standards (p. 6-7). According to Tolk, the quality of education and unity of academic institutions is essential to the progression of the professional organization and that certification of professionals was no different (p. 7). Employers, related academia, government, and industry, must be able to rely upon the quality of an individual presented as a professional within the organization.

Professional community is often defined as a composite of all organizations related and progressing the cause of a specific profession (Lacy, Gross, Ören, & Waite, 2010). Members, industry, government, and others understand expectations and can draw upon actual information to unify discipline-based knowledge and provide a structured way to identify and obtain discipline-related information (p. 4). Thus, a community is made up of professional organizations that individually progress the profession and collectively make up the profession. Organizations provide a community for individuals within the profession (p. 4). Professionals within the organizations share information and grow a foundation of knowledge whereupon to draw professional experience and expertise.

Body of Knowledge

Many professional organizations have rallied around a common lexicon and knowledge base to promote unity and organization within structured society (Oliver, 2012; Ören, 2014). Codifying a BoK gives organizations inclusiveness. It is the beginning and solidifying base

upon which all the additional parts build. "A Body of Knowledge is the complete set of concepts, terms, and activities that make up a professional domain, as defined by the relevant learned society or professional association" (Oliver, 2012, p. 3).

Oliver (2012), believed that from the common understanding created by the application of a recognized and accepted BoK, all elements of a professional organization flow. A profession's BoK is a collection of "structured knowledge" used to provide guidance regarding all aspects of the field of work (Ören, 2014). The BoK of any academic area should provide foundations, information, and practices related to the professional domain. The better understanding a professional has of his or her field, the easier it will be for that professional to articulate the value and need of those skills to others.

The knowledge inside a profession is imperative. A professional BoK is intended to ensure high-level knowledge areas and specifically defined terms and definitions shared in common with all, academia, government, and industry stakeholders (Durak, Ören, & Tolk, 2017). The BoK includes the ontological framework for a field, as such the integration of domain knowledge that must be thoughtful, systematic, and agreed upon by multiple stakeholders (Ören, 2014).

Modeling and Simulation Body of Knowledge

The recognition of the need for an M&S BoK dates back to 1997 when a consortium of M&S individuals from both academia and industry met together to discuss the future of M&S as a profession (Birta, 2003; Rogers, 1997; Szczerbicka et al., 2000). At the time M&S was an emerging domain with potential. Only a few academic programs were offering M&S advanced degrees, all of which were initiated by industry demand (Crosbie, 2000; DeVin, 2001). These

programs, as well as the profession of M&S, needed a unifying force of information, a common body of knowledge.

Since that time multiple researchers have written in favor of the need for an M&S BoK (Birta, 2003; Durak et al., 2017; Lacy et al., 2010; Ören, 2005c, 2011a, 2012, 2014; Ören & Waite, 2007, 2010; Tolk, 2010). Ören indicated that the M&S profession could not continue to survive without a structured BoK (Ören, 2011a). Lacy and colleagues (2010) believed that academia, government, and industry needed to come together to create a common understanding regarding the information that must be codified as M&S specific.

With the unique multi-discipline aspect of M&S, it is difficult to imagine M&S professionals from different industries and disciplines gravitating toward each other in order to unify and solidify understandings. However, this is what appeared to be happening in the early 2000s.

Ören, a professor at the University of Ottawa, initiated the outline of the first codified M&S BoK (Ören, 2005c; Ören & Waite, 2007). This outline is currently posted on a website hosted by the University of Ottawa and kept up-to-date by Ören (Ören, 2018). Other M&S BoKs followed, such as the DoD's joint publication and the de-facto use of the CMSP. It is apparent that no one, individual or entity, except Ören, has rendered the effort required to identify and maintain unified information regarding the focus and direction of an M&S BoK.

Ören's BoK

Ören believed the creation of a BoK for M&S was imperative. He indicated that a BoK must be at the center of the M&S profession (Ören, 2011a). To that end, Ören developed an index for an M&S BoK (Ören, 2005c). He posted the index on a website and invited professionals from all over the world to support the effort of updating the BoK index (Ören &

Waite, 2010). Many papers and articles were written to help support Ören's efforts, all of which were listed on the M&S BoK website (Lacy et al., 2010; Ören, 2011a, 2014; Ören & Waite, 2010).

Ören maintained the M&S BoK should be structured with knowledge at the center (Ören, 2011a). M&S stakeholders produce knowledge (p. 41). Ören capitalized on the idea that M&S was a system of systems. He modeled his version of the M&S BoK from multiple organizations wherein knowledge-based documents already existed. Figure 2, described below, is Ören's vision of an M&S BoK organization.

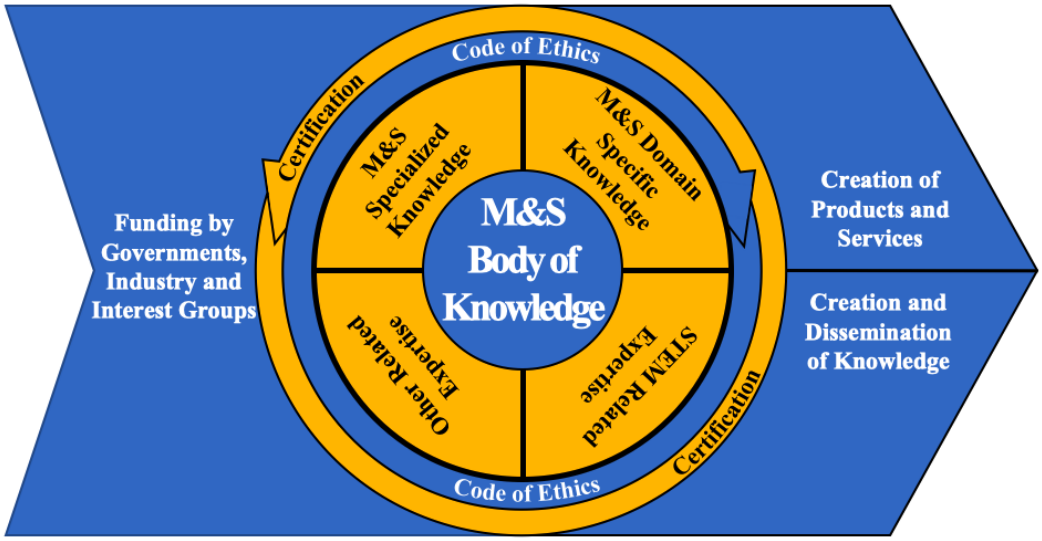


Figure 2: M&S Body of Knowledge

Ören indicated the BoK would be driven through the production of needs and requirements (p. 40). Industry, government, and M&S interest groups, who are the usual funders of M&S, need to solve problems or acquire knowledge (p. 41). Thus funding, in Ören's (2011a) viewpoint would drive the production of M&S services and product as an indicator of what was needed or wanted (p. 41). Other related expertise would be driven by the domain in which the requirement was fielded. The flow of Ören's diagram suggests from beginning to end:

funding/requirement production, knowledge and conduct, and activities or the creation of products and services and the creation and discrimination of knowledge (p. 40-43).

The outcome, according to Ören's diagram would be one or both of the two tails: the creation of specific M&S products and services or the creation of M&S specific knowledge. The process repeats as a recognition of need (p. 41). The creation and dissemination of knowledge add to the codified body of knowledge in order to meet future needs (p. 42). The BoK would generate and disseminate knowledge for academia on two levels. Academia is the forefront in research and development of new ideas. Ideas support stakeholders' drive toward the accomplishment of need. Academia also supports employers' need by ensuring that individual professionals have appropriate levels of knowledge and skills in order to assist the end goal (Ören, 2011a, p. 41).

The central layer of Ören's model is the M&S BoK core, which consists of four levels of knowledge. The BoK is directly associated with four areas: STEM-related expertise – the foundation knowledge taken from STEM disciplines, other related expertise – knowledge of the foundational domain as the origin of the requirement, M&S domain-specific knowledge – knowledge related to business, project management, systems engineering, foundational M&S knowledge, and supporting tools and techniques, and M&S specialized knowledge – knowledge related to application areas such as training, analysis, and engineering; knowledge related to technical skills required for model building and running simulations (p. 40-42).

The outside area knowledge includes the code of ethics and certification. Ören indicated that a code of ethics was required to ensure the sound practice and responsible behavior of M&S practitioners (Ören, 2005a). The knowledge and enforcement of the ethical code codified in the BoK provide security for the overall base of knowledge (Ören, 2011a).

Certification has a similar relationship with the BoK. The professional community has a responsibility to ensure the consistent and uniform skill set and educational level the employer and the end user can expect to receive when associating with an M&S professional (Bair & Jackson, 2013; Ören, 2011a). The BoK, therefore, includes knowledge associated with certification.

Ören stated an M&S BoK would be the primary document in the unification of the M&S community. The BoK would guide the M&S profession's standards and practices, and provide a common ontology for the domain (Ören, 2014). He indicated his intended purpose in creating a BoK was to establish competency requirements and create a common lexicon.

Currently, Ören's BoK can be found on his website hosted by the University of Ottawa (Ören, 2018). The BoK is outlined in four parts: background including preliminary information and terminology, M&S BoK core areas, M&S BoK supporting domains, and references, as well as miscellaneous information such as news stories and M&S related blogs. Interspersed throughout the BoK document are papers and presentations, from various authors, providing additional information, clarification, and ideas for future inclusion.

The site lists twenty members of the BoK committee working on the project. Committee members are from all over the world including, two from Canada, one each from China, France, Germany, Pakistan, the United Kingdom and ten members from the US. Members are from academia, government, and industry stakeholder groups.

The M&S BoK posted on the University of Ottawa website is an index of information. It is not a comprehensive source of information. Ören's M&S BoK is by far the most comprehensive and complete M&S BoK available in the public domain. Yet, it is only the beginning of what is needed to be a useful professional BoK. Ören's BoK committee is on draft

version nine of an M&S BoK index. However, little movement has occurred on the project since 2011 after Ören invited others to participate in the establishment of the M&S BoK index (Ören & Waite, 2010).

In 2018, Ören's index was adopted by the Society for SCS. The society picked up Ören's work in 2018 and is now displaying it in an effort to promote the continuous progression of M&S ("The Society for Modeling and Simulation International (SCS)," 2018).

The Department of Defense's Body of Knowledge

In 2008, two years after its inception, the Department of Defense Modeling and Simulation Coordination Office (MSCO) published a joint M&S BoK (Office, 2008). The MSCO was organized in 2006 under the US Undersecretary of Defense for Acquisition, Technology, and Logistics (AT&L). The office was organized to centralize M&S efforts across the four branches of the military: Army, Navy, Air Force, and the Marine Corps.

The DoD BoK is 180 pages of competencies, definitions, and usage. It provides information and education required for M&S professionals and competencies expected. It fails to translate to the remainder of the M&S profession outside the military. The BoK was created in a vacuum, without the aid of, or support from any of the services. Currently, the DoD BoK is under revision.

The "De-Facto" Body of Knowledge

The Modeling and Simulation Professional Certification Commission (MSPCC), under the hierarchical leadership of the NTSA, published a list of competencies associated with the CMSP certification program. The original intent of the list of topics was to give potential test takers an idea of the test question areas indicated in Figure 3 (Bair & Jackson, 2013).

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		

Figure 3: CMSP Exam Topic Areas

In 2012, Petty indicated that the CMSP examination would align with the M&S BoK and be used for both users and developers of M&S (Petty et al., 2012). Petty did not explain or expound upon the BoK used for the examination only to indicate that the examination topics would expand and change as the M&S BoK matures. Petty indicted the examination topics were proven and backed by fact-checking and authoritative peer-reviewed authorship (2012). These indicators gave the impression the exam topics themselves were the BoK used to produce the questions for the CMSP examination.

In 2015, Bair and Jackson indicated the CMSP examination topics were considered a de-facto M&S BoK (Bair & Jackson, 2015). Solidifying the idea that the MSPCC used their own

topics and information as the BoK indicated in Petty's CMSP examination announcement. Others are also using the CMSP examination topics as a BoK as indicated by Old Dominion University's M&S degree program (Sokolowski & Mielke, 2017).

The CMSP list of topic areas works as a de-facto M&S BoK. The topic list is separated into eight competency areas as indicated by the MSPCC website ("The Organization for Developing and Providing Professional Certification," n.d.): Concepts and Context – indicating fundamental terms, paradigms, and history, Application of M&S – indicating how M&S may be used, Domains of Use of M&S – domains and industries wherein M&S is developed and used, Modeling Methods – indicating methods used to create models both computational and otherwise, Simulation Implementation – indicating the life cycle of simulations from standards and verification, validation, and accreditation (VV&A) to processes/types of simulations, Supporting Tools, Techniques and Resources, Business and Management of M&S, and Related Communities of Practice and Disciplines. Petty et al. (2017) indicates the de-facto M&S BoK is consensus-based, covering a topical index specifically for the purposes of the CMSP exam.

Similar to Ören's BoK, the CMSP examination topic areas of the de-facto BoK gives a list of topics only. Whereas the questions on the examination are backed up by published information, the topic areas are not directly associated with any background information published or unpublished.

The de-facto M&S BoK is incomplete as a unifying force in the M&S community. The MSPCC provides very little education or instruction on the CMSP examination topics. The topics themselves do not have any written background available to the public. There does not appear to be anyone, organization or individual, who provides instruction on the CMSP de-facto BoK topics.

Modeling and Simulation Body of Knowledge Gaps

The primary gap regarding the identified M&S BoKs is the simple fact that there is not one that fulfills the contemporary education or certification needs of the professional community or the needs of M&S stakeholders in academia, government, and industry.

M&S as a profession and discipline needs a BoK in order to provide a general competency base of understanding available to professionals (simulationist) and all stakeholders. To explain the domain; a comprehensive and concise description of concepts terms and activities is needed (Durak et al., 2017). Both Ören's index and the CMSP examination topics have been in the public's preview since 2002. Yet, neither one of them has been overtly accepted as an M&S BoK by the professional community.

The community of M&S professionals continues to grow rapidly. As of this publication, it is nearly impossible to truly understand the varied applications, uses and development of M&S in every discipline from only one perspective. Diallo suggested, that if the diversity of M&S continued to grow regarding independently developed theories and tools, it would continue to be a great hindrance to building an overall unified framework of a BoK for M&S as a more extensive professional organization (Diallo, Mustafee, & Zacharewicz, 2015). Consequently, it is possible that M&S is growing too rapidly for a unified BoK to be solidified.

There are many professional organizations, under various M&S subject areas, that have published BoKs in order to cover the varied topics related to their industry. It is likely, given the many disciplines of M&S that it will need multiple BoKs (Ören, 2014). Durak suggests there is room to have a BoK specifically for Simulation Systems Engineering as a sub-domain of M&S (Durak et al., 2017). Further research could be done regarding the need for multiple BoKs, wherein each is dedicated to a domain associated with M&S.

Indeed, the rapid growth of M&S creates difficulties in obtaining a unified and consistent knowledge base regarding an overall M&S BoK. It is challenging for all stakeholders to understand the myriad of M&S competencies available because of the wide range of M&S products and services used and developed. It is difficult to know or understand what KSAs are required from M&S professionals because of the increasingly wide range of industries using M&S (Bair & Jackson, 2013).

Yet, there remains a salient need for clear and defining knowledge regarding the M&S profession. Those within the profession and all other stakeholders must have a similar understanding, a base of core competencies, a set of key KSA standards. The public at large, those outside the profession, must recognize the profession as a unified professional force. The global public needs to know what KSAs M&S professionals bring with them to benefit the overall process. M&S professionals need to be held accountable to a professional standard by the M&S professional organization.

Further, the M&S professional society does not have clarity (Tolk et al., 2015). Bair and Jackson suggest advances in the M&S BoK, the CMSP certification, and professional organizations such as the National Modeling and Simulation Coalition (NMSC) have done little to help solidify an understanding of what constitutes an M&S professional or the M&S organization (Bair & Jackson, 2013).

Education and Certification

Education and certification in specific subject areas, provide those inside and outside the professional community with the assurance of authority and credibility. Credibility provides trust and confidence to those who employ professionals and confirm that those employed have the KSAs to accomplish desired objectives. The process of education or certification gives the

bearer of the diploma or certificate the authority to act as if possessing the KSAs obtained by completion of the education or certification (Loper & Turnitsa, 2017).

The quality of the education and certification is dependent upon the public's perception regarding the unanimity and alignment with professional standards (Tolk, 2017). Thus, the employer, academia, government, industry, or any other related stakeholder must be able to rely upon the quality of education and certification in order to offer subject matter authority for the employee and provide credibility to the process.

Ören reminded the M&S professional community that proper education was essential and that without education the community would be inviting disaster. Consequently, without quality education and credible certification in any M&S fields of study, the profession as a whole and the individual professional is in jeopardy (Ören, 2014).

Modeling and Simulation Graduate Academic Programs

In 2007, the US House of Representatives passed House Resolution 487 titled "Recognizing the contribution of modeling and simulation technology to the security and prosperity of the US, and recognizing modeling and simulation as a National Critical Technology" (Congress, 2007).

At that time, The US House of Representatives officially recognized the contribution of M&S critical to technological advancement within the US and affirmed and encouraged the continued development and expansion of M&S academic programs within higher education. As of this publication, the US House of Representatives supports the development of government classification codes for M&S occupations by the US Department of Labor.

M&S higher education in the US was already well underway. The year 2002 marked the first graduating class of M&S professionals from the University of Alabama, Huntsville (Ören,

2005b). In 2007, 23 higher level academic institutions with M&S degree types were established within the US (Olwell, Johnson, & Didoszak, 2007). In 2012, Bair and Jackson conducted an internet search of available M&S programs to determine 26 degree/certification plans were available for M&S applications throughout the US (Bair & Jackson, 2013).

Programs identified by Bair and Jackson (2013) ranged from certifications, undergraduate programs, and graduate programs. The search included standalone M&S programs with curriculum directly associated with other programs such as engineering. For example, Arizona State University has an M&S program under the umbrella of their Engineer School of Science. M&S programs available in the US are listed in Table 1.

Academic programs are developed primarily in response to industry needs (Sokolowski & Mielke, 2017). As of this publication, a general Google search using the search term "modeling and simulation" resulted in five doctor of philosophy programs, 13 master's degree programs, three certificate programs, and two undergraduate programs internationally; a total of 23 global M&S programs. These programs attempt to answer the increased need for educated, trained, and certified personnel in academia, government, and industry in direct relation to the growing use of M&S (Loper & Turnitsa, 2017).

Table 1: M&S Education in the US

Name of Institution	Program Available					
	Certificate	Bachelor	Masters (M&S)	Masters (Eng)	Doctorate (M&S)	Doctorate (Eng)
Arizona State University				X		X
Drexel University			X			
George Mason University	X					
Georgia Institute of Technology	X					
Naval Post Graduate School	X		X		X	
Old Dominion University	X	X		X		X
Purdue University			X			
University of Alabama	X		X		X	
University of Central Florida	X		X		X	
University of Pittsburg					X	

M&S programs are available to students to pursue an education in the M&S field. Programs are, for the most part, tailored by the individual student. Degree programs have required core competency classes and each academic institution posts a list of acceptable elective courses. This study investigated four master's level programs in the US in order to provide an understanding and comparisons of the significant diversity among them. The programs investigated include the University of Central Florida, the Naval Post Graduate School, Old Dominion University and Drexel University. The diversity of these programs' core courses suggest cause for alignment to meet stakeholder needs and expectations. Information regarding each university was taken from the university program websites for academic calendar 2017-2018.

University of Central Florida

The UCF's M&S program is organized under the School of Modeling, Simulation, and Training (SMST). The entire program is contained within SMST. Core requirements for both degrees include: perspectives on M&S, mathematical foundations of M&S, understanding humans for M&S, simulation techniques, and research design or research methods for M&S ("Modeling and Simulation MS," n.d). UCF boasts a transdisciplinary approach to M&S education. Electives for the master's degree can be chosen from diverse topic areas including: M&S fundamentals, cybersecurity, human systems, computer visualization, M&S quantitative methods and analysis, simulation in healthcare, simulation management, simulation infrastructure, and simulation intelligent systems. UCF's M&S program is designed to facilitate learning M&S in regards to people, processes, and technology (Wiegand, 2019).

Naval Post Graduate School

The Naval Post Graduate School's (NPS) M&S program is organized under the Modeling, Virtual Environments, and Simulation (MOVES) Institute. Students in the master's program follow courses as outlined in the first and second year matrix according to the MOVES website ("Modeling, Virtual Environments and Simulation Institute," n.d.), such as history and fundamentals of M&S, applied mathematics, computer systems, virtual environments, training and human systems, and M&S systems lifecycle management. MOVES graduates receive a heavy concentration of mathematics, programming, and DoD based simulations. The program was created to support uniformed M&S professionals in the four branches of military service.

Old Dominion

Old Dominion University's (ODU) M&S program is organized under the established Department of Visualization Engineering (MSVE) within the College of Engineering and

Technology. ODU is the only university to offer an accredited degree from the Accreditation Board for Engineering and Technology (ABET) (Sokolowski & Mielke, 2017). Students graduate with a Master of Engineering – M&S or a Master of Science and Engineering – M&S. Core requirements for both degrees include: an overview of M&S, exploration of simulation methodological approaches, simulation systems principles and techniques, computer visualization and visual simulation, and principles of stochastic analysis ("Modeling, Simulation, and Visualization Engineering," n.d.). ODU has certificate programs and minors associated with other colleges within the university as indicated in Figure 4. ODU boasts the development of an undergraduate M&S degree program within the department of engineering (Leathrum & Mielke, 2012).

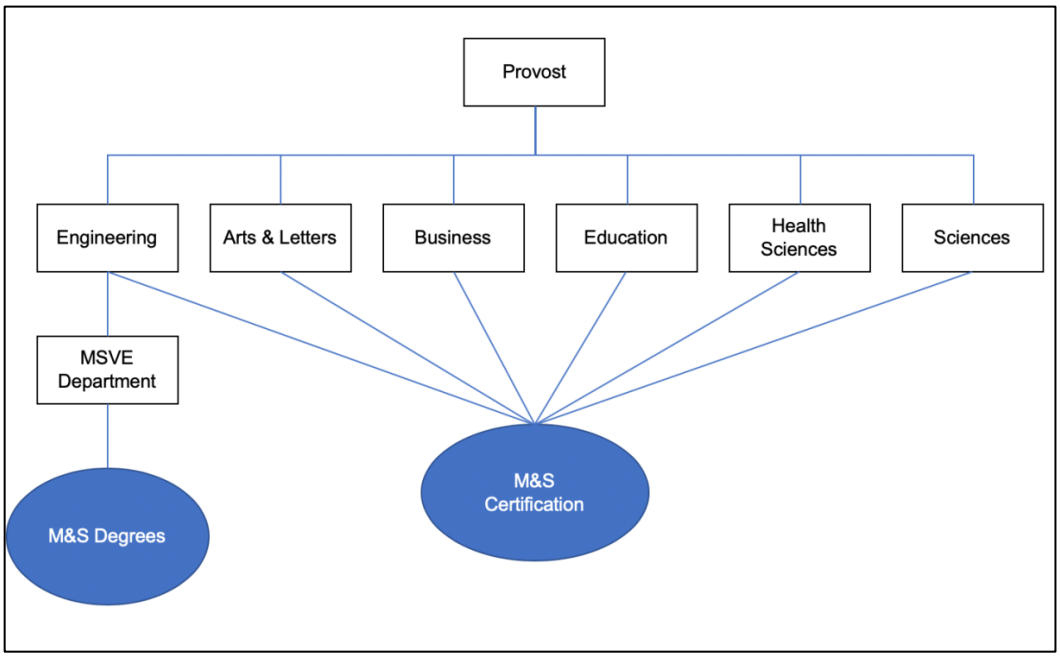


Figure 4: ODU Degree Tracks

Drexel University

The Drexel University College of Medicine has produced a Master of Science in Medical and Healthcare Simulation (MSMS) as part of the available degree choices for medical

personnel. The course is intended to provide students with skills related to simulation-based medical education. Required core subjects include: simulation curriculum, debriefing, feedback, and programmatic evaluation, management of simulation resources and interpret innovations in healthcare simulation education and application ("Medical and Healthcare Simulation (MSMS) Program," n.d.). The program is not connected to the Drexel University College of Engineering or the Drexel University College of Science.

Modeling and Simulation Certification

Professional certifications are intended to set apart professionals who have attained knowledge and experience specifically related to the profession. Professional certifications are prevalent in society, such as the Program Management Professional (PMP), the Certified Public Accountant (CPA) and the Cisco Certified Internetwork Expert (CCIE). Stakeholders support these professional certifications. These professional designations indicate the holder is competent and skillful enough to practice within the confines of the professional atmosphere and often require evidence of required continuing education. Industry stakeholders hire those individuals who have qualified themselves as knowledgeable in the profession as evidenced by the attainment of the certification

There are multiple certification programs available to the M&S professional organization. Many of the universities mentioned in the previous section have certification programs. The certification offered by a university is intended to provide evidence that students have accomplished academic requirements and possess core competencies associated with the topic of the certification. These courses are structured academic tracks of education offered to focus on specific areas identified as needed by the institution. There is only one professional M&S

certificate program intended to be a qualification for M&S professionals as a whole – The CMSP.

The Certified Modeling and Simulation Professional

The CMSP certification was created by the NTSA to provide the M&S professional organization an industry standard ("The Organization for Developing and Providing Professional Certification," n.d.). The MSPCC provides academia, government, and industry a method to certify the quality of M&S professionals employed by their organizations. The NTSA recognizes the need for formal certification to bring the M&S community unity and a common verified standard. The CMSP was intended to propagate the use of best practices, provide an indexed BoK, and assemble a pool of certified professionals who were qualified to practice the profession (Lewis & Rowe, 2010).

In order to establish the CMSP, the MSPCC was created from multiple M&S professional organizations, M&S academic professionals and M&S industry professionals. In 2010, a board of governors was established by the MSPCC in order to ensure the CMSP was kept up-to-date and relevant to current trends and advancements. At that time the CMSP was reorganized, explicitly identifying the differences between M&S professionals who are user/manager and developer/technical (Petty et al., 2017).

The CMSP requires recertification every four years. During the four years, recertification units (RU) are required to show continued education in the M&S profession ("The Organization for Developing and Providing Professional Certification," n.d.). RUs can be obtained by attending professional conferences, as well as, multiple prep and refresher courses, taught be academia. For example, The University of Alabama has a CMSP preparation course intended to provide initial information to help professionals pass the CMSP exam (Loper & Turnitsa, 2017).

Many experts suggested industries seeking M&S professionals would utilize the CMSP certification as proof of individual skill/knowledge level (Bair & Jackson, 2013; Lewis & Rowe, 2010; Petty et al., 2017).

From 2002, the CMSP inception, to 2012, marking the change to the CMSP to include users/developers, Perry reported only 200 people had ventured to take the examination to certify as a CMSP (Petty et al., 2012). The bulk of this number likely includes the initial group responsible for the development of the exam.

Between 2012 and 2017 the number of people claiming CMSP certifications did not increase (Petty et al., 2017). Employers, as a whole, have not been compelled to ensure their M&S employees were certified. There is not, nor has there been, a requirement to employ simulationists who hold a certain level of certification (Ören, 2011a). During the previously mentioned internet search for M&S related jobs, none of the employers seeking simulations related professionals required the CMSP certification.

Modeling and Simulation Education and Certification Gaps

There has never been more education available to M&S professionals then there is as of this publication. M&S is such a critically advancing field, that academic programming will undoubtedly continue to emerge. However, the continued and crucial problem with rapidly emerging education is the term "common." M&S lacks an academically common foundation (Kincaid et al., 2003; Szczerbicka et al., 2000). M&S does not have a recognized, official BoK, or national set of M&S standards.

Students from one academic institution cannot transfer to another and expect to learn the same M&S topics. M&S academic courses do not transfer from institution to institution (Wiegand, 2019). Each academic institution appears to be focused on their own unique

perspective of M&S. The different academic institutions recognize the need to promote M&S in professional organizations. However, it is evident that the institutions themselves do not have a clear understanding of M&S as a profession (Bair & Jackson, 2015; Yilmaz et al., 2008). Loper suggested, it is not easy to transfer M&S understanding from one academic institution to another; the different intuitional education systems and course information are too dissimilar (Loper & Turnitsa, 2017).

It is clear, the use of simulation is well expressed for disciples related to the sciences. Education appears to target simulationists working in the science domains. However, little is known regarding the KSAs needed for simulationists working in non-science related domains. Academic institutions are forced to work within their boundaries. Most academicians do well to ensure that local M&S trends are considered with course development. Yet, it is extremely difficult to keep abreast of global M&S trends, especially with the exponential rate of discovery and the myriad of domains involved in M&S.

There is no national requirement for education or certification within the profession of M&S. Industry does not require M&S degrees or certification. M&S professionals must be educated in a comprehensive range of fields including mathematics, science, computer science, and engineering. Keeping updated becomes even more critical as M&S complexity becomes increasingly vast (Sokolowski & Mielke, 2017). The evolution of the CMSP, progressing to include two tracks; one for engineers and developers and another for managers and users is an indicator of the diversity and range of expertise needed/related to the M&S profession (Bair & Jackson, 2013).

Academia and industry must work together to develop M&S core competencies (Loper & Turnitsa, 2017). Solutions from diverse problem domains are critical to M&S success

(Sokolowski & Mielke, 2017). A consensus is needed in the community regarding M&S education. A general knowledge of what M&S looks like and the KSAs attained by graduates of the education process would give industry stakeholders the confidence to employ certified and degreed M&S professionals.

Workforce development will continue to be a gap in M&S education and certification until there are M&S standards throughout all academic programs (Loper & Turnitsa, 2017). Bair and Jackson's study of higher education laid out the importance of formulating a common lexicon and following a rubric of study as conveyed by an authoritative source (2013). Providing academia, government, and industry the confidence required to promote M&S as a professional organization is imperative. Commonality may start with a federally recognized unique career code designating core competencies for M&S professionals.

Recently, a consortium of M&S professional organizations submitted a request to the Economic Classification Policy Committee (ECPC) to have M&S included in the NAICS as a professional industry. The organizations involved included the NTSA, the SCS, the Simulation Interoperation Standards Organization (SISO), National Center for Simulation (NCS), New England M&S Consortium, Mid-Atlantic Institute for Simulation and Analysis, the Virginia Modeling, Analysis, and Simulation Center. The original request for recognition was submitted in 2012 (Bair & Jackson, 2013). The proposal was rejected, resubmitted in 2017, and rejected again.

The ECPC failed to accept the proposal likely due to the complexity of the M&S education and standards gap. Many organizations have attempted to overcome the education gap by creating institutional education courses. The US Army is one of those establishments (Loper & Turnitsa, 2017).

As M&S grows throughout the world, differing understanding, definitions, and theories emerge. M&S remains an unrecognized professional organization by legal precedence. Tolk suggested M&S is not a recognized community or profession because there are such widely differing views regarding what M&S is, what it does, and how to apply M&S (Tolk et al., 2015). Padilla suggests that M&S is merely a tool used by other disciplines to further promote their own discipline (Padilla et al., 2011).

M&S will likely remain a tool until a basis of comparison is created wherein M&S is uniquely recognized and identified from within its professional organization and distinguished from other disciplines.

Present Surveys

There is a critical need within the M&S professional organization to understand and clearly identify who is a simulationist, what a simulationist does; specifically, what are a simulationists KSAs, and what expertise/education is required by simulationists (Bair & Jackson, 2013). Academia, government, and industry must work together to answer these questions. As a result, M&S as a whole will better differentiate itself from other industries; it will engender esprit-de-corps and unity among simulationists and M&S professionals, and allow human resource (HR) and managers of stakeholders to better understand what core competencies are needed by those hired. Answering these key questions will also inform academia by supporting and substantiating common paths across educational entities around the globe.

A detailed survey of M&S associated academia, government, and industry to answer these questions is warranted. Four surveys, conducted in the US, have identified the lack of synergy between academia and other stakeholders: One published survey by industry (Bair and

Jackson Survey), one published survey by DoD (NPS Survey), one unpublished survey by DoD (AMSO Survey) and an unpublished survey by the author of this paper (UCF Survey).

Bair and Jackson Survey

In 2015, Lisa Bair and James Jackson, employed by Science Applications International Corporation (SAIC), published "Modeling and Simulation Professionals – Meeting the Demand," in order to ascertain the degree to which academia was meeting the needs of industry (Bair & Jackson, 2015).

Bair and Jackson took the CMSP topic areas as a standard and conducted a survey in order to see the unanimity of the topics and the topic use within industry. By their admission, the survey conducted was not intended to be scrutinized. The survey questions did not undergo validity testing. The survey was not written, conducted, or analyzed within any acceptable academic methodology. Bair and Jackson indicated that their survey was just the tip of the preverbal iceberg and that a more in-depth, long term, academically sound survey needed to be conducted (2015).

The Bair and Jackson's survey was distributed via email to NTSA and SAIC email list members. The survey had to be sent out twice, the second time with a motivational message, in order to obtain 146 respondents. The majority of respondents, a total of 116, reported employment in the government sector. Respondents who reported employment as a technical professional number 102 and only a small percentage (less than 20%) of them working in a self-identified M&S role. Almost 15% of respondents listed an M&S degree as necessary in their respective career fields. Bair and Jackson postulated the results of the survey indicated there were not enough industry pressures/needs/requirements to make obtaining the CMSP certification, or any academic M&S degree worth the effort (2015).

Naval Post Graduate School Survey

Mathias Kölsch, an adjunct professor at NPS, authored "A Snapshot of the Modeling and Simulation Community and Education," published in 2011, in order to validate the perception of important education within the military workforce (Kölsch, 2011). Kölsch wrote the paper on behalf of AMSO. Kölsch surveyed FA57s (Army Modeling and Simulation uniformed Officers) and CP36s (Army Modeling and Simulation civilians). Kölsch's intended to define the KSAs required by a simulationist.

The NPS survey was administered via email directly to the listserv of uniformed and civilian US Army personnel. Soldiers and civilians were asked to complete the KSA related survey, thus making a check on progress for the then current US Army M&S population. Only 34 of the over 600 uniformed and civilian M&S professionals responded. The survey asked respondents to rate, in order of importance, the KSAs related to DoD M&S.

The KSAs listed in Kölsch's survey was taken from the DoD BoK. These KSAs included: general M&S topics, management, systems engineering, simulation theory, human modeling, games, graphics, physics, computing foundations, experiments, and mathematical foundations. Kölsch postulated by frequency counts that the most important skills were communications, fundamental concepts of M&S, distributed simulations, training systems, computer networks, program management, and VV&A (Kölsch, 2011). A detailed graph of Kölasch's work can be viewed as Appendix A.

Kölsch submitted the survey results on behalf of AMSO to NPS in order to assist in modifying the educational course structure. This study was useful in identifying M&S needs within the DoD but did not transcend to other industries. This research was the first of its kind

for the US armed forces. Asking simulationist what KSAs were important for employment success was a novel approach.

Army Modeling and Simulation Office Survey

The Army continues to update the related KSAs available to uniformed and civilian simulationists in order to keep up with the increasing technological demand of industry. Nolan observed, AMSO conducts regular training and workforce analysis of duties related to both uniformed and civilian M&S professionals in order to maintain current and up-to-date training, to keep on top of current technology requirements (Nolan et al., 2017).

In 2017-2018, Christopher Herrmann, under the direction of AMSO, facilitated the Analysis, Modeling and Simulation Education, Training and Development Effort. This study was intended to identify M&S KSA used throughout multiple industries specifically related to Army commands. Industries identified included healthcare, communications, research and development, acquisitions, and training. The intent was that the study results would help AMSO identify what M&S education was necessary throughout the Army structure.

A survey was conducted utilizing a self-administered survey tool and face-to-face interviews of 147 military & civilians across intelligence, experimentation, and training communities and 140 military & civilians across analysis, acquisition, and test and evaluation communities to identify needs and required individual M&S tasks. The data from these interviews were compiled and analyzed in two face-to-face workshops involving Army M&S managers. The survey findings resulted in prioritizing 24 competencies by frequency count identified as FA57 and CP36 competencies as indicated in Figure 5 (Herrmann, 2018).

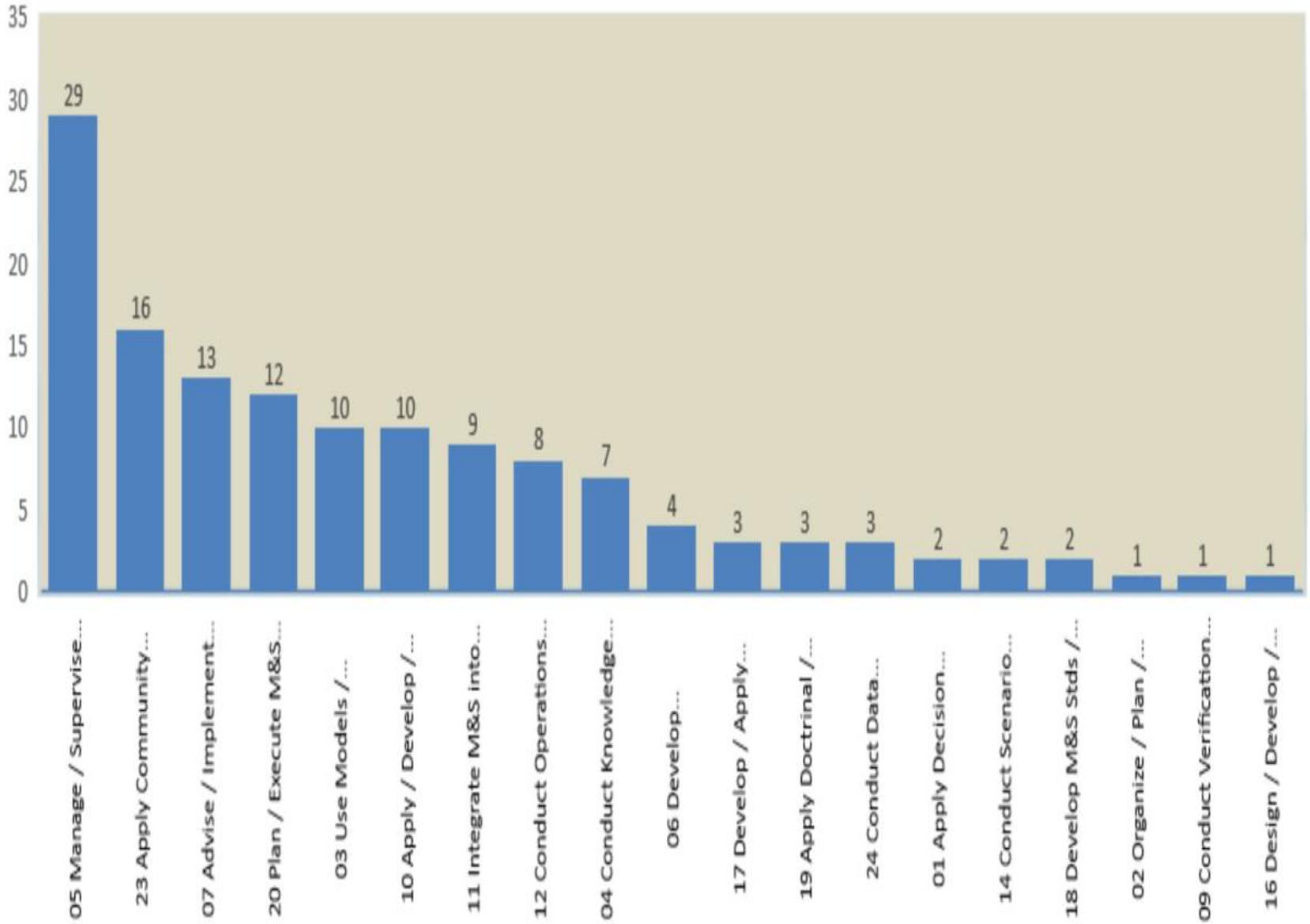


Figure 5: Needs by Competency/Category

Through descriptive statistical analysis of survey respondents responses, the 19 identified competencies are as follows: 1. apply decision support tools, 2. organize, plan, execute studies, 3. use modeling and simulation, 4. conduct knowledge management, 5. manage/supervise M&S, 6. develop requirements, 7. advise, implement M&S architectures, 8. conduct verification/validation, 9. apply, develop and integrate M&S, 10. integrate M&S into game-supported training environment, 11. conduct operation research and analysis, 12. conduct scenario planning and development, 13. design, develop and apply LVC simulations, 14. develop and apply synthetic natural environment, 15. develop M&S standards, policy, guidance, and directives, 16. apply doctrinal and operational knowledge, 17. plan and execute M&S to drive an exercise, 18. apply community assets, and 19. conduct data generation and management. The numbered competencies correspond with the numbers on Figure 5.

The competencies were prioritized by respondents indicating the first five in a list of priority: manage/supervise M&S, apply community assets, advise, implement M&S architectures, plan and execute M&S to drive an exercise and use modeling and simulation.

The AMSO survey findings demonstrated that the most important and most needed competencies were in managing and supervising M&S professionals, followed by apply community assets, advising and implementing M&S architectures, and planning and executing M&S to drive an exercise. This survey comes seven years after the first Army-directed survey. KSAs related to uniformed M&S personnel progressed from seemingly basic skills and knowledge in the Kölsch survey to a demonstrated need for skills in application. Both studies yielded valuable information in the training and education of Army M&S professionals. This research was exemplary in identifying M&S needs within the DoD, but it did not transcend to other industries.

CHAPTER THREE:
METHODS

A search on a popular internet job search site provided insight into the differing jobs related to M&S. The search was conducted using no location indicator in October of 2018. The assumption was that various M&S stakeholders, including those in academia, government, and industry, posted employment opportunities in the M&S field.

The search for "modeling & simulation" resulted in 2,094 hits. The preponderance of job titles for the first three pages of results includes systems analyst, M&S analyst, M&S engineer, analyst, statistician, M&S support, M&S research, M&S operator/trainer and M&S operations. Various industry and government contractors were responsible for the majority of job postings. Education requirements listed from jobs posted on the first three pages include degrees in engineering, computer science, operations research, mathematics, science, and related fields. Searches for "simulation" and "M&S," produced a similar number of hits, all from homogeneous industries and with related job titles and educational requirements.

The search yielded a myriad of job fields wherein M&S was applied from engineering, sociology, psychology, and medical. Few of the employment opportunities required an M&S degree. KSAs related to these jobs were not directly associated with the M&S profession. Instead, most available job opportunities presented required experience and education specifically related to the primary domain rather than M&S.

Thus, while M&S is becoming a more widely recognized field, it appears that M&S stakeholders may not perceive a degree in M&S necessary for job securement or success. While not the only conclusion to be made, this perception may be due to mismatched stakeholder needs

and applied M&S KSAs obtained through the contemporary education and certification processes.

Bair and Jackson (2015), indicated that whereas the need and desire for M&S has risen dramatically in the US; the complexity of development and application has also risen, creating a dilemma with regards to education (academia), professionalization (simulationists' roles), and practice (industry & government) (p 10).

Consequently, there does not appear to be synchronization between the stakeholder groups of academia and industry, as identified by Bair and Jackson (2015). The M&S professional organization as a whole does not recognize a single BoK as an authoritative reference for M&S KSAs. There is not the standardization of an M&S BoK upon which academic institutions can rely. Therefore, educational degree and certification programs are likely built primarily to provide competency to local M&S industries. This dichotomy has created and continues to create inconsistencies between academic programs that support M&S professions and employer (stakeholder) needs. The absence of standardized M&S educational programming may have contributed to a lack of confidence within M&S professionals and industry. Consequently, KSAs obtained by academic institutions and certifications may not provide adequate or consistent employee specialties or meet employer needs.

In 2018, an exploratory study was conducted under the oversight of UCF. The study incorporated a survey intended to provide an understanding of the core M&S KSAs identified and needed by academia, government, and industry stakeholders. This section describes the methods used for the cross-sectional study. The chapter is organized into six subsections: Purpose of the Study, Research Questions and Hypotheses, Participants, Survey Instrument,

Procedures Plan and Analysis Plan. The UCF Institute for Simulation and Training (IST) sponsored the research.

Purpose of the Study

The purpose of the present research study was to investigate perceived gaps between various M&S stakeholders which include academic, government, and industry and infer a possible course of action to realign such programming to industry employment markets to increase employee KSAs and overall employment opportunities.

The work is exploratory, dominated by a quantitative design and supported by a qualitative component.

The survey instrument explored the perceived core KSAs related to different M&S industries, graduate academic programs, and government. The instrument was administered to multiple M&S stakeholders or respondents. Respondents were introduced to the study, the purpose of the work, and the survey via email communication. The survey was administered using Qualtrics, which is a computer-based survey design tool used by UCF.

The results of this research will be used to identify which of the currently identified, literature supported M&S KSAs are important to M&S stakeholders and which M&S KSAs are necessary for employment attainment. The methods used in this study may also be used in the future to formulate a more robust and standardized model wherein the M&S domain can be studied.

Research Questions and Hypothesis

Table 2 lists each research question and associated hypothesis related to the current study. The research questions hinge upon the perception that academia, government, and industry are misaligned relative to the KSAs supporting M&S.

The current study will not explore the reasons for the misalignment, but instead, explore the current position of employment attainment related to the current M&S KSAs and stakeholder perceptions regarding the identification and value of M&S KSAs.

Table 2: Research Question and Hypotheses

Research Question	Hypothesis	Null Hypothesis
R_1: Are stakeholder perceptions aligned regarding valued M&S KSAs?	**H_1:** KSAs identified by various stakeholder groups are not aligned regarding valued M&S KSAs.	**H_0:** KSAs identified by various stakeholder groups are aligned regarding valued M&S KSAs.
R_2: Do the KSAs identified as being of value by individual stakeholder groups align with KSAs necessary for employment attainment in the M&S field?	**H_2:** M&S KSAs identified to be of value by stakeholder groups do not align with KSAs necessary for employment attainment.	**H_0:** M&S KSAs identified to be of value by stakeholder groups align with KSAs necessary for employment attainment.

Participants

The current study identified various stakeholder groups available via email listservs to the study administrators. The study administrators had access to academic email listservs such as UCF employees, UCF students, UCF alumni via MaSK; professional organization email listservs such as NTSA and NCS; and government email listservs via the AMSO.

Targeted stakeholders include the M&S student population, M&S administrative and faculty population, academic research affiliated M&S personnel, M&S alumni working in various industry sectors, M&S uniformed and civilian employees, M&S industry employees and employers, and M&S professional organizations volunteers and employees.

The survey was sent to every name available on the listserv in an attempt to cast the widest net possible and receive a maximum amount of responses. The instrument relied upon the participants self-identifying as M&S professionals. Thus, the study anticipated surveying a

representative sample of the total population of stakeholders, which would yield insight into the relationships between all stakeholders.

The formal request for participation was distributed via email. The total number of listserv email addresses exceeded 300. The study hoped to obtain enough respondents to generalize results to the M&S professional community at large

All administrators of the survey tool and analysis team were trained using the Collaborative Institution Training Initiative (CITI) as part of the Institutional Review Board (IRB) compliance at UCF. Training included ethics and human subject research protocol. No Personal Identifiable Information (PII) was collected such as names and phone numbers of participants.

Participants were required to read and indicate agreement with an informed consent waiver before participating in the survey. The informed consent waiver was administered electronically to each participant just prior to survey execution. Procedures and policies related to survey tools administered within the IST were followed. The survey and analysis of collected information were supervised by UCF faculty Dr. Bruce Caulkins. Precautions were taken to ensure the human participants in the study were treated ethically and data was managed, stored, and analyzed appropriately in accordance with the rules and regulations regarding human subject research.

Demographic information, such as age, gender, and education level, was taken in order to provide context to survey tools only. Demographic information was not collected to define demographics within the professional M&S community even though it may have some significant correlations. Survey demographic information was used to correlate analysis directly related to the perceptions of the KSAs from different M&S stakeholder groups.

Participation in the study was voluntary. No participants were compensated. There were no anticipated risks to participants. Participants identified themselves as 18 years or older in order to participate in the survey. Participants self-identified as an M&S stakeholder. Participants were permitted to withdraw from the survey tool at any time and skip survey items.

The survey was web-based using UCF Qualtrics. Participates were able to complete the survey at their discretion using any remote computer/network-based platform. Participates had 60 minutes to complete the survey. The survey was open from late November 2017 to early February 2018. The extended timeline was due to publication and university semester requirements. Analysis of information collected was expected to be completed by the end of February 2018. Data is stored at UCF IST and may be accessed via encrypted campus web portals. Participants were informed that they may request copies of any published work resulting from the survey.

Survey Instrument

Previous surveys asking for the same type of information were considered in the creation of the present survey instrument. Existing measures include three surveys. Two published surveys, which included, one completed by Bair and Jackson with SAIC, and one completed by Kölsch at the NPS. The third instrument included an unpublished survey conducted by Herrmann at AMSO. The Kölsch and Herrmann survey tools were built specifically for use with uniformed and civilian employees of the DoD (Herrmann, 2018; Kölsch, 2011). The measures from both surveys were developed using KSAs specific to the DoD. Because the KSAs used were not widely known, their survey tools do not translate well into civilian stakeholder (academia, government – non-military, and industry) language. These measures were not considered for use in the present survey instrument.

The Bair and Jackson (2015) survey is likely the closest survey available in regards to the purpose of the present study. The Bair and Jackson survey instrument used the CMSP exam topics as M&S specific KSAs. The survey was not completed in an academic setting. A copy of their survey instrument was requested; however, the request was not approved because SAIC sponsored the study and the sponsor did not approve the release of the survey instrument. The Bair and Jackson survey focused on the population available to SAIC which included a SAIC and a NTSA listserv.

None of the existing survey instruments were available to use as a model for the present measure. Consequently, the current study's survey was unique in that it focused on a broader participant population and included more KSAs than what could be found using only the CMSP list.

In order to ensure content validity of the survey instrument, a draft of the survey was reviewed by a panel of SMEs comprised of university officials holding degrees in research related fields to determine if the design was adequately matched to the desired outcomes and purposes of the study.

Survey Construction

Rebecca Leis and John Lord created the current survey instrument. The measure's creation was overseen by Dr. Bruce Caulkins of the UCF IST. The survey consists of 75 total questions (see Appendix B). The measure was split into four sections: demographics, opinion, KSAs, CMSP. The survey contained a number of open-ended and close-ended questions, Likert scale questions, rank order questions, single-select, and multi-select questions.

The majority of questions were intended to gather perceptions and provide the ability to correlate viewpoints between M&S stakeholder groups. Approximately 39 questions were asked

to provide demographics such as “Do you have a degree in Modeling and Simulation?” and “What is your current occupational title?” This section of the survey instrument was comprised of both open-ended short answer questions and single-select questions.

The opinion section was comprised of approximately 12 questions indented to provide a view of the populations understanding, knowledge, and personal opinion regarding M&S as a professional organization. The survey contained questions such as “What do you believe constitutes an M&S industry?” and “Who should be in charge of the topics contained within the M&S BoK?” This section of the survey was comprised of both open-ended and single-select questions.

The KSAs section was intended to provide an understanding of the M&S KSAs used by all stakeholders. A systematic review of 30 peer-reviewed M&S related articles was conducted using the UCF library database, the Google Scholar database, and multiple professional organization databases. Publications from M&S professional organizations and/or M&S related conferences include: the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) Knowledge Repository ("I/ITSEC Knowledge Repository," n.d.), and the SCS ("The Society for Modeling and Simulation International (SCS)," 2018). The result of the literature review identified a salient list of M&S related KSAs. Knowledge gathered from the article review is indicated in Table 3. Skills gathered from the article review are indicated in Table 4. Abilities gathered from the article review are indicated in Table 5.

The KSA section contained 12 questions related to the M&S KSAs and M&S domains obtained from the literature review. The section contained Likert scale questions and short answer questions.

Table 3: List of "Knowledge" Words and Phrases Obtained from Literature Review

Interoperability	Parallel Computing	Flows
Simulation-component Reuse	Computer Networks	Delays
Simulation Infrastructure	Modular Program Design	Synchronous Agents
Simulation Management	Quality Assurance Techniques	Asynchronous Agents
M&S History	Testing	Autonomous Agents
Modeling Methods	Simulation Life-cycle	Modeling-Cycle
Data Structures	Computer Architecture	Decision-making
Computational Framework	Operating Systems	Memory Processes
Quantitative Aspects	Artificial Intelligence	Sensory Processes
Computer Visualization	Expert Systems	Attention
Issues of Computational	Fuzzy Systems	Geographic Information Systems
Complexity	Genetic Algorithms	K-12 Education
Numerical Modeling Methods	Neural Networks	Adult Education
Specialized Simulation Languages	Intelligent Agents	Industry-training
Experimental Design	Assessment	Military-based Training
Instructional Systems Design	Organizational Behavior	User-simulator Interaction
Business Practices	Boolean Algebra	Supply Networks
System Design	Linear Algebra	Time-series
System Analysis	Ordinary Differential Equations	Proof-of-concept
System Optimization	Partial Differential Equations	Hybrid-systems
Distributed Environments	Conceptual Modeling Formalisms	Code of Ethics
Human Behavior Evaluation	Rule-based Specification	Serious Games
Training Applications	Finite State Machines	Simulation-based Science
Virtual Environments	Data Visualization	Simulation-based Engineering
Petri Nets	Graphics	Simulation-based Social Science
Bond Graphs	Animation	Computational Neuroscience
Error Control Mechanisms	Virtual Reality	Simulation-based Training
Probability Distributions	Standards	Simulation-based Learning
Variance	Model Repositories	Materials Science
Reduction	Synthetic Environments	Algorithms
Optimization	Thermodynamics	Software
Database Systems	Electric Circuits	Hardware
Computer Administration	Statistics	Cyber Infrastructure
Entertainment	Stocks Metrics	Contemporary Issues
Human Perception	User Interface Design	Probability
Distributed Computing	Performance Measures	Scientific Method
Distributed Systems	Stress	Symbolic Reasoning
Computer Operating Systems	Workload	Strategic Communications
Object-oriented Programming	Cognition	Psychological Operations
Conceptualizations	Adoption Rate	Information Operations
Empiricism	Queuing	Civil-military Operations
Presentation Methods	Stocks	Unconventional Warfare
Assessment Heuristics	Transnational Criminal Activities	Foreign Internal Defense
Sensory Perception	Illicit Arms Dealing	Intelligence Activities
Psycho-physiology	Illegal Financial Transactions	Current Simulation Tools
Cognitive Representation	Law Enforcement Activities	Measures of Merit
Knowledge Representation	Performance Moderator Functions	Counterinsurgency
Logic Methods		Combating Terrorism
Conflict Modeling		Number Generation Techniques

Table 4: List of "Abilities" Words and Phrases Obtained from Literature Review

Complex Problem Solving	Functioning on Multidisciplinary Teams	Written Communication
Communication	Life-long Learning	Verbal Communication
File Management	Practical Experience	Group Interaction
Project Management	Leadership	Skill Acquisition
Visionary Outlook	Recognize/Adapt to Technology Changes	Abstraction
Open-mindedness		Interdisciplinarity
Tolerant Behavior		

Table 5: List of "Skills" Words and Phrases Obtained from Literature Review

Verification	Programming	Risk Analysis
Validation	Step-size Selection	Data Collection
Accreditation	Requirements Specification	Problem Definition
Data Support	Software Development	Critical Elements Identification
Data Integration	Documentation	Develop Functional Specifications
Computational Languages	Training Analysis	Data Reduction
Computer Architectures	Linear Programming	Simulation Support to Domain Expert
Data Management	Dynamic Programming	Developing Scenarios
Simulation Development	Nonlinear Programming	Planning and Outcome
Management	Sensitivity Analysis	Experimentation
Decision Support	Numerical Analysis	Behavior Analysis
Training Design	Maintenance	Giving Presentations
Training Assessment	Hypothesis Testing	Cost-Benefit Analysis
Acquisition	Variance Reduction	Feasibility Assessment
Prototyping	Execution	
Socioeconomic Modeling	Verbal Protocol Analysis	
Simulation Output Analysis	Cognitive Task Analysis	

The last section in the survey instrument was related to the topics and sub-topics of the CMSP. The CMSP topic list (Figure 3) appears to be the de-facto BoK for the M&S professional community (Bair & Jackson, 2015; Lewis & Rowe, 2010). The section contained nine rank order questions asking participants to place priorities on each section and subsection of the CMSP topic list. This section intended to understand the topics and subtopics used, valued, and prioritized by M&S stakeholder community.

Questions in the current survey instrument are specifically related to and address study research questions. The following list (Table 6) indicates the previously provided research questions (RQ) and correlated survey questions (SQ). For example, research question one (RQ1), "Are stakeholder perceptions aligned regarding M&S valued KSAs?" is directly related

to survey questions three (SQ3), which asks, “Which Modeling and Simulation (M&S) Stakeholder group do you Identify with the most?”

The survey questions not listed have no measured effect on the questions related to this research study. Survey questions 53, 55, and 56 (SQ53, SQ55, and SQ56), as illustrated in Table 6, list specific knowledge, skill, and ability words and phrases gleaned from the previously mentioned literature review. Survey questions 67-75 (SQ67-SQ75), as illustrated in Table 6, list topics related specifically to the CMSP topic list in Figure 3.

Table 6: Research Questions Relative to Survey Questions

RQ1, RQ2	SQ 3: Which M&S stakeholder group do you identify with the most?
RQ1, RQ2	SQ 11: Please identify what type of industry you work in.
RQ1, RQ2	SQ 12: What do you believe constitutes as an M&S industry (as opposed to Engineering, Computer Science, etc.)?
RQ1, RQ2	SQ 14: Who should be in charge of determining the topics within the M&S BoK? Please be specific (e.g., a person, organization).
RQ1	SQ 16: Who should be in charge of determining standard topics for M&S curricula? Please be specific (e.g., a person, organization).
RQ2	SQ 17: Who should be in charge of determining accreditation standards for M&S educational programs? Please be specific (e.g., a person, organization).
RQ2	SQ 25: Do your superiors encourage you to enroll in an M&S graduate program?
RQ2	SQ 28: Have you obtained an M&S degree of some sort?
RQ1, RQ2	SQ 33: What types of jobs do you expect to get once you have finished your degree?
RQ1, RQ2	SQ 37: Do you currently hold an M&S (or M&S related) job?
RQ1, RQ2	SQ 42: Which M&S skills did you emphasize on your resume/CV for your current job?
RQ1, RQ2	SQ 45: What types of qualifications/skills do you look for in perspective qualified candidates?
RQ2	SQ 47: Do you prefer to hire candidates with M&S degrees from specific universities?
RQ1, RQ2	SQ 52: Please define what an M&S professional is to you.
RQ1, RQ2	SQ 53: How important are the following topics to your job?
RQ1, RQ2	SQ 54: How would you categorize M&S professionals?
RQ1, RQ2	SQ 55: How important are the following skills to your job? (
RQ1, RQ2	SQ 56: How important are the following abilities to your job?
RQ1, RQ2	SQ 57: How important are the following domains/fields to your job?
RQ1, RQ2	SQ 58: What other knowledge areas are important to your job that are not listed above?
RQ1, RQ2	SQ 59: What other skills are important to your job that are not listed above?
RQ1, RQ2	SQ 60: What other abilities are important to your job that are not listed above?
RQ1, RQ2	SQ 61: What other domains/fields are important to your job that are not listed above?
RQ1, RQ2	SQ 62: Do you program in your current job?
RQ1, RQ2	SQ 63: Which programming languages do you use?
RQ1, RQ2	SQ 64: Do you use simulation software in your current job?
RQ1, RQ2	SQ 65: Which simulation software do you use?
RQ1, RQ2	SQ 67-75: Please rate the importance of following topics to your job/research.

Administration and Score of Survey

The survey instrument was announced by an introductory message via email using the listservs available to the administrators. Participants received a welcome letter via email which

directed them to a web link. The survey instrument was administered using the software system Qualtrics on a web-based platform hosted at UCF.

The majority of the survey was opinion based; therefore, the score of that portion of the survey was conducted via visual inspection. The Likert scale questions, prioritization and rank-order questions, and other closed-ended questions were scored using electronic means available within the Qualtrics platform. Collection and analysis of data were completed and reviewed by the survey administers. Oversight of the process was completed by IST faculty.

Procedures Plan

This section describes the step-by-step procedures conducted in the administration of the survey instrument. The study went through multiple phases in regards to the overall implementation of the survey: preparation, approval, implementation, and analysis.

During preparation, the administrators of the survey correlated the intent and expected outcome and identified specific measurements that would answer stated research questions and fulfill the purpose of the research. As well, the indented survey questions were discussed and evaluated in regards to their ability to directly or indirectly answer the proposed research questions. The available survey audience, survey method of delivery, and all assumptions, limitations, and delimitation of the instrument as it relates to the overall study were reviewed and evaluated. The end state of the preparation phase yielded a viable plan of action.

The approval phase of the procedure had three action items. The first was the approval from the UCF IRB to conduct the survey. The IRB approval letter is attached (see Appendix C). The second sought the approval of the survey instrument itself from the IST faculty responsible for the oversight of this study. The final item in this phase was the process of uploading the

survey response data into Qualtrics in preparation for data analysis, findings, conclusions, and real-world implications based on research results.

Implementation of the study began after the IRB approval. During implementation, the administrators of the study sent out an introduction statement to members of the variously identified listservs. The introduction email (see Appendix D) contained a link directing willing participants to the Qualtrics website containing the survey instrument.

Participants of the study completed the present survey on their own devices through the Qualtrics web platform. Participants identified themselves as over 18 years of age in order to participate. Participants read over a privacy and informed consent statement prior to completing the survey. Informed consent was first secured. Then, each participant was asked demographic questions in order to identify experience and education. Lastly, participants were asked a series of short answer questions, priority questions, close and open-ended questions, and Likert scale questions in order to gauge opinions and perceptions regarding M&S KSAs. The survey instrument took participants no longer than 60 minutes to complete. The study was open on Qualtrics for approximately two months.

The analysis phase of the study began after the study was closed and no further participant responses were collected – the administrators of the study compiled and completed the analysis phase.

Analysis Plan

This study reviewed M&S stakeholder perceptions to address primary research questions: RQ1: Are stakeholder perceptions aligned regarding M&S valued KSAs? RQ2: Do the KSAs identified as being of value by individual stakeholder groups align with KSAs necessary for employment attainment in the M&S field?

This research exploration was rooted in a quantitative methodological component with the primary survey data synthesized and analyzed by descriptive statistics. The quantitative data was supported by a qualitative approach and analyzed by content analysis of open-ended survey data.

Quantitative Research Analysis Plan

The UCF IRB sanctioned Qualtrics program was used to prepare the data. The quantitative research analysis utilized descriptive statistics to discover and substantiate patterns and relationships. The analysis procedures used to analyze the survey instrument data were determined by their ability to address the research questions. Each coded question was summarized and reported by descriptive methods, which included frequency counts, percentages and cross-tabulations. The Likert scale questions with response categories, "extremely important," "very important," "moderately important," "slightly important," and "not important at all" were used to measure the relative intensity of the different listed items and calculate the average mean score for those respondents agreeing with each of the individual purposes.

Likert scale questions are a reliable way to measure opinions and perceptions. These questions were used to measure and prioritize the different listed items by subgroup. Subgroup comparisons across each informant group were used to determine if relationships existed between informant or respondent perceptions.

Qualitative Research Analysis Plan

The qualitative research analysis used in this study to analyze the open-ended and short answer questions was to collect, identify, and reduce the data into a simplified format, then code the data as individual pieces by classification and categorization. Administrators employed these content analysis methodologies, by reading and rereading the data and identifying patterns for

frequencies, structures, and meanings. – All, in an effort to find an overall order to the qualitative survey data.

CHAPTER FOUR:
FINDINGS

This section discusses the findings of the cross-sectional study and corresponding M&S survey. The section consists of two subsections: Respondent Results and Research Questions and Answers.

Data analysis of the quantitative survey responses employed descriptive methods, which included frequency counts, percentages, and cross-tabulations. Data analysis of the qualitative survey data employed the use of content analysis. Results of the analysis were calculated using the statistical program Qualtrics.

Respondent Results

The current study was expected to be completed by over 300 participants. Overall, a total of 39 respondents participated in the survey. Of the 39 respondents, 37 self-identified themselves as part of an M&S stakeholder group, either academia, government/military or industry.

All 37 responses were used for the purposes of analysis in this research. A breakdown of the respondents can be seen in Figure 6. Three participants self-identified as an M&S student (8.10%). Five respondents self-identified as M&S Academia (13.51%). Nine respondents self-identified as M&S industry (24.32%). Respondents who self-identified as M&S government/military numbered 20 (54.05%). Of the 20 participants who identified as M&S government, 18 respondents self-identified themselves as a member of the DoD or armed forces (Army, Navy, Air Force, Marine Corps) with the preponderance of the respondents identifying as a member of the US Army (13 respondents/68.42%).

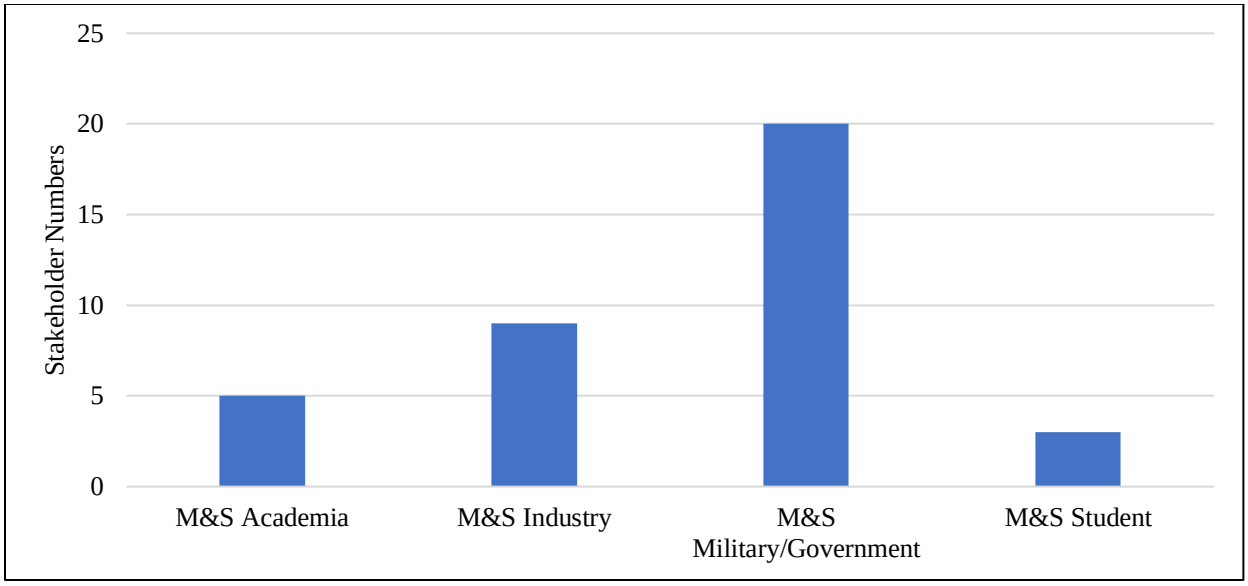


Figure 6: Self-identified Stakeholder Frequency Distribution

Not all of the questions on the survey were answered. It appears only 14 respondents completed every question presented on the survey instrument. It is unknown if respondents chose not to answer questions or if questions did not appear correctly in the survey. It can be assumed that the questions correctly appeared, because the pre-distribution survey test was successful and most of the questions on the measure received at least one response. However, there were sections of the measure that received no responses. The number of participates will be discussed with each research question in the following section.

The low number of respondents from the respective stakeholder groups created a problem with statistical comparisons. Due to the low group sizes, statistical analysis looking for the probability to reject the null hypothesis is inappropriate. The trends from this small-scale research, continue to merit descriptive analysis. The opinions gained from the stakeholder groups may still give a statistically appropriate majority opinion even with the small sample numbers.

Research Questions and Answers

This section reviews the research queries to the survey instrument questions. Survey questions were correlated with each M&S stakeholder population who answered the questions. Tables 7 and 8 detail the research questions commensurate with the survey instrument questions and the number of respondents from each stakeholder category (academia, government, and industry). Students respondents are included in the table in order to provide context. Students were not tabulated with the academia stakeholder group. The majority of the participants in the study were from the government portion of the M&S stakeholder population as indicated in the previous section.

A number of questions were not answered by any of the stakeholder groups. Questions with no respondents or too few (less than five) respondents were removed from the answer pool.

Table 7: Survey Questions Answered by Stakeholder Group Correlated to Research Question One

Research Question	Respondents by Stakeholder					Survey Instrument Questions
	Academia	**Student**	**Government**	**Industry**	**TOTAL**	
R_1: Are stakeholder perceptions aligned regarding valued M&S KSAs?	0	0	0	9	**9**	SQ 11: Please identify what type of industry you work in.
	3	2	6	5	**16**	SQ 12: What do you believe constitutes as an M&S industry (as opposed to Engineering, Computer Science, etc.)?
	0	0	0	8	**8**	SQ 42: Which M&S skills did you emphasize on your resume/CV for your current job?
	0	0	5	8	**13**	SQ 45: What types of qualifications/skills do you look for in perspective qualified candidates?
	3	2	6	5	**16**	SQ 52: Please define what an M&S professional is to you.
	3	2	8	6	**19**	SQ 53: Are there types of M&S professionals?
	3	2	8	3	**16**	SQ 54: How would you categorize M&S professionals?
	2	2	8	2	**14**	SQ 67-75: Please rate the importance of following topics to your job/research.

Table 8: Survey Questions Answered by Stakeholder Group Correlated to Research Question Two

Research Question	Respondents by Stakeholder					Survey Instrument Questions
	Academia	**Student**	**Government**	**Industry**	**TOTAL**	
R_2: Do the KSAs identified as being of value by individual stakeholder groups align with KSAs necessary for employment attainment in the M&S field?	0	0	0	8	**8**	SQ 42: Which M&S skills did you emphasize on your resume/CV for your current job?
	0	0	5	8	**13**	SQ 45: What types of qualifications/skills do you look for in perspective qualified candidates?
	3	2	8	6	**19**	SQ 53: Are there types of M&S professionals?
	3	2	8	3	**16**	SQ 54: How would you categorize M&S professionals?
	3	2	8	3	**16**	SQ 62: Do you program in your current job?
	3	2	8	3	**16**	SQ 64: Do you use simulation software in your current job?
	0	0	4	2	**6**	SQ 65: Which simulation software do you use?
	2	2	8	2	**14**	SQ 67-75: Please rate the importance of following topics to your job/research.

Survey questions 11 asked, “Please identify what type of industry you work in.” This question was given only to respondents who self-reported as part of the industry stakeholder group. However, three of nine respondents (33%) indicated they worked in the “defense or government” industry. Other answers to this question include aerospace, training, research, and development (virtual reality and motion tracking development).

Survey question 12 asked, “What do you believe constitutes as an M&S industry (as opposed to Engineering, Computer Science, etc.)?” Of the 16 respondents who answered the open-ended question, nine defined the terms modeling and simulation. One respondent suggested, “M&S is focused on creating a virtual environment that can be used to simulate scenarios or conditions in order to determine likely outcomes that result from variables (decisions, etc.) that are introduced into the environment.” Another respondent stated, “modeling and simulation refers to using models, physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process, as a basis for simulations methods for implementing a model (either statically or) over time to develop data as a basis for managerial or technical decision making.”

Just over half of the respondents, seven of 16, answered the question by indicating an M&S industry incorporated an aspect of training. Thus, “training” is a consistent term among respondents in defining the terminology “modeling and simulation” and can be identified as a qualitative categorization.

Survey question 42 asked, “What M&S skills did you emphasize on your resume/CV for your current job?” Industry stakeholders provided all eight responses. Three of eight respondents indicated “experience” was the most important aspect to employment attainment.

Three of eight responses were not related to M&S such as “program management” and “management.”

Survey question 45 asked, “What types of qualifications/skills do you look for in perspective qualified candidates?” This question was asked and answered by government and industry stakeholder groups. Half of the respondents, six of 13, indicated they were looking primarily for “technical and operational experience.” Additional verbatim responses indicating a pattern of important qualifications/skills in employment retention include, “More important than specific technical skills are the ability to learn, a good attitude and demonstrated self-motivation.” This response from an industry stakeholder gives some qualitative insight into the importance of self-motivation and the willingness to learn which five of 13 respondents indicated was important.

Survey question 52 asked, “Please define what an M&S professional is to you?” Respondents answered this open-ended question by identifying roles. During content analysis of the answers, common text components and structures allowed a general definition of what an M&S professional is among survey respondents to surface. An M&S professional is one who uses M&S tools to answer questions in a multidisciplinary environment. To support this contextual definition, five of 17 respondents used the phrases “M&S tools” and “make decisions” in order to answer the question and just under 50% of respondents, seven of 17, used the word “ multidisciplinary” or “interdisciplinary” as exemplified by one respondent’s response, “An individual with technical expertise (computers, networks, data) who can apply that expertise to other functions (training, testing, analysis) in order to produce/facilitate outputs (readiness, validation, insights).” Another respondent answers with, “an M&S professional is someone who performs higher level, interdisciplinary problem solving; who can implement the process of

problem-solving using modeling and simulation techniques, regardless of industry." A salient qualitative pattern is noted by the frequency of the word "interdisciplinary" and the idea of multidisciplinary KSAs in this question.

Survey question 53 asked, "Are there types of M&S professionals?" All of the 19 respondents who answered this question indicated in the affirmative (100%). There are different types of M&S professionals. The types of M&S professionals are further defined in survey question 54.

Survey question 54 asked, "How would you categorize M&S professionals?" Respondents self-indicated categories wherein they depicted how they would identify an M&S professional. The question required a short answer response. Most respondents provided more than one category. Respondent answers were categorized and tabulated as indicated in Figure 7. Training was indicated more than any other category followed by development, research, and analysis. The term "training" is a reoccurring theme in many answers to a host of different questions. Therefore, "training" is a general theme substantiated by a consistent qualitative pattern.

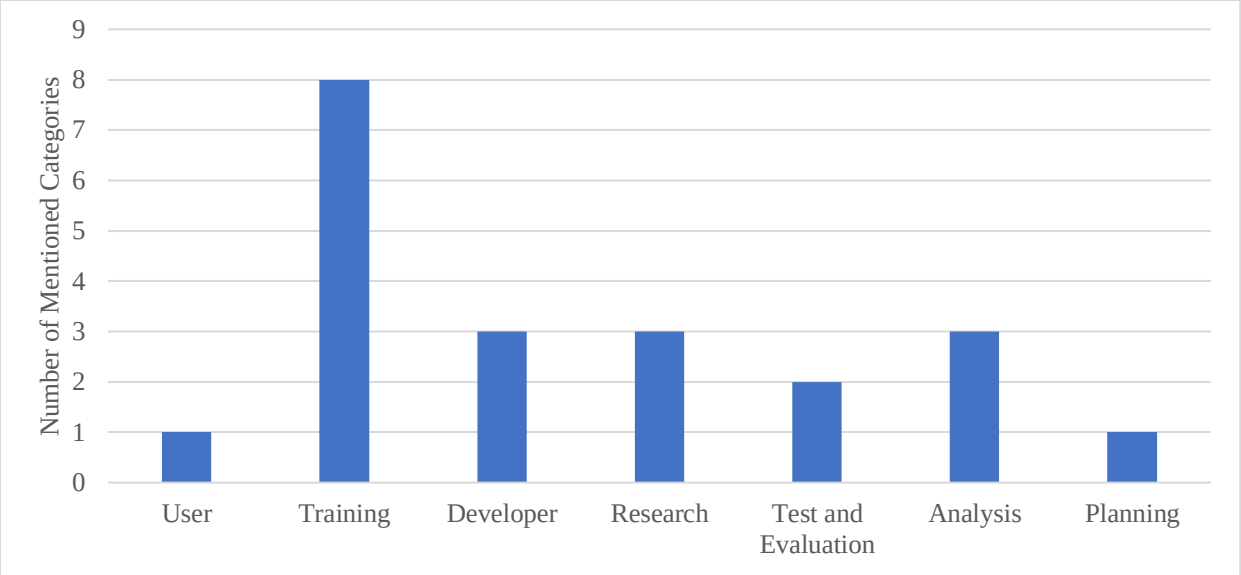


Figure 7: How Would You Categorize M&S Professionals?

Survey question 62 asked, "Do you program at your current job?" Respondents who reported that they did not program in their current job were 14 of the 16 as indicated in Figure 8. Respondents indicating coding was important were from the academic stakeholder group. The majority of respondents from this question were from the government/military stakeholder group. It appears that academic stakeholders may feel that "programming" is an important KSA, while military/government and industry do not.

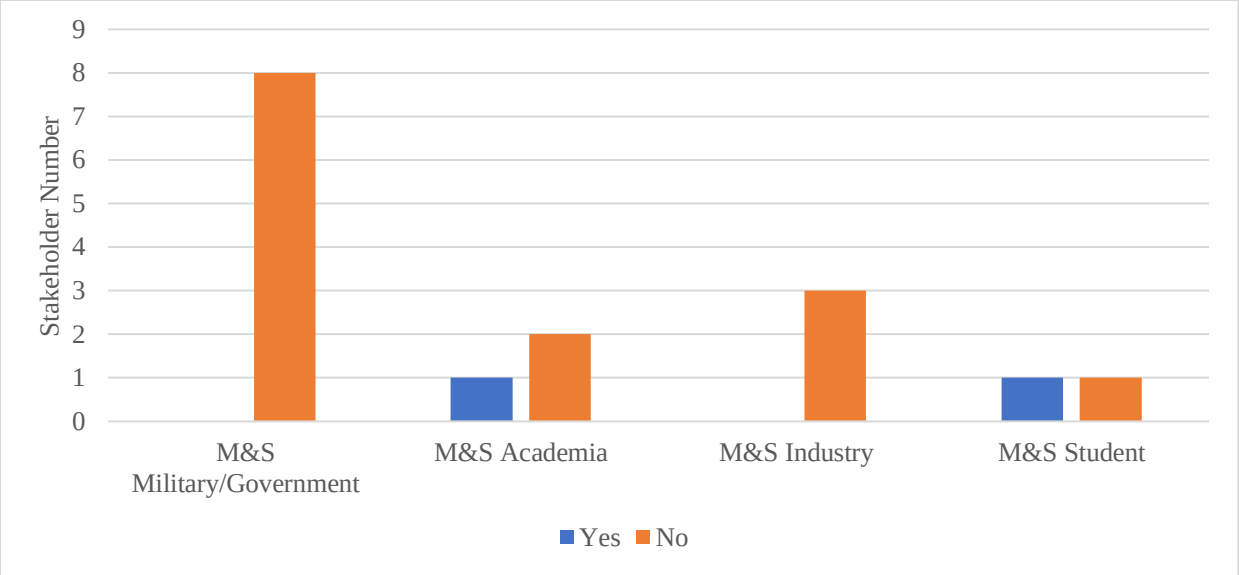


Figure 8: Do You Program at Your Current Job?

Survey question 64 asked, "Do you use simulation software in your current job?" Only six of 16 (37.5%) respondents indicated they use simulation software in their current job as indicated in Figure 9. The type of simulation software used is further explained in question 65. Simulation software appears to be primarily used by military/government, and industry stakeholder groups. The majority of respondents do not use simulation software in their M&S employment.

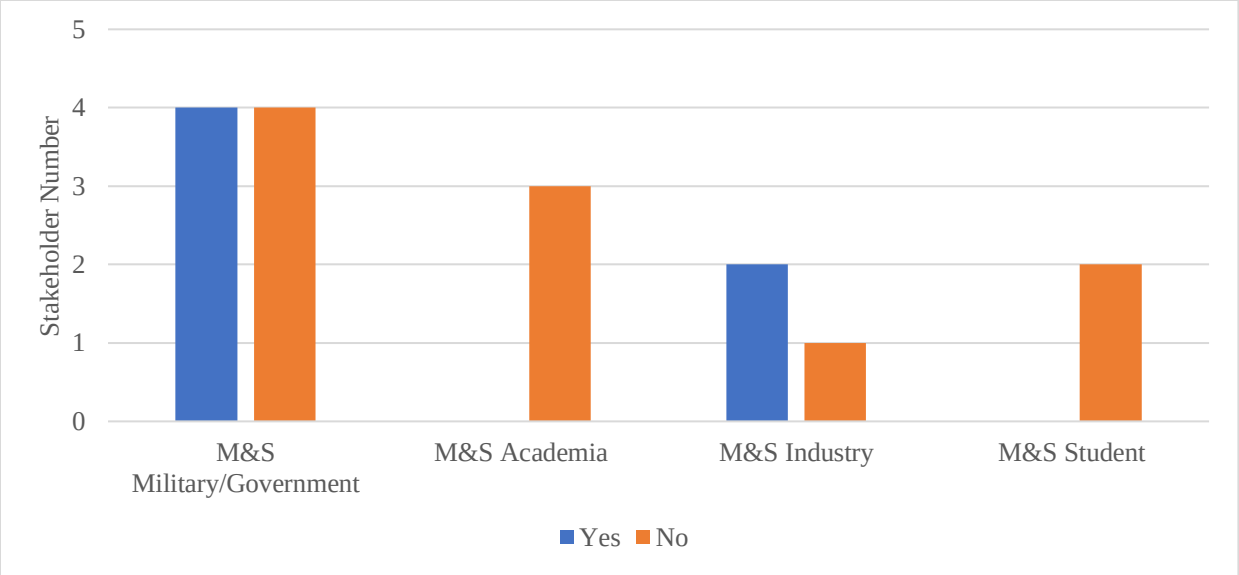


Figure 9: Do You Use Simulation Software in Your Current Job?

Survey question 65 asked, "Which simulation software do you use?" Only six respondents provided answers to this question – four from the government/military stakeholder group and two from the industry stakeholder group.

Five of the six respondents indicated some type of DoD specific simulation software. All of the software indicated are used for DoD constructive simulation training such as Joint Theater Level Simulation (JTLS), Joint Conflict and Tactical Simulation (JCATS), and Joint Live-Virtual-Constructive (JLVC)."

Questions 67-74 were answered by 14 respondents as indicated in Table 7 and 8. The government/military stakeholder group was the largest respondents with eight of 14 respondents self-reporting. Two respondents each self-reported being from the other stakeholder groups: academic and industry. Topics were prioritized by importance on a Likert scale indicating one for the most important topic and the higher number for the least important topic. Only the government/military stakeholder group had more than two respondents for these questions. Tables 9-17 indicate priority placements for rank one and two by stakeholder groups.

Survey question 67 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and the eight being the least important) the CMSP main topic list as indicated in Figure 3.

In Figure 10 respondents placed the highest priority (rank one) in "Modeling Methods" and "Business and Management of M&S." Table 9 indicates that priority was placed on "Modeling and Methods" by 13% of government/military respondents and 50% of industry and academia respondents respectively; "Business and Management of M&S" received 37.5% of government/military respondents and 50% of academic and industry respondents respectively. Priority was placed on "Business and Management of M&S" by 37.5% of government/military respondents.

Considering rank one and rank two switches priority to "Concepts and Context" and "Simulation Implementation." All of the prioritization was spread out among the categories. Considering "Concepts and Context"; it was ranked one, two, or three by more than 70% of the respondents. Other topics identified with low ranks overall, were still identified by some with higher rankings.

This variation in answers suggests that stakeholders are divided on the importance of each parent topic. The academic and industry stakeholders placed value in multiple categories. Regarding the government/military stakeholders every category received at least one vote except for "Supporting Tools, Techniques, and Resources." This division is likely justified because of the changing nature of the M&S field and the varied and diverse needs of each stakeholder group.

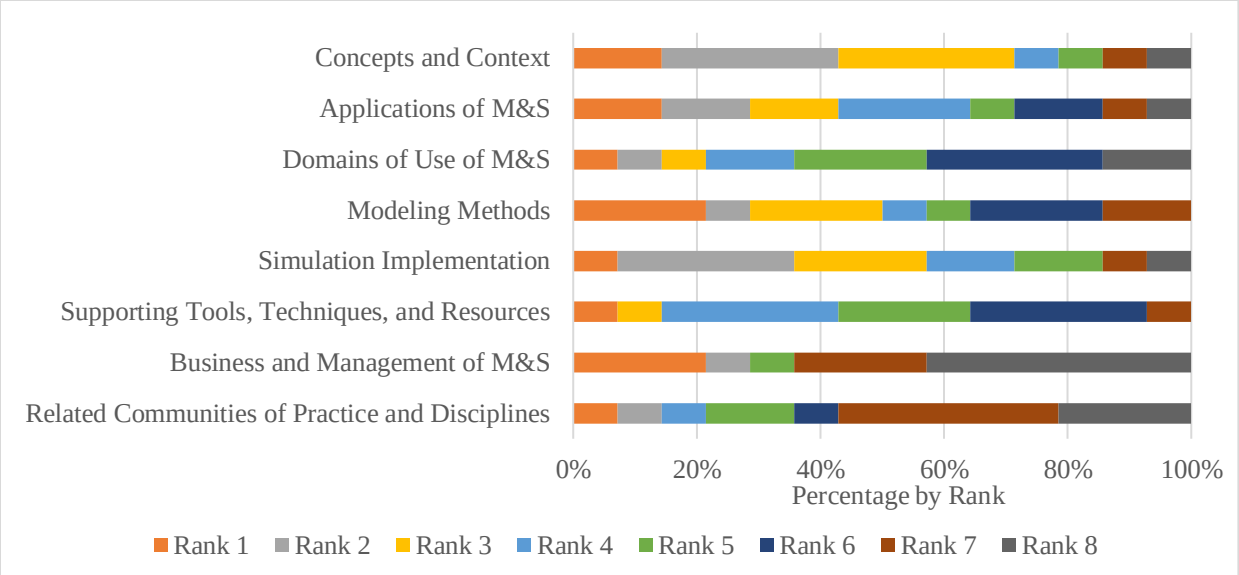


Figure 10: CMSP Main Topics Rank Ordered by Importance

Table 9: CMSP Main Topics Priorities by Stakeholder Group

CMSP Topic List	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Concepts and Context	12.5%	25%	50%	0%	0%	50%
Applications of M&S	12.5%	12.5%	0%	0%	50%	0%
Domains of Use of M&S	12.5%	0%	0%	50%	0%	0%
Modeling Methods	12.5%	12.5%	50%	0%	50%	0%
Simulation Implementation	12.5%	37.5%	0%	50%	0%	0%
Supporting Tools, Techniques, and Resources	0%	0%	0%	0%	0%	0%
Business and Management of M&S	37.5%	0%	0%	0%	0%	50%
Related Communities of Practice and Disciplines	0%	12.5%	0%	0%	0%	0%
	Government		**Academia**		**Industry**	

Survey question 68 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and three being the least important) the CMSP sub-topic related to "Context and Concepts" as indicated in Figure 11 and Table 10. Respondents placed the highest priority (rank one), 55% in "M&S Categories and Paradigms." Considering just the government/military stakeholders; respondents placed the

highest priority (rank one) in "M&S Fundamental Terms and Concepts." "M&S History" received no rank one votes which make it appear to be the least important to all stakeholders.

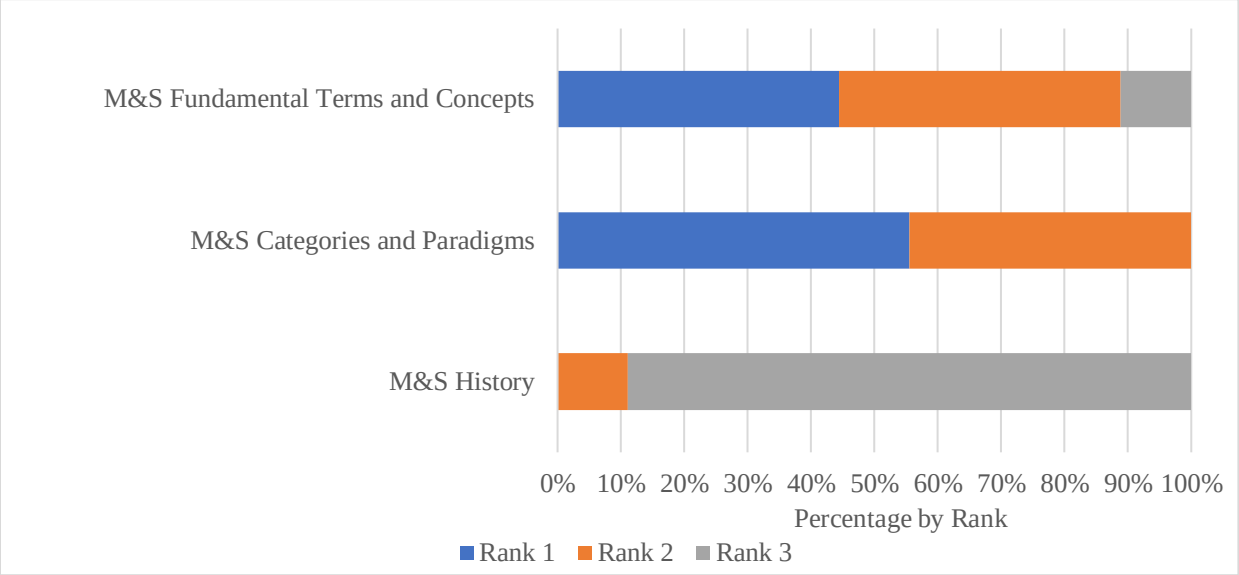


Figure 11: CMSP Sub-topic M&S Concepts and Context Rank Ordered by Importance

Table 10: CMSP Sub-topic M&S Concepts and Context Priority by Stakeholder Group

Concepts and Context	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
M&S Fundamental Terms and Concepts	60%	20%	50%	50%	0%	50%
M&S Categories and Paradigms	20%	60%	50%	50%	100%	0%
M&S History	0%	0%	0%	0%	0%	50%
	Government		**Academia**		**Industry**	

Survey question 69 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and six being the least important) the CMSP sub-topic related to "Applications of M&S" as indicated in Figure 12 and Table 11. Overall, respondents placed the highest priority (rank one) in both "Training" and "Analysis" 35% each. The priority of these two categories is primarily due to individual stakeholder groups. "Training" received 50% of government/military respondents. "Analysis"

received 100% of academic respondents. When considering rank one and rank two, a higher priority was placed on "Analysis" (21%). "Training" and "Analysis" are the only categories wherein all three stakeholder groups placed priority.

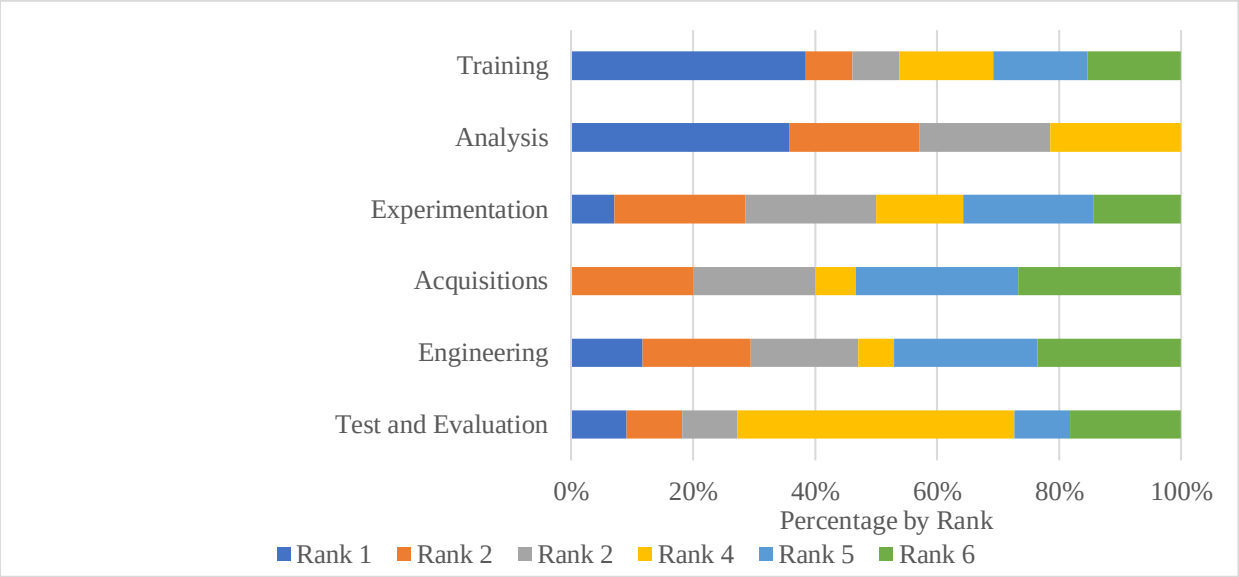


Figure 12: CMSP Sub-topic M&S Applications Rank Ordered by Importance

Table 11: CMSP Sub-topic Applications of M&S Priority by Stakeholder Group

Applications of M&S	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Training	50%	0%	0%	50%	50%	0%
Analysis	12.5%	25%	100%	0%	0%	50%
Experimentation	12.5%	12.5%	0%	0%	0%	50%
Acquisitions	0%	37.5%	0%	50%	0%	0%
Engineering	12.5%	12.5%	0%	0%	50%	0%
Test and Evaluation	12.5%	12.5%	0%	0%	0%	0%
	Government		**Academia**		**Industry**	

Survey question 70 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and 12 being the least important) the CMSP sub-topic related to "Domains of M&S" as indicated in Figure 13 and Table 12. Respondents assigned the highest priority (rank one) to "Combat and Military"

(42%); every stakeholder group placed at least 50% in this category. "Computer and Communication Systems" received the second highest priority (42%) when considering rank one and rank two. This response is likely due to the government/military stakeholder group placing 50% rank two priority. Every category received at least one respondent's vote in rank one through three. Across all stakeholders "Combat and Military" received the highest ranking; 85% considering rank one through three.

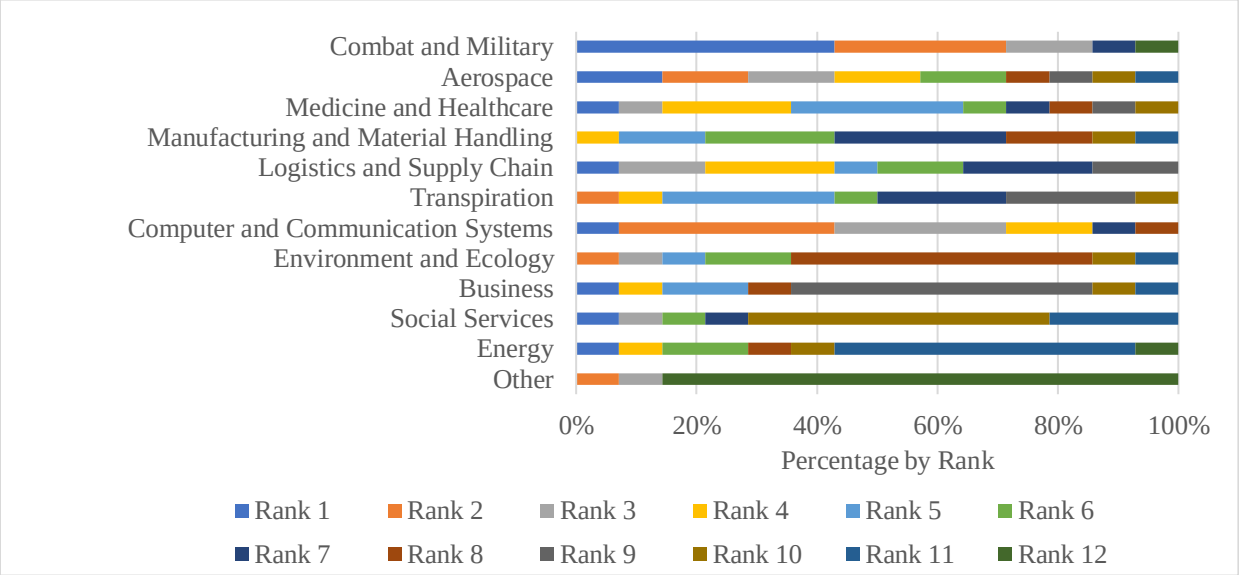


Figure 13: CMSP Sub-topic Domains of M&S Rank Ordered by Importance

Table 12: CMSP Sub-topic Domains of M&S Priority by Stakeholder Group

Domains of M&S	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Combat and Military	50%	25%	50%	0%	50%	50%
Aerospace	25%	12.5%	0%	0%	0%	50%
Medicine and Healthcare	0%	0%	0%	0%	50%	0%
Manufacturing and Material Handling	0%	0%	0%	0%	0%	0%
Logistics and Supply Chain	12.5%	0%	0%	0%	0%	0%
Transpiration	0%	12.5%	0%	0%	0%	0%
Computer and Communication Systems	0%	50%	0%	50%	0%	0%
Environment and Ecology	0%	0%	0%	50%	0%	0%
Business	12.5%	0%	0%	0%	0%	0%
Social Services	0%	0%	0%	0%	0%	0%
Energy	0%	0%	50%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%
	Government		**Academia**		**Industry**	

Survey question 71 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and ten being the least important) the CMSP sub-topic related to "Modeling Methods" as indicated in Figure 14 and Table 13. Government/military stakeholder respondents, the only group who ranked "Physics-based Modeling," assigned the highest priority (rank one) (28%). The priority placement surfaced likely because the stakeholder group government/military was the only group who ranked "Physics-based Modeling" in either rank one or two. Fifty percent (50%) of the government/military group placed "Physics-based Modeling" in rank one. "Human Behavior Modeling" is the second highest priority (rank one) at 21%. "Human Behavior Modeling" and "Continuous Simulation" are the only two categories wherein all three stakeholder groups placed

rank one or two priority. Considering rank one and two the overall priority changed to "Continuous Simulation" at 35%.

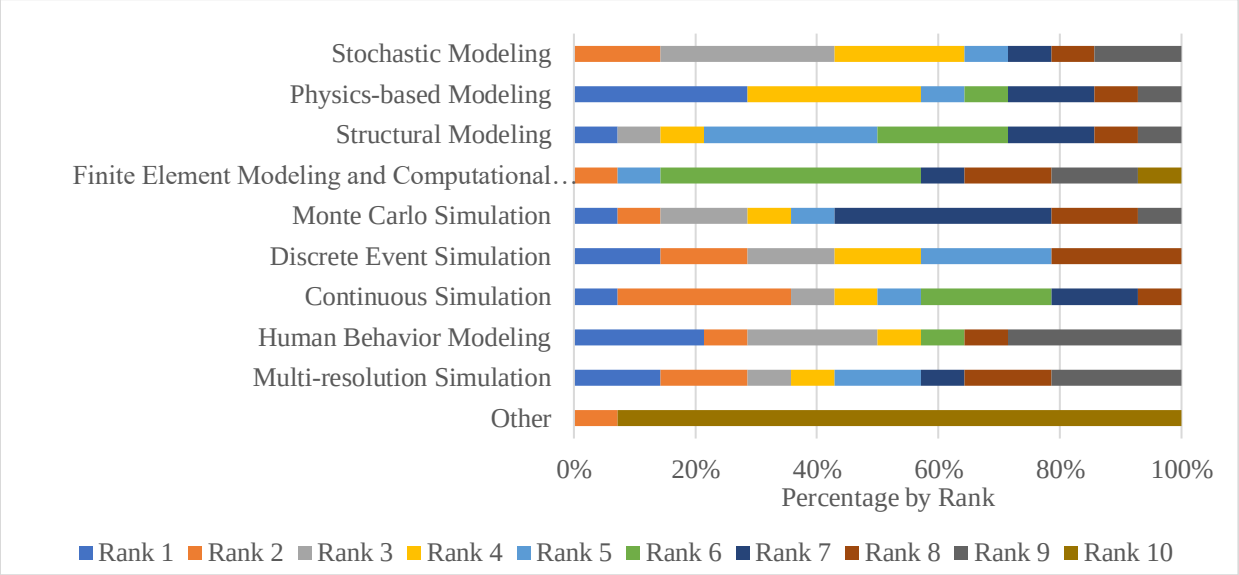


Figure 14: CMSP Sub-topic Modeling Methods Rank Ordered by Importance

Table 13: CMSP Sub-topic Modeling Methods Priority by Stakeholder Group

Modeling Methods	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Stochastic Modeling	0%	0%	0%	0%	0%	50%
Physics-based Modeling	50%	0%	0%	0%	0%	0%
Structural Modeling	0%	0%	0%	0%	0%	0%
Finite Element Modeling and Computational Fluid Dynamics	0%	12.5%	0%	0%	0%	0%
Monte Carlo Simulation	0%	12.5%	0%	0%	50%	0%
Discrete Event Simulation	12.5%	12.5%	50%	50%	0%	0%
Continuous Simulation	12.5%	12.5%	0%	50%	0%	50%
Human Behavior Modeling	0%	12.5%	50%	0%	50%	0%
Multi-resolution Simulation	25%	25%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%
	Government		**Academia**		**Industry**	

Survey question 72 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and 11 being the least important) the CMSP sub-topic related to "Simulation Implementation" as indicated in Figure 15 and Table 14. Overall priority (rank one) was assigned to "M&S Standards" (28%). Fifty percent (50%) of the government/military stakeholder group placed "M&S Standards" in rank one priority. No other stakeholder group placed priority, rank one or rank two, in this category. Considering rank one and rank two the priority changes to "Conceptual Modeling" (35%). The only category to receive votes from all three stakeholder groups, rank one or rank two, was "Virtual Environments and Virtual Reality."

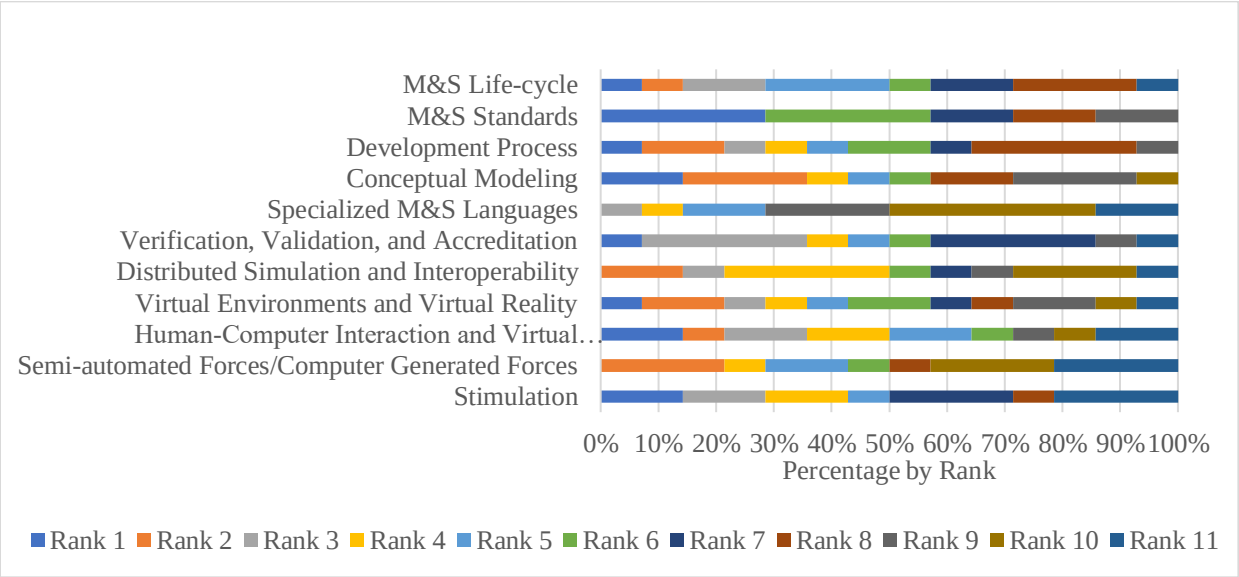


Figure 15: CMSP Sub-topic Simulation Implementation Rank Ordered by Importance

Table 14: CMSP Sub-topic Simulation Implementation Priority by Stakeholder Group

Simulation Implementation	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
M&S Life-cycle	0%	12.5%	0%	0%	50%	0%
M&S Standards	50%	0%	0%	0%	0%	0%
Development Process	12.5%	0%	0%	50%	0%	0%
Conceptual Modeling	0%	25%	50%	0%	0%	0%
Specialized M&S Languages	0%	0%	0%	0%	0%	0%
Verification, Validation, and Accreditation	12.5%	0%	0%	0%	0%	0%
Distributed Simulation and Interoperability	0%	25%	0%	0%	0%	0%
Virtual Environments and Virtual Reality	12.5%	0%	0%	50%	0%	50%
Human-Computer Interaction and Virtual Environments	0%	12.5%	50%	0%	0%	0%
Semi-automated Forces/Computer Generated Forces	0%	25%	0%	0%	0%	50%
Stimulation	12.5%	0%	0%	0%	50%	0%
	Government		**Academia**		**Industry**	

Survey question 73 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and three being the least important) the CMSP sub-topic related to "Supporting Tools, Techniques, and Resources" as indicated in Figure 16 and Table 15. This question received only four government/military, two industry, and one academia responses.

Respondents assigned equal importance in all categories. Considering rank one and rank two the priority is "M&S Resource Repositories" (77%). Seventy-five percent (75%) of the government/military group placed the highest priority (rank one) in "Major Simulation Infrastructure."

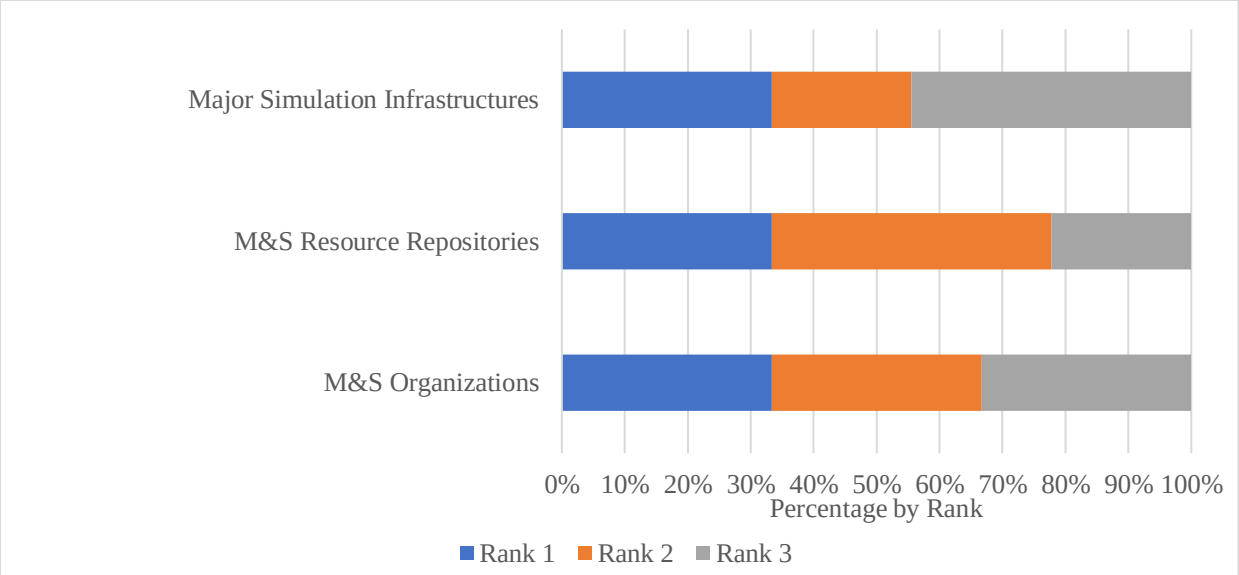


Figure 16: CMSP Sub-topic Supporting Tools, Techniques, and Resources Rank Ordered by Importance

Table 15: CMSP Sub-topic Supporting Tools, Techniques, and Resources Priority by Stakeholder Group

Supporting Tools, Techniques, and Resources	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Major Simulation Infrastructures	75%	25%	0%	0%	0%	50%
M&S Resource Repositories	25%	25%	0%	100%	50%	50%
M&S Organizations	0%	50%	100%	0%	50%	0%
	Government		**Academia**		**Industry**	

Survey question 74 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and five being the least important) the CMSP sub-topic related to "Business and Management of M&S" as indicated in Figure 17 and Table 16. Respondents assigned the highest priority (rank one) in "Management of M&S Projects and Processes" (50%). Seventy-five percent (75%) of government/military respondents placed "Management of M&S Projects and Processes" as their highest priority (rank one). All of the industry respondents placed "M&S Business Practice and

Economics" as their highest priority (rank one). "M&S Industrial Development" did not receive any rank one responses.

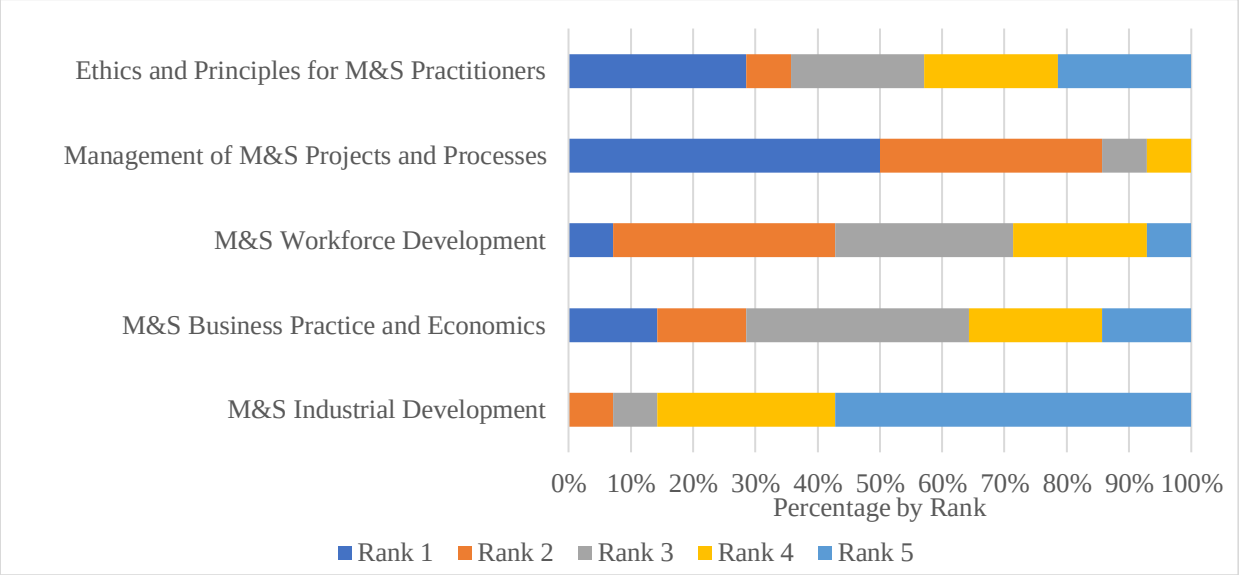


Figure 17: CMSP Sub-topic Business and Management of M&S Rank Ordered by Importance

Table 16: CMSP Sub-topic Business and Management of M&S Priority by Stakeholder Group

Business and Management of M&S	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Ethics and Principles for M&S Practitioners	12.5%	0%	50%	0%	0%	50%
Management of M&S Projects and Processes	75%	12.5%	50%	50%	0%	50%
M&S Workforce Development	12.5%	37.5%	0%	50%	0%	0%
M&S Business Practice and Economics	0%	37.5%	0%	0%	100%	0%
M&S Industrial Development	0%	12.5%	0%	0%	0%	0%
	Government		**Academia**		**Industry**	

Survey question 75 asked, "Please rate the importance of the following topics to your job/research." Respondents were asked to rank order (one being most important and four being the least important) the CMSP sub-topic related to "M&S Related Communities of Practice and Disciplines" as indicated in Figure 18 and Table 17. Respondents assigned the highest priority

(rank one) in “Software Engineering and Development” (50%). “Mathematics” did not receive any rank one responses.

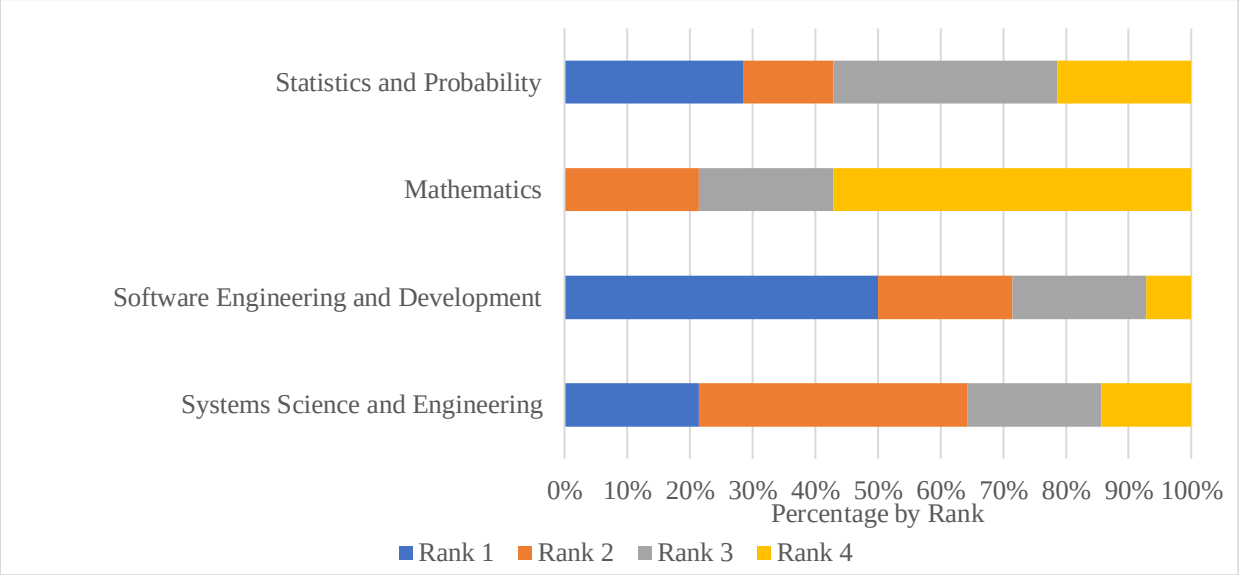


Figure 18: CMSP Sub-topic Related Communities of Practice and Disciplines Rank Ordered by Importance

Table 17: CMSP Sub-topic Related Communities of Practice and Disciplines Priority by Stakeholder Group

Related Communities of Practice and Disciplines	Prioritization by Stakeholder Group					
	Rank 1	Rank 2	Rank 1	Rank 2	Rank 1	Rank 2
Statistics and Probability	25%	25%	50%	0%	0%	0%
Mathematics	0%	25%	0%	50%	0%	0%
Software Engineering and Development	50%	25%	50%	0%	50%	50%
Systems Science and Engineering	25%	25%	0%	50%	50%	50%
	Government		**Academia**		**Industry**	

CHAPTER FIVE:
DISCUSSION

The current research explored the interrelated perceptions of M&S stakeholders. In this section, the findings of this research are summarized with explanations for the results postulated, as well as a list of research limitations. Finally, conclusions based on the results of the study, the implications of the study and recommendations for further research are discussed.

With the continued exponential advancements and uses of M&S, it is essential for all stakeholders, to understand the core KSAs that hold the most value or are of the most importance within the professional organization. The current study substantiated the notion presented by Bair and Jackson that the vast range of disciplines related to M&S makes it difficult to describe the education, training, and employment of an M&S professional accurately, specifically as these relate to KSAs (Bair & Jackson, 2013).

Employers need available M&S KSAs to be reliably identified in order to accomplish M&S related work. KSAs should be taught by educational institutions in order to support the needs of all stakeholders, whether they are employers or not. The attainment of important KSAs will never be a singular event. Stakeholders must continuously be aware of the changing M&S environment and prepared to meet the ever-increasing demands and challenges of the M&S profession.

Rogers, writing in the late 1990s, knew that continued updates would need to be made in the M&S organization in order to keep up with the increasing advancements of the field (Rogers, 1997). As of this publication, news of continued M&S advancements is coming from an ever more increasingly diverse fields of study (Padilla, Diallo, Lynch, & Gore, 2018; Swenson, Gravitz, & Lightner, 2017; Zhang, Wu, & Yang, 2017). Professional practitioners are stepping

up to support the M&S organization. The SCS, staffed by volunteers, works to be the champion of M&S and bring the organization together with common ethics, a BoK of core and valued KSAs, conferences and multiple publications ("The Society for Modeling and Simulation International (SCS)," 2018).

The results of this research, yield remarkable insight and general trends for the entire M&S community. The perception of 83% of respondents who reported that M&S is a distinct discipline rather than a specialization of another discipline supports the credibility of the entire M&S domain. M&S is a crucial part of the human existence. It is a growing, changing, and evolving discipline that merits a unified and distinct body of knowledge, academic programming and credentialing, and a code of ethics across stakeholders.

This research sought to examine the current state of M&S through a comprehensive literature review and the identification of current domain perceptions through the eyes of a sample of M&S stakeholders. These stakeholders are professional from the major M&S fields of academia, government/military, and industry. Consequently, to find that 50% of the survey respondents identified as military or government stakeholders is not surprising considering government contracts likely account for most of the funded M&S projects and workload. Initially, the driving force for M&S solutions came into existence primarily due to government needs, through DARPA (Goldsman et al., 2009). The fact that the majority of M&S KSAs identified are centered around user needs, while academic and industry professionals require more robust KSAs at the practitioner level is a logical conclusion of this research and substantiates research presented in the literature review.

Based on the analysis of qualitative and quantitate data the following findings were identified as significant and grouped under each research question, RQ1: Are stakeholder

perceptions aligned regarding valued M&S KSAs? RQ2: Do the KSAs identified as being of value by individual stakeholder groups align with KSAs necessary for employment attainment in the M&S field?

The primary stakeholder group who answered the survey were from the government/military stakeholder group (54%). Twenty-four percent of respondents reported being from the industry stakeholder group. Respondents reporting the academic stakeholder group numbered 13.5%. All three stakeholder groups were represented. This research sample population may be an accurate representation of the M&S stakeholder population. Therefore, findings at the minimum identify general trends in the M&S stakeholder groups.

Research Question One

Research question one asked, "Are stakeholder perceptions aligned regarding valued M&S KSAs?" This question was addressed by a number of survey questions as indicated in Table 7. M&S stakeholder perceptions regarding valued KSAs appear to be varied and unique to each stakeholder group. Descriptive analysis of this exploratory research appears to support the hypothesis of research question one indicating that KSAs identified by various stakeholder groups are not aligned regarding valued M&S KSAs.

Considering a quantitative cross tabulation of SQ 11, 42, 45, 52, and 54, all short answer questions, resulted in a smattering of valued KSAs of importance to the stakeholder groups. Terms related to KSAs from each question were triangulated with respondents within the respective stakeholder group. The number of times each term was used indicated the level of importance placed upon that particular KSA.

Government/military respondents (Figure 19) overwhelmingly indicated that "M&S Training" was the most critical KSA. "M&S Training" was followed with the "Use of M&S

Tools" representing half the responses. This respondent group was the largest group to complete the survey. Having 12 responses with the majority of responses within the first six categories may indicate this group is considerably more unified in regards to the KSAs of importance as compared to the other two stakeholder groups.

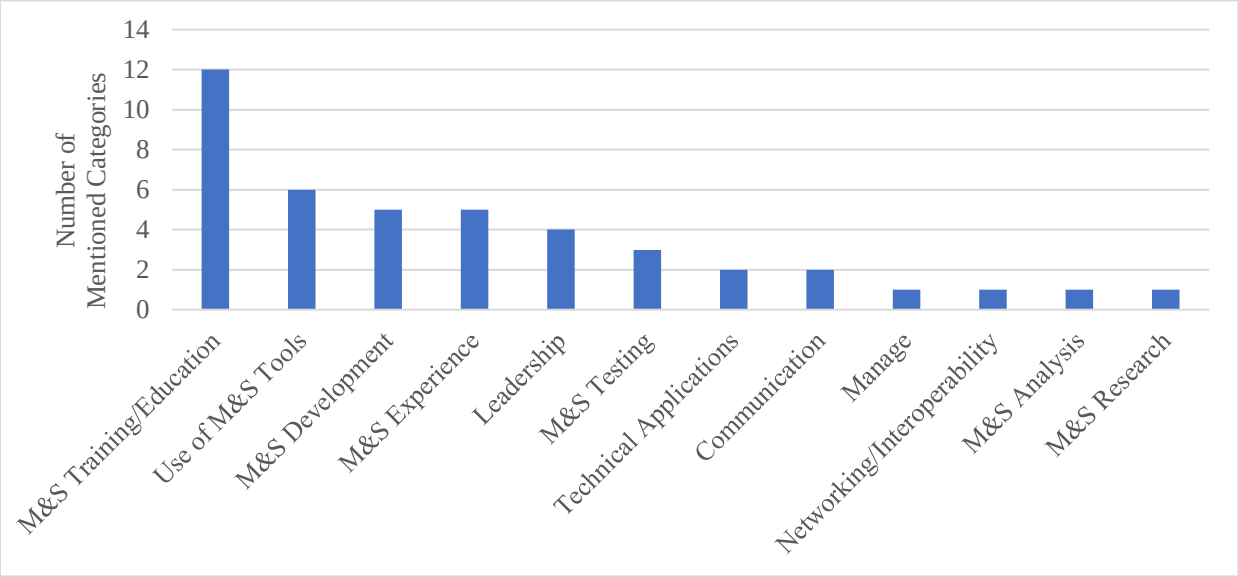


Figure 19: Government/Military KSAs of Importance

Of the 24% self-reported as industry stakeholders, 33% of respondents reported their industry was government and defense-related. Two respondents indicated they worked in M&S manufacturing. Two respondents indicated they worked in the engineering field such as aerospace. One respondent indicated training and one respondent indicated economic development as an industry. Industries represented by the current survey, therefore, were manufacturing, engineering, training, economic development, and defense.

Industry respondents (Figure 20) indicated "M&S Experience" was their most valued KSA followed by "M&S Application Knowledge" and "M&S Development" being of equal value to industry stakeholders. Over half the KSA terms received less than two responses which may indicate this stakeholder group is considerably diverse with regards to valued KSAs. KSAs

of importance to the manufacturing industry: knowledge of industry-specific "M&S Tools," "eagerness to perform" and "M&S Related Experience." KSAs of importance to the engineering industry: "Management." KSAs of importance to the defense/government industry: "Programming," "Systems Engineering," "Management," "Self-motivation," and "M&S Experience."

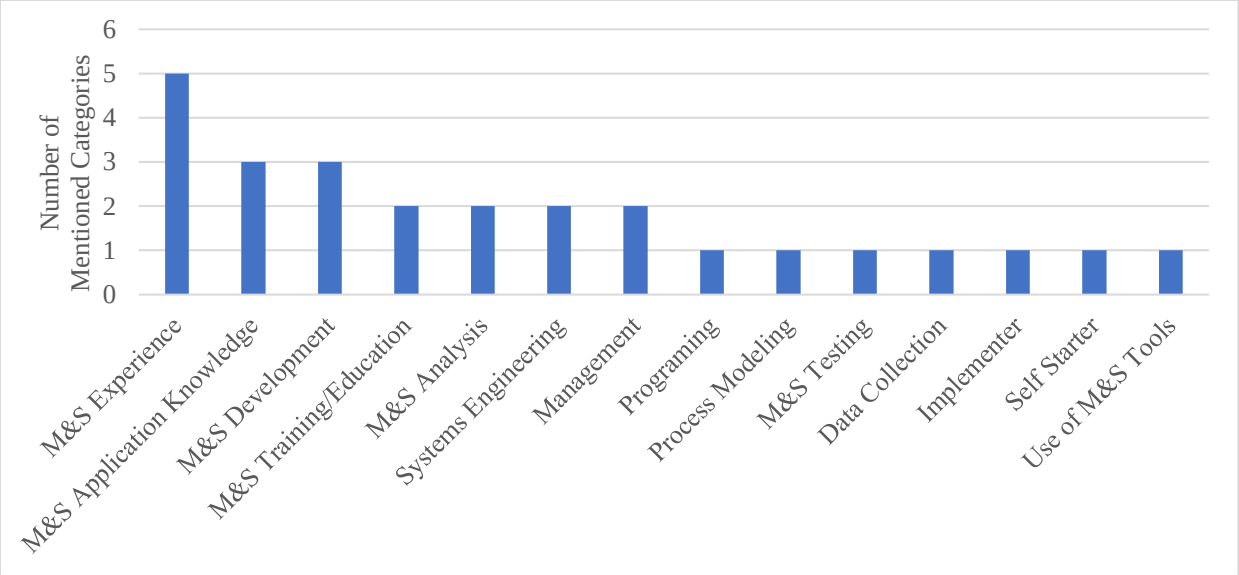


Figure 20: Industry KSAs of Importance

The smallest stakeholder group represented was academia. Academic respondents (Figure 21) reported that "M&S Development" was the most critical KSA. None of the responses in this stakeholder group received more than two mentions. This result may be an indicator of the diversity of KSAs within this stakeholder group.

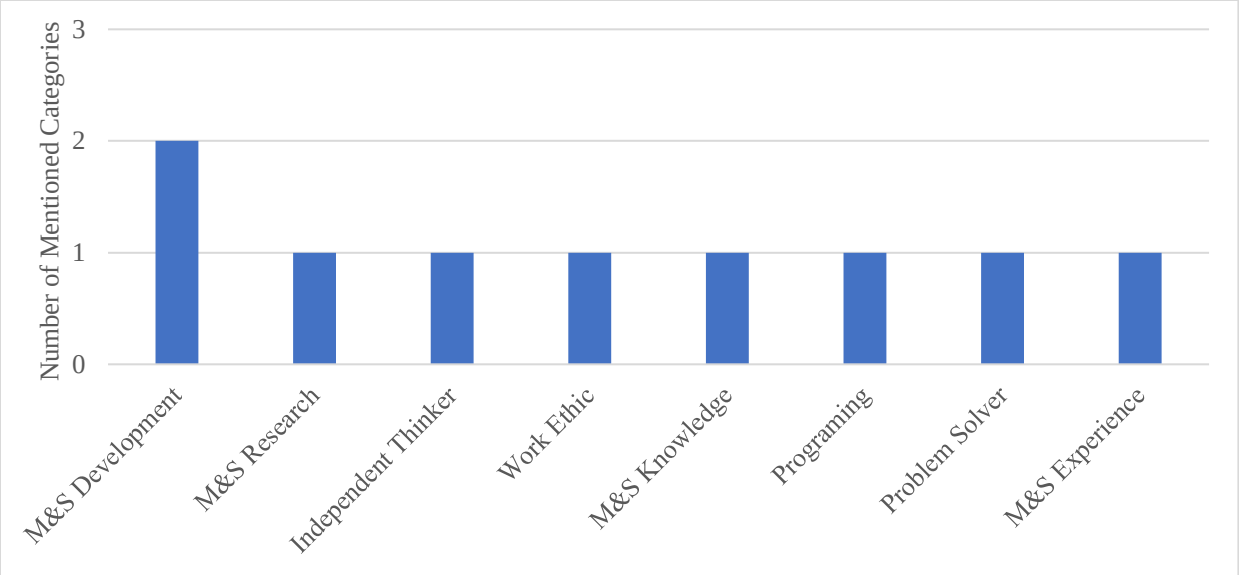


Figure 21: Academic KSAs of Importance

There are some similarities within the KSAs reported by each stakeholder group. "M&S Development" is within the top three KSAs reported by all three groups. Figure 22 overlays all the stakeholder perceptions and identifies specific trends. Although similarities exist, it is evident that each stakeholder group relies upon uniquely different KSAs to support their needs. Government/military stakeholders' top two priorities, "M&S Training" and "Use of M&S Tools" are not top priorities for the other two stakeholder groups. Academia stakeholders' second priority, "M&S Research" is only listed on Government/military but not in the top four. Two of the academia stakeholders' top four priorities are not mentioned at all by the other two groups: "Independent Thinker" and "Work Ethic." Industry stakeholders' top four priorities include, "M&S Application Areas" which are not mentioned by the other two groups.

Each stakeholder group also reported non-M&S related KSAs. Government/military reported "Leadership," "Communication," and "Management" as critical KSAs. Industry reported, "Management," "Implementor," and "Self-starter" as important KSAs. Academia reported "Independent Thinker," "Work Ethic," and "Problem Solver" as important KSAs. In

juxtaposing these non-M&S related KSAs reported by stakeholders, we find “Management,” “Leadership,” and “Communication” as general trends of extraneous KSAs valued by all M&S stakeholders.

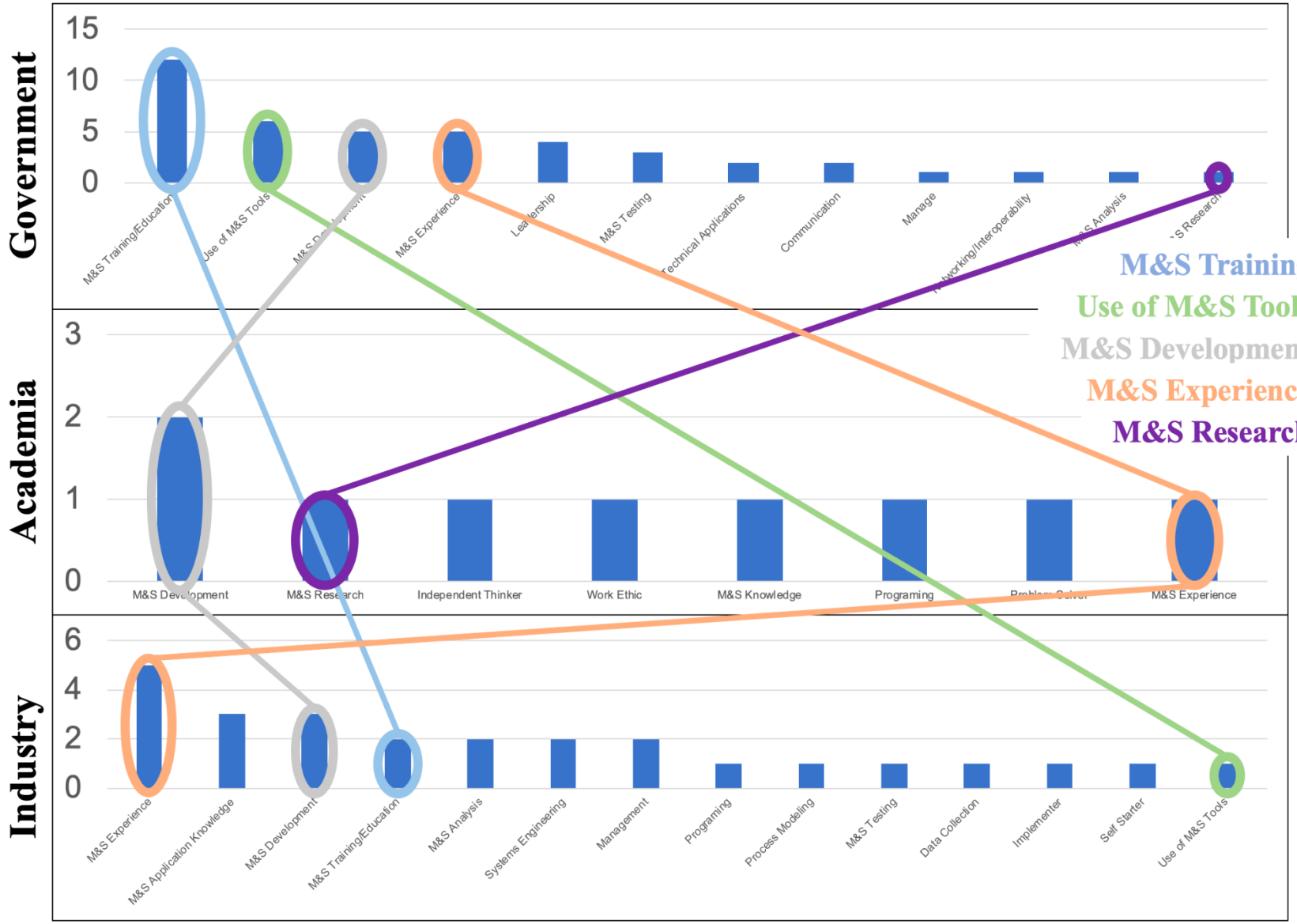


Figure 22: Juxtaposition of Stakeholder Perceptions

A quantitative review of the data includes SQ 67-75 the CMSP topic list prioritizations. A cross-tabulation of SQ 3 and SQs 67-75 was conducted and depicted in Tables 9-17. The priority list of each category (Table 18) provides an understanding of important KSAs related to the CMSP. Only categories wherein two or more respondents were recorded are listed in the table. Therefore, the government/military respondent group created more categories. The categories under academia and industry are listed because both respondents agreed upon the prioritization. Categories with the highest percentages of each stakeholder group: Government/military – "Major Simulation Infrastructures," "Management of M&S Projects and Processes" and "M&S Fundamental Terms and Concepts"; Academia – "Analysis"; Industry – "M&S Categories and Paradigms" and "M&S Business Practice and Economics." These varied responses from stakeholders support the fact that the majority of M&S KSAs identified in this study are centered around user needs. It also shows general and continued trends concerning valued KSAs of each stakeholder group being unique to their individual group.

Table 18: CMSP Priority Intensity by Stakeholder Group

Government/Military		Academia		Industry	
75%	Major Simulation Infrastructures	100%	Analysis	100%	M&S Categories and Paradigms
75%	Management of M&S Projects and Processes			100%	M&S Business Practice and Economics
60%	M&S Fundamental Terms and Concepts				
50%	Training				
50%	Combat and Military				
50%	Physics-based Modeling				
50%	M&S Standards				
50%	Software Engineering and Development				
37.5%	M&S Business Practice and Economics				

The analysis of this data suggests that stakeholders hold priority on different KSAs supporting the validity of RQ1's hypothesis. KSAs identified by various stakeholder groups are not aligned regarding valued M&S KSAs.

Research Question Two

Research question two asked, "Do the KSAs identified as being of value by individual stakeholder groups align with KSAs necessary for employment attainment in the M&S field?" M&S stakeholder perceptions regarding valued KSAs necessary for employment appear to be similar across stakeholder groups. Descriptive analysis of this exploratory research appears to support the null hypothesis of research question two indicating that M&S KSAs identified to be of value by stakeholder groups align with KSAs necessary for employment attainment.

This question was addressed by a number of survey questions illustrated in Table 8. Since the M&S field is growing and expanding, this research supports not only the need for

continued identification of the KSAs valued by stakeholders but what employment needs now and possibly into an unknown future. This point-in-time perception of what is valued today should inform stakeholder groups from academics, government/military, industry, and provide general trend data for all.

From the data analysis, it is clear that M&S employers appear to value "Experience" and employee characteristics such as, "Willingness to Work." Respondents consistently identified both of these terms when completing survey questions.

KSAs required for employment in the M&S field are related to survey question 42 and 45 as indicated in Table 18. Table 19 is a juxtaposition of SQ 3, 15, 42 and 45. Survey respondents recognized M&S as having a multidisciplinary structure (SQ 53, 54) wherein many KSAs would be necessary and important; they appeared to identify prior M&S experience (SQ 42, 45) as the most essential KSA. The majority of respondents indicated technical and operational experience was of great value to the employer and in the overall employment attainment process. KSAs of importance, also appear to be related to management (SQ 42, 45 and 74). Qualitative response data substantiate the importance of management by identifying a consistent theme of the term "Management" as indicated in Figure 19-21.

Table 19: KSAs Required for Employment Attainment

SQ 15: What is your current occupational title?	SQ 3: Which M&S stakeholder group do you identify with?	SQ 42: Which M&S skills did you emphasize on your resume/CV for current job?	SQ 45: What types of qualifications/skills do you look for in perspective, qualified candidates?
Senior Lecturer	Academia		"Independent thinking. Strong work ethic. Ability to talk themselves through a problem without freaking out. Knowledge of relevant foundational vocabulary and facts"
International Business Leader	Industry	Experience	"Experience and Education"
President and CEO	Industry	Systems Engineering	"Self-starter, organized and goal-oriented, and appropriate interpersonal skills"
President and CEO	Industry		"Experience in developing and testing scenarios."
Director of New Business Development	Industry	Experience	"Product knowledge and eagerness to work"
Program Director	Industry	Experience	"Systems integration"
Deputy Commander	Government/Military	Management	"Experience in the field, integration and execution of distributed training devices/exercises and communication ability"
Production Shift Manager	Government/Military		"Leadership, Communication, and Commitment"

Overall, qualitative themes which surfaced in the content analysis of the majority of open-ended questions supported the need for training and experience in the field of M&S as significant indicators in employment attainment. Stakeholders cite interpersonal skills, such as "Communication" as a salient employment skill. The term, "Communication" in some form, was used repeatedly in order to identify qualified candidates.

Additional KSAs which appear to be important are those related to being a "Self-starter" and having an "Eagerness to Work" as indicated in Table 19. One respondent suggested, "More important than specific technical skills is the ability to learn, good attitude and demonstrated self-motivation." These varied responses from M&S stakeholders suggest that the characteristics

and values of an M&S professional needed for employment attainment are the same among stakeholders, but the set of skills is specific to each stakeholder group.

In its entirety, the survey data and subsequent analysis provide fresh insight into what KSAs stakeholders value in employees, reveal what job candidates should develop as recommended KSAs for employment attainment and provides insight into general human resource trends for the M&S profession as a whole. The KSAs identified as being of value by individual stakeholder groups align with the identified KSAs necessary for employment attainment supporting RQ2's null hypothesis, M&S KSAs identified to be of value by stakeholder groups align with KSAs necessary for employment attainment.

Limitations

One of the most significant limitations to this study was the survey sample size, which was expected to be much larger than achieved. The majority of respondents of the survey were from government/military stakeholder group. It is likely that the population of M&S stakeholders overall include more government/military than industry and academia.

However, it will be necessary in the future to ensure responses from a reasonable number of stakeholders in each category to obtain a representative sample of the M&S domain to truly generalize results. In fact, because of the diversity among the industry stakeholders, future research should endeavor to include a broader range of M&S professionals from diverse domains.

The limited respondent group size was likely due to the short length of time the survey was available to respondents and the emphasis/advertisement of the survey instrument as necessary to the M&S culture. Due to competing requirements, the survey was only available for two months. Survey administrators only sent out one official request for involvement. The

survey may have been better received if it were available for a more extended period and if a recognized M&S professional organization had sponsored the research.

The survey instrument touted a total of 76 questions. Of the 37 respondents that started the survey only 15 respondents finished the survey. The survey questions not answered, by any stakeholder group, were likely not presented correctly to the respondents. If this was the case, it might have been an error related to the survey development or platform. It is also likely that the respondents skipped questions they felt were too cumbersome or did not finish the survey because the overall survey was too time consuming and housed more questions than needed. In any case, this situation could be resolved during survey development. In the future, studies such as this one should house focused questions and be preceded by a pre-test in order to measure overall survey question effectiveness, including organization and development.

Conclusions and Future Work

It is evident from this research that M&S as a professional organization lacks a clear understanding of who is using and developing M&S. This misunderstanding is likely due to the exponential growth of M&S globally and the underrepresentation of various stakeholder groups. Such is the case in the present study with "industry" stakeholders. Although, one respondent self–reported as an M&S stakeholder from the industry of "Economic Development," a domain not commonly associated with M&S. Consequently, this suggests an area for researchers and practitioners alike to focus on in the future.

This research is a starting point upon which to build a repository of valued M&S KSAs that align with stakeholder needs and ensure identified KSAs support the necessary skills and characteristics for employment attainment and retention. The results should also be used to

provide a more robust and consistent standardized method of aligning M&S academic programming at every level to industry needs.

Relevant conclusions culled from this research include, but are not limited to:

- M&S stakeholders are spread over a broad spectrum of domains. They do not hold the same value for the existing or standard M&S KSAs.
- Employers do not have the confidence to hire M&S graduates because of the varied value of KSAs specific to their domain, which may create an inconsistency of employment preparation levels.
- M&S academic programs do not present all the KSAs necessary to appease each and every M&S employer.

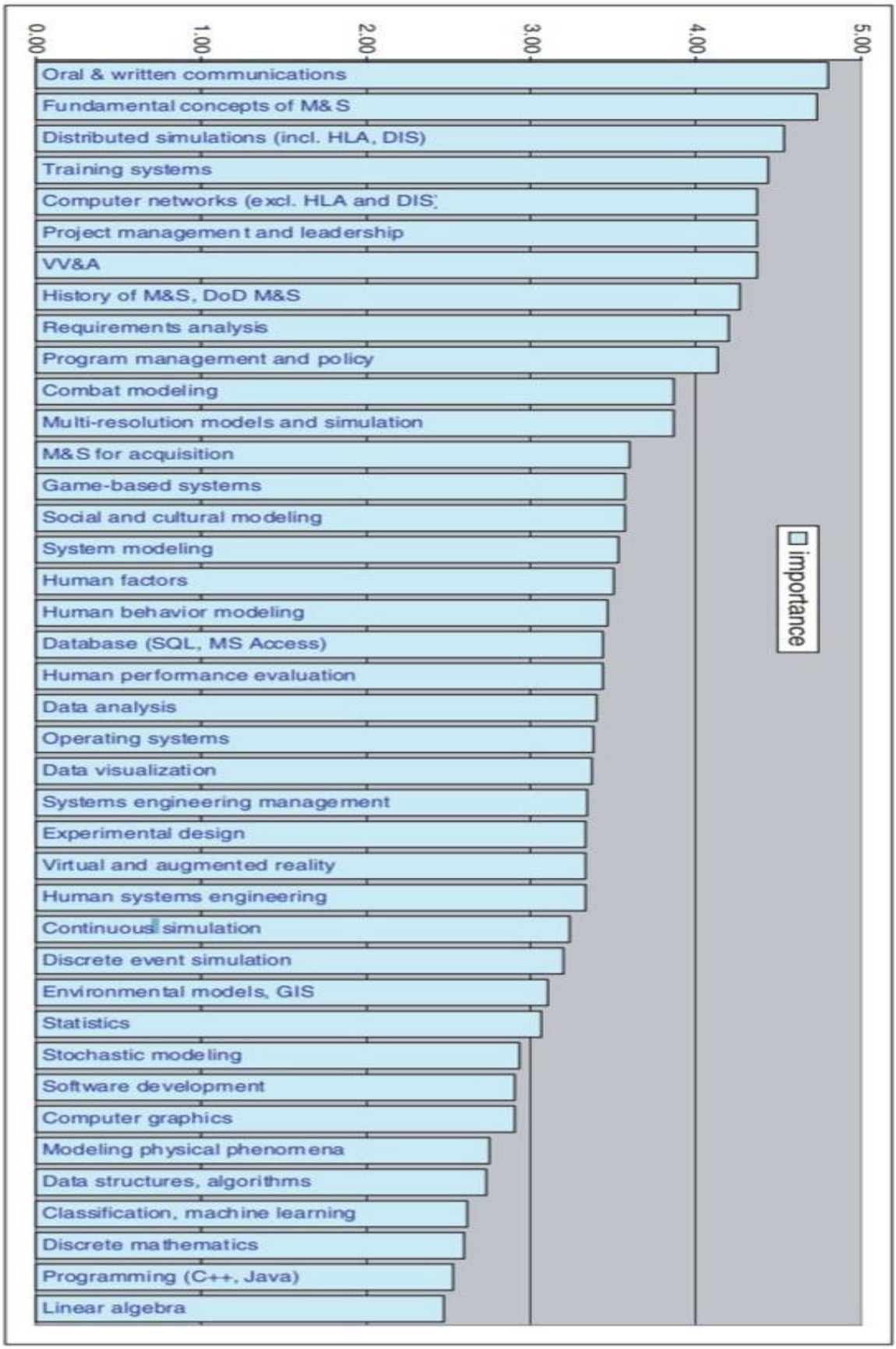
The literature review and past research presented in this study postulated that the existing gaps within the M&S professional organization might be propagated by the divergence of KSAs perceived to be important by different stakeholders. Consequently, it is possible the perceived gaps, including the lack of an M&S BoK and the disunity of M&S education and certification, might be solved by an increased understanding of priority stakeholder KSAs. Thus, this research substantiates the salient need for research in the following areas:

- An in-depth study of stakeholder needs.
- An identification of M&S stakeholders. These stakeholders must be identified over a broad spectrum including known domains and unknown domains where M&S is being used.
- Exploratory research on academic programming and credentialing alignment with employer needs and requirements.
- A panel discussion resulting in a salient and unified M&S BoK. The panel must be comprised of representatives from identified domains.

The most relevant conclusion culled from this research is the point-in-time perspectives of the stakeholders that identified valued KSAs that are either currently part of the M&S culture or are needed as part of the overall BoK of all M&S professionals. It is of critical importance that the M&S professional society adopt an M&S BoK.

Based on this research and the research from the literature review, the best topic index that the field of M&S has, as of this publication, may be the CMSP topic index, assembled by SMEs in the field of M&S and used on the CMSP exam. However, this index cannot stand alone as an M&S BoK. An M&S BoK must provide stakeholders with a comprehensive viewpoint, unlimited by the changing landscape of the M&S domain, a snapshot of core competencies and a general perception of the upcoming trends and challenges facing M&S.

APPENDIX A: KÖLSCH'S SNAPSHOT OF THE ARMY M&S COMMUNITY


0.00
1.00
2.00
3.00
4.00
5.00
Oral & written communications
Fundamental concepts of M&S
Distributed simulations (incl. HLA, DIS)
Training systems
Computer networks (excl. HLA and DIS)
Project management and leadership
VV&A
History of M&S, DoD M&S
Requirements analysis
Program management and policy
Combat modeling
Multi-resolution models and simulation
M&S for acquisition
Game-based systems
Social and cultural modeling
System modeling
Human factors
Human behavior modeling
Database (SQL, MS Access)
Human performance evaluation
Data analysis
Operating systems
Data visualization
Systems engineering management
Experimental design
Virtual and augmented reality
Human systems engineering
Continuous simulation
Discrete event simulation
Environmental models, GIS
Statistics
Stochastic modeling
Software development
Computer graphics
Modeling physical phenomena
Data structures, algorithms
Classification, machine learning
Discrete mathematics
Programming (C++, Java)
Linear algebra
importance

APPENDIX B: SURVEY INSTRUMENT

Understanding Modeling and Simulation Graduate Education Stakeholder Perceptions

Informed Consent

Start of Block: Demographics and M&S Professionalism

Q12 Please complete the Demographics Questionnaire. Responses are kept confidential, so please answer honestly and completely.

Q18 Age

_____

Q2 Sex

- ○ Male
- ○ Female

Q13 What is the highest degree or level of education you have completed? If currently enrolled, highest degree received.

- ○ Some high school, no diploma
- ○ High school graduate, diploma or the equivalent
- ○ Some college credit, no degree
- ○ Trade/technical/vocational school
- ○ Associate degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ Professional degree (MD, JD, etc.)
- ○ Doctoral degree

Q15 What is your current occupational title?

_____

Q3 Which Modeling and Simulation (M&S) Stakeholder group do you Identify with the most?

- ○ M&S Military/Government
- ○ M&S Academia
- ○ M&S Industry
- ○ M&S Student
- ○ M&S Professional Organization Personnel
- ○ M&S Alumni
- ○ I do not identify as an M&S Stakeholder

Display This Question:

If Q3 = M&S Military/Government

Q24 What branch of the military/government do you work for?

_____

Display This Question:

If Q3 = M&S Military/Government

Q25 Do your superiors encourage you to enroll in an M&S graduate program?

- ○ Yes
- ○ No

Display This Question:

If Q3 = M&S Academia

Q10 Please chose the primary role you fill.

- ○ Faculty
- ○ Administration
- ○ Both

Display This Question:

If Q10 = Both

Q26 If you chose both, please indicate how many hours are allocated to administrative tasks and how many are allocated to faculty related tasks.

_____

Display This Question:

If Q3 = M&S Industry

Q11 Please identify what type of industry you work in.

_____

Display This Question:

If Q3 = M&S Industry

Q28 Have you obtained an M&S degree of some sort?

- ○ Yes
- ○ No

Display This Question:

If Q28 = Yes

Q29 If yes, which degree did you obtain?

_____

Display This Question:

If Q28 = Yes

Q31 Do you occupy the same job before you obtained your degree?

- ○ Yes
- ○ No

Display This Question:

If Q28 = Yes

Q30 If yes, which institution did you obtain your degree from?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Industry

Q42 Which M&S skills did you emphasize on your resume/CV for your current job?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Student

Q21 What degree are you currently pursuing?

_____

Display This Question:

If Q3 = M&S Student

Q22 Did you work for any type of M&S organization prior to enrolling in your current program?

- ○ Yes
- ○ No

Display This Question:

If Q22 = Yes

Q23 If so, what was your previous job title before enrolling in your current program?

_____

Display This Question:

If Q3 = M&S Student

Q33 What types of jobs do you expect to get once you have finished your degree?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Student

Q43 Why did you chose an M&S program?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Alumni

Q37 Do you currently hold an M&S (or M&S related) Job?

- Yes
- No

Display This Question:

If Q37 = Yes

Q40 Which organization do you work for?

_____

_____

_____

_____

_____

Display This Question:

If Q37 = Yes

Q38 Did you have this job prior to enrolling in your M&S program?

- Yes
- No

Display This Question:

If Q3 = M&S Alumni

Q45 Why did you chose an M&S program?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Alumni

Q39 Do you feel like your M&S degree has benefited you?

- Yes
- No

Display This Question:

If Q39 = Yes

Q40 What about your degree has benefited you?

_____

_____

_____

_____

_____

Display This Question:

If Q39 = No

Q41 Why do you believe your degree has not benefited you?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = M&S Professional Organization Personnel

Q34 Do you serve in a official or administrative position for your organization?

- ○ Yes
- ○ No

Display This Question:

If Q34 = Yes

Q41 What is the purpose of the organization?

_____

_____

_____

_____

_____

Display This Question:

If Q34 = Yes

Q43 What is your organization's primary funding source?

_____

_____

_____

_____

_____

Q4 What is your area of expertise? Please list three or more area(s) that best fit your skill set.

_____

_____

_____

_____

_____

Q44 Do you make any direct hiring decisions for your organization?

- ○ Yes
- ○ No

Display This Question:

If Q44 = Yes

Q45 What types of qualifications/skills do you look for in perspective qualified candidates?

_____

_____

_____

_____

_____

Display This Question:

If Q44 = Yes

Q46 Do you hire M&S degreed candidates?

- Yes
- No

Display This Question:

If Q46 = Yes

Q47 Do you prefer to hire candidates with M&S degrees from specific universities?

- Yes
- No

Display This Question:

If Q47 = Yes

Q48 If so, which Universities?

_____

_____

_____

_____

_____

Q35 Do you belong to any M&S Professional Organizations?

- ○ Yes
- ○ No

Display This Question:

If Q35 = Yes

Q36 Which professional M&S organization(s) do you belong to?

_____

_____

_____

_____

_____

End of Block: Demographics and M&S Professionalism

Start of Block: Short Answer Open-Ended Questions: Modeling and Simulation Professionalism

Q12 What do you believe constitutes as a Modeling and Simulation (M&S) Industry (as opposed to Engineering, Computer Science, etc.)?

_____

_____

_____

_____

_____

Q14 Who should be in charge of determining the topics within the M&S Body/Book of Knowledge (BoK)? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q16 Who should be in charge of determining standard topics for M&S Curricula? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q17 Who should be in charge of determining accreditation standards for M&S Educational Programs? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q18 Who should be in charge of determining an M&S Code of Ethics? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q13 Who should be in charge of M&S Standardization? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q19 Who should be in charge of M&S Licensing? Please be specific (e.g., a person, organization).

_____

_____

_____

_____

_____

Q50 Is M&S it's own discipline or a specialization of another discipline?

- ○ Own discipline
- ○ Specialization

Display This Question:

If Q50 = Specialization

Q51 Which discipline is M&S a specialization of?

_____

_____

_____

_____

_____

Q52 Please define what an M&S professional is to you.

_____

_____

_____

_____

_____

Q53 Are there types of M&S professionals?

- ○ Yes
- ○ No

Display This Question:

If Q53 = Yes

Q54 How would you categorize M&S professionals?

_____

_____

_____

_____

_____

End of Block: Short Answer Open-Ended Questions: Modeling and Simulation Professionalism

Start of Block: M&S KSAs

Display This Question:

If Q37 = Yes

Q53 How important are the following topics to your job?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
interoperability	○	○	○	○	○
simulation-component reuse	○	○	○	○	○
simulation infrastructure	○	○	○	○	○
simulation management	○	○	○	○	○
M&S history	○	○	○	○	○
modeling methods	○	○	○	○	○
data structures	○	○	○	○	○
computational framework	○	○	○	○	○
quantitative aspects	○	○	○	○	○
computer visualizations	○	○	○	○	○
issues of computational complexity	○	○	○	○	○
numerical modeling methods	○	○	○	○	○
specialized simulation languages	○	○	○	○	○
experimental design	○	○	○	○	○
instructional systems design	○	○	○	○	○
business practices	○	○	○	○	○

system design	○	○	○	○	○
system analysis	○	○	○	○	○
system optimization	○	○	○	○	○
distributed environments	○	○	○	○	○
human behavior evaluation	○	○	○	○	○
training applications	○	○	○	○	○
virtual environments	○	○	○	○	○
petri nets	○	○	○	○	○
bond graphs	○	○	○	○	○
error control mechanisms	○	○	○	○	○
probability distributions	○	○	○	○	○
variance	○	○	○	○	○
reduction	○	○	○	○	○
optimization	○	○	○	○	○
database systems	○	○	○	○	○
computer administration	○	○	○	○	○
entertainment	○	○	○	○	○

human perception	○	○	○	○	○
distributed computing	○	○	○	○	○
distributed systems	○	○	○	○	○
parallel computing	○	○	○	○	○
computer networks	○	○	○	○	○
modular program design	○	○	○	○	○
quality assurance techniques	○	○	○	○	○
testing	○	○	○	○	○
simulation life-cycle	○	○	○	○	○
computer architecture	○	○	○	○	○
operating systems	○	○	○	○	○
artificial intelligence	○	○	○	○	○
expert systems	○	○	○	○	○
fuzzy systems	○	○	○	○	○
genetic algorithms	○	○	○	○	○
neural networks	○	○	○	○	○
intelligent agents	○	○	○	○	○

assessment	○	○	○	○	○
organizational behavior	○	○	○	○	○
Boolean algebra	○	○	○	○	○
linear algebra	○	○	○	○	○
ordinary differential equations	○	○	○	○	○
partial differential equations	○	○	○	○	○
conceptual modeling formalisms	○	○	○	○	○
rule-based specification	○	○	○	○	○
finite state mechanics	○	○	○	○	○
data visualization	○	○	○	○	○
graphics	○	○	○	○	○
animation	○	○	○	○	○
virtual reality	○	○	○	○	○
standards	○	○	○	○	○
model repositories	○	○	○	○	○
synthetic environments	○	○	○	○	○
thermodynamics	○	○	○	○	○

electric circuits	○	○	○	○	○
statistics	○	○	○	○	○
metrics	○	○	○	○	○
user interface design	○	○	○	○	○
performance measures	○	○	○	○	○
stress	○	○	○	○	○
workload	○	○	○	○	○
cognition	○	○	○	○	○
adoption rate	○	○	○	○	○
queuing	○	○	○	○	○
stocks	○	○	○	○	○
flows	○	○	○	○	○
delays	○	○	○	○	○
synchronous agents	○	○	○	○	○
asynchronous agents	○	○	○	○	○
autonomous agents	○	○	○	○	○
modeling-cycle	○	○	○	○	○

decision-making	○	○	○	○	○
memory processes	○	○	○	○	○
sensory processes	○	○	○	○	○
attention	○	○	○	○	○
geographic information systems	○	○	○	○	○
K-12 education	○	○	○	○	○
adult education	○	○	○	○	○
industry-training	○	○	○	○	○
military-based training	○	○	○	○	○
user-simulator interaction	○	○	○	○	○
supply networks	○	○	○	○	○
time-series	○	○	○	○	○
proof-of-concept	○	○	○	○	○
hybrid systems	○	○	○	○	○
code of ethics	○	○	○	○	○
serious games	○	○	○	○	○
simulation-based science	○	○	○	○	○

simulation-based engineering	○	○	○	○	○
simulation-based social science	○	○	○	○	○
computational neuroscience	○	○	○	○	○
simulation-based training	○	○	○	○	○
simulation-based learning	○	○	○	○	○
materials science	○	○	○	○	○
algorithms	○	○	○	○	○
software	○	○	○	○	○
hardware	○	○	○	○	○
cyber infrastructure	○	○	○	○	○
contemporary issues	○	○	○	○	○
probability	○	○	○	○	○
scientific method	○	○	○	○	○
computer operating system	○	○	○	○	○
object-oriented systems	○	○	○	○	○
conceptualizations	○	○	○	○	○
empiricism	○	○	○	○	○

presentation methods	○	○	○	○	○
assessment heuristics	○	○	○	○	○
sensory perception	○	○	○	○	○
psycho-physiology	○	○	○	○	○
cognitive representation	○	○	○	○	○
knowledge representation	○	○	○	○	○
logic methods	○	○	○	○	○
symbolic reasoning	○	○	○	○	○
strategic communications	○	○	○	○	○
psychological operations	○	○	○	○	○
information operations	○	○	○	○	○
civil-military operations	○	○	○	○	○
unconventional warfare	○	○	○	○	○
foreign internal defense	○	○	○	○	○
intelligence activities	○	○	○	○	○
transnational criminal activities	○	○	○	○	○
illicit arms dealing	○	○	○	○	○

illegal financial transactions	○	○	○	○	○
law enforcement activities	○	○	○	○	○
performance moderator functions	○	○	○	○	○
current simulation tools	○	○	○	○	○
measures of merit	○	○	○	○	○
insurgency/counterinsurgency	○	○	○	○	○
combating terrorism	○	○	○	○	○
conflict modeling	○	○	○	○	○
pseudo-random number generation	○	○	○	○	○
random number generation	○	○	○	○	○

Display This Question:

If Q37 = Yes

Q58 What other knowledge areas are important to your job that are not listed above?

_____

_____

_____

_____

_____

Display This Question:

If Q37 = Yes

Q55 How important are the following skills to your job?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
verification	○	○	○	○	○
validation	○	○	○	○	○
accreditation	○	○	○	○	○
data support	○	○	○	○	○
data integration	○	○	○	○	○
computational languages	○	○	○	○	○
computer architectures	○	○	○	○	○
data management	○	○	○	○	○
simulation development	○	○	○	○	○
management	○	○	○	○	○
decision support	○	○	○	○	○
programming	○	○	○	○	○
step-size selection	○	○	○	○	○
requirements specification	○	○	○	○	○
software development	○	○	○	○	○
documentation	○	○	○	○	○

training analysis	○	○	○	○	○
linear programming	○	○	○	○	○
dynamic programming	○	○	○	○	○
nonlinear programming	○	○	○	○	○
sensitivity analysis	○	○	○	○	○
numerical analysis	○	○	○	○	○
maintenance	○	○	○	○	○
hypothesis testing	○	○	○	○	○
variance reduction	○	○	○	○	○
execution	○	○	○	○	○
verbal protocol analysis	○	○	○	○	○
cognitive task analysis	○	○	○	○	○
training design	○	○	○	○	○
training assessment	○	○	○	○	○
acquisition	○	○	○	○	○
prototyping	○	○	○	○	○
socioeconomic modelling	○	○	○	○	○

simulation output analysis	○	○	○	○	○
feasibility assessment	○	○	○	○	○
cost-benefit analysis	○	○	○	○	○
risk analysis	○	○	○	○	○
data collection	○	○	○	○	○
problem definition	○	○	○	○	○
critical elements identification	○	○	○	○	○
develop functional specifications	○	○	○	○	○
data reduction	○	○	○	○	○
simulation support for domain expert	○	○	○	○	○
developing scenarios	○	○	○	○	○
planning and outcome experimentation	○	○	○	○	○
behavior analysis	○	○	○	○	○
giving presentations	○	○	○	○	○

Display This Question:

If Q37 = Yes

Q59 What other skills are important to your job that are not listed above?

_____

_____

_____

_____

_____

Display This Question:

If Q37 = Yes

Q56 How important are the following abilities to your job?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
complex problem-solving	○	○	○	○	○
communication	○	○	○	○	○
file management	○	○	○	○	○
project management	○	○	○	○	○
visionary	○	○	○	○	○
open-minded	○	○	○	○	○
tolerant	○	○	○	○	○
functioning on multidisciplinary teams	○	○	○	○	○
life-long learning	○	○	○	○	○
practical experience	○	○	○	○	○
leadership	○	○	○	○	○
recognize/adapt to technology changes	○	○	○	○	○
interdisciplinarity	○	○	○	○	○
written communication	○	○	○	○	○
verbal communication	○	○	○	○	○

group interaction	○	○	○	○	○
skill acquisition	○	○	○	○	○
abstraction	○	○	○	○	○

Display This Question:

If Q37 = Yes

Q60 What other abilities are important to your job that are not listed above?

_____

_____

_____

_____

_____

Display This Question:

If Q37 = Yes

Q57 How important are the following domains/fields to your job?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Mathematics	○	○	○	○	○
Computer Science	○	○	○	○	○
Manufacturing	○	○	○	○	○
HealthCare	○	○	○	○	○
Heath Sciences	○	○	○	○	○
Medicine	○	○	○	○	○
Instructional Systems Design	○	○	○	○	○
Fluid Dynamics	○	○	○	○	○
Social Science	○	○	○	○	○
Military Science	○	○	○	○	○
Technology	○	○	○	○	○
Engineering	○	○	○	○	○
Software Engineering	○	○	○	○	○
Operations Research	○	○	○	○	○
Systems Engineering	○	○	○	○	○
Physics	○	○	○	○	○

Computational Science	○	○	○	○	○
Business Analytics	○	○	○	○	○
Decision Analysis	○	○	○	○	○
Supply Chain Management	○	○	○	○	○
Architecture	○	○	○	○	○
Information Science	○	○	○	○	○
Biomedical Engineering	○	○	○	○	○
Civil Engineering	○	○	○	○	○
Chemical Engineering	○	○	○	○	○
Mechanical Engineering	○	○	○	○	○
Game Design	○	○	○	○	○
Game Development	○	○	○	○	○
Intelligence Analysis	○	○	○	○	○
Marine Science	○	○	○	○	○
Psychology	○	○	○	○	○
Urban Studies and Planning	○	○	○	○	○
Physical Sciences	○	○	○	○	○

Human Factors	○	○	○	○	○
System Dynamics	○	○	○	○	○
Statistics	○	○	○	○	○
Industrial Engineering	○	○	○	○	○
Education/Training	○	○	○	○	○
Business	○	○	○	○	○
Natural Sciences	○	○	○	○	○
Art	○	○	○	○	○
History	○	○	○	○	○
Geography	○	○	○	○	○
Economics	○	○	○	○	○
Biology	○	○	○	○	○
Chemistry	○	○	○	○	○
Sociology	○	○	○	○	○
Project Management	○	○	○	○	○
Political Science	○	○	○	○	○
Transportation Management	○	○	○	○	○

International Studies	○	○	○	○	○
Cybernetics	○	○	○	○	○
Engineering Management	○	○	○	○	○
Epidemiology	○	○	○	○	○
Ergonomics	○	○	○	○	○
Electrical Engineering	○	○	○	○	○
Anthropology	○	○	○	○	○
Archaeology	○	○	○	○	○
Linguistics	○	○	○	○	○
Computational Social Science	○	○	○	○	○
Aerospace	○	○	○	○	○
Human-Computer Interaction	○	○	○	○	○
Human systems	○	○	○	○	○
Astrophysics	○	○	○	○	○
National Defense	○	○	○	○	○
National Security	○	○	○	○	○
Climate Change	○	○	○	○	○

Planetary Behavior	○	○	○	○	○
Human Biology	○	○	○	○	○
Military Training	○	○	○	○	○
Aviation Psychology	○	○	○	○	○

Display This Question:

If Q37 = Yes

Q61 What other domains/fields are important to your job that are not listed above?

_____

_____

_____

_____

_____

Q62 Do you program in your current job?

○ Yes

○ No

Display This Question:

If Q62 = Yes

Q63 Which programming languages do you use?

_____

_____

_____

_____

_____

Q64 Do you use simulation software in your current job?

- ○ Yes
- ○ No

Display This Question:

If Q64 = Yes

Q65 Which simulation software do you use?

_____

_____

_____

_____

_____

End of Block: M&S KSAs

Start of Block: CMSP

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q67 Please rate the importance of following topics to your job/research (1 being most important and 8 being least important).

_____ M&S concepts and context
_____ M&S applications
_____ M&S domains of use
_____ M&S modeling methods
_____ M&S simulation implementation
_____ M&S supporting tools, techniques, and resources
_____ M&S business and management
_____ M&S related communities of practice and disciplines

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q68 Please rate the importance of following topics to your job/research (1 being most important and 3 being least important).

_____ M&S fundamental terms and concepts
_____ M&S categories and paradigms
_____ M&S history

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q69 Please rate the importance of following topics to your job/research (1 being most important and 6 being least important).

_____ Training
_____ Analysis
_____ Experimentation
_____ Acquisition
_____ Engineering
_____ Test and Evaluation

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q70 Please rate the importance of following topics to your job/research (1 being most important and 12 being least important).

_____ Combat and Military
_____ Aerospace
_____ Medicine and Health Care
_____ Manufacturing and Material Handling
_____ Logistics and Supply Chain
_____ Transportation
_____ Computer and Communication Systems
_____ Environment and Ecology
_____ Business
_____ Social Science
_____ Energy
_____ Other:

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q71 Please rate the importance of following topics to your job/research (1 being most important and 10 being least important).

_____ Stochastic Modeling
_____ Physics-Based Modeling
_____ Structural Modeling
_____ Finite Element Modeling and Computational Fluid Dynamics
_____ Monte Carlo Simulation
_____ Discrete Event Simulation
_____ Continuous Simulation
_____ Human Behavior Modeling
_____ Multi-Resolution Simulation
_____ Other

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q72 Please rate the importance of following topics to your job/research (1 being most important and 11 being least important).

_____ M&S life-cycle
_____ M&S standards
_____ development process
_____ conceptual modeling
_____ specialized modeling and simulation languages
_____ verification, validation, and accreditation
_____ distributed simulation and interoperability
_____ virtual environments and virtual reality
_____ human-computer interaction and virtual environments
_____ semi-automated forces/computer generated forces
_____ stimulation

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q73 Please rate the importance of following topics to your job/research (1 being most important and 3 being least important).

_____ major simulation infrastructures
_____ M&S resource repositories
_____ M&S organizations

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q74 Please rate the importance of following topics to your job/research (1 being most important and 5 being least important).

_____ ethics and principles for M&S practitioners
_____ management of M&S projects and processes
_____ M&S workforce development
_____ M&S business practices and economics
_____ M&S industrial development

Display This Question:

If Q3 != I do not identify as an M&S Stakeholder

Q75 Please rate the importance of following topics to your job/research (1 being most important and 4 being least important).

_____ statistics and probability
_____ mathematics
_____ software engineering and development
_____ system science and engineering

End of Block: CMSP

APPENDIX C: UCF IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Determination of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Rebecca Leis** and **John Lord**

Date: **February 02, 2018**

Dear Researcher:

On 02/01/2018, the IRB reviewed the following activity as human participant research that is exempt from regulation:

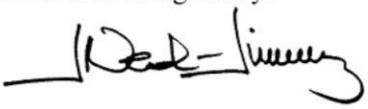
Type of Review:	Exempt Determination Category 2 – Adult Participants N=5000
Project Title:	Understanding Modeling and Simulation Graduate Education Stakeholder Perceptions
Investigator:	Rebecca Leis
IRB Number:	SBE-17-13705
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

All data must be retained and secured for a minimum of five years past the completion of this research.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

This letter is signed by:



Signature applied by Jennifer Neal-Jimenez on 02/02/2018 12:44:35 PM EST

Designated Reviewer

APPENDIX D: SURVEY INTRODUCTION LETTER

The recruitment email used, reads as follows:

Subject Line: Participants needed for research study

Hello, you have been invited to participate in a survey assessing and prioritizing the current competencies required of Modeling and Simulation (M&S) Professionals. Results from this study may show ways in which M&S education can be improved based on the needs of the industry. Volunteer participants will complete a subjective survey concerning tasks typically associated with various M&S jobs. Participant engagement is estimated to take no more than 60 minutes. To participate, please click on the URL below. If you have any questions, please email the study coordinator Rebecca Leis at rleis@ist.ucf.edu. Thank you for your time and effort!

REFERENCES

Aamodt, M. G. (2012). Industrial/Organizational Psychology; an Applied Approach (5 ed.): Nelson Edcuation.

Bair, L. J., & Jackson, J. J. (2013). M&S Professionals Domains, Skills, Knowledge, and Applications. Paper presented at the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando, FL.

Bair, L. J., & Jackson, J. J. (2015). Modeling and Simulation Professionals - Meeting the Demand. Paper presented at the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), Orlando, FL.

Birta, L. G. (2003). The Quest for the Modelling and Simulation Body of Knowledge. Paper presented at the 6th Conference on Computer Simulation and Industry Applications, Instituto Tecnologico de Tijuana, Mexico.

Congress, t. (2007). Recognizing the contribution of modeling and simulation technology to the security and prosperity of the United States, and recognizing modeling and simulation as a National Critical Technology. Retrieved from https://www.congress.gov/bill/110th-congress/house-resolution/487/text

Crosbie, R. E. (2000). Simulation Curriculum: A Model Curriculum in Modeling and Simulation: Do we need it? Can we do it? Paper presented at the Winter Simulation Conference.

Darken, R. P., & Blais, C. L. (2017). The Uniformed Military Modeling and Simulation Professional. In The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 151-166). Hoboken, NJ: John Wiley & Sons, Inc.

DeVin, L. J. (2001). Why we need to Offer a Modeling and Simulation Engineering Curriculum. Paper presented at the Winter Simulation Conference.

Diallo, S. Y., Mustafee, N., & Zacharewicz, G. (2015). Towards an Encyclopedia of Modeling and Simulation Methodology. Paper presented at the Winter Simulation Conference (WSC), Huntington Beach, CA.

Durak, U., Ören, T., & Tolk, A. (2017). An Index to the Body of Knowledge of Simulation Systems Engineering. In A. Tolk & D. H. Ölwell (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 2). Hoboken, NJ: John Wiley & Sons, Inc.

Recognizing the contribution of modeling and simulation technology to the security and prosperity of the United States, and recognizing modeling and simulation as a National Critical Technology., H.Res.487, https://www.congress.gov/bill/110th-congress/house-resolution/487/text (2007).

Garrett, R. B., Robb, J. A., Severinghaus, R. J., & Fujimoto, R. (2017). Building a National Modeling and Simulation (M&S) Coalition. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 353-371). Hoboken, NJ: John Wiley & Sons, Inc.

Goldsman, D., Nance, R. E., & Wilson, J. R. (2009). A Brief History of Simulation. Paper presented at the Winter Simulation Conference.

Greenwood, E. (2010). Attributes of a Profession. In K. W. A. (Ed.), Role of the Design Professional in Society (pp. 65-74). San Diego, CA: University 'Readers.

Herrmann, C. (2018). Analysis, Modeling and Simulation Edcuation, Training and Development Effort.

I/ITSEC Knowledge Repository. (n.d.). Retrieved from http://www.iitsecdocs.com

Kincaid, J. P., Hamilton, R., Tarr, R. W., & Sangani, H. (2003). Simulation in Education and Training. In M. S. Obaidat & G. I. Papadimitriou (Eds.), Applied System Simulation Methodologies and Applications (pp. 437-456). Boston, MA: Springer Science and Business Media.

Kölsch, M. (2011). A Snapshot of the Modeling and Simulation Community and Education. The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, 8(4), 217-224. doi:10.1177/1548512910387953

Lacy, L. W., Gross, D. C., Ören, T., & Waite, B. (2010). A Realistic Roadmap for Developing a Modeling and Simulation Body of Knowledge Index. Paper presented at the Fall Simulation Interoperabiloity Workshop, Orlando, FL.

Leathrum, J. F., & Mielke, R. R. (2012). Outcome-Based Curriculum Development for an Undergraduate M&S Program. Paper presented at the AutumnSim 2012, Conference on Education and Training Modeling and Simulation.

Leis, R. (2017) The Profession of Modeling and Simulations/Interviewer: J. Lord. Modeling and Simulations.

Lewis, F., & Rowe, P. (2010). The Certified Modeling & Simulation Professional (CMSP) Program: Why It was Created, Where it Stands Now, and What You Can Do to Support It. SCS M&S Magazine, 01, 1-5.

Little, D. (2006). History and Basics of M&S. Washington DC Retrieved from https://apps.dtic.mil/dtic/tr/fulltext/u2/a470681.pdf

Loper, M. L., & Turnitsa, C. D. (2017). Academic Education Supporting the Professional Landscape. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 87-108). Hoboken, NJ: John Wiley & Sons, Inc.

Medical and Healthcare Simulation (MSMS) Program. (n.d.). Retrieved from https://drexel.edu/medicine/academics/graduate-school/medical-and-healthcare-simulation/

Modeling and Simulation MS. (n.d). Retrieved from http://ucf.catalog.acalog.com/preview_program.php?catoid=4&poid=1387

Modeling, Simulation, and Visualization Engineering. (n.d., 8 October 2018). Retrieved from https://www.odu.edu/msve

Modeling, Virtual Environments and Simulation Institute. (n.d.). Retrieved from https://my.nps.edu/web/moves/home

Nolan, J. M., Balogh, I., McDowell, P., Telford, B., Degnan, E., & Oswalt, I. (2017). Developing U.S. Service M&S Professionals: Inter-Service Differences in the Education, Training, and Management of Uniform and Government M&S Personnel. Paper presented at the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando, FL.

Office, M. a. S. C. (2008). Department of Defense Modeling and Simulation Body of Knowledge (BoK).

Oliver, G. (2012). Foundations of the Assumed Business Operations and Strategy Body of Knowledge (BOSBOK): An Outline of Shareable Knowledge: Darlington Press.

Olwell, D. H., Johnson, J. M., & Didoszak, J. M. (2007). Application of Systems Engineering Principles in the Design of Acquisition Workforce Curricula. Paper presented at the Systems Engineering Conference.

Ören, T. (2005a). Ethics in Modeling and Simulation (SimEthics). Paper presented at the Interservice/Industry Training, Simulation, and Education (I/ITSEC), Orlando, FL.

Ören, T. (2005b). Maturing Phase of the Modeling and Simulation Discipline.

Ören, T. (2005c). Toward the Body of Knowledge of Modeling and Simulation. Paper presented at the Interservice/Industry Training, Simulation, and Education Confrence (I/ITSEC), Orlando, FL.

Ören, T. (2011a). A Basis for a Modeling and Simulation Body of Knowledge Index: Professionalism, Stakeholders, Big Picture, and Other BoKs. SCS M&S Magazine, 2(1), 40-48.

Ören, T. (2011b). The Many Facets of Simulation through a Collection of about 100 Definitions. SCS M&S Magazine, 2(2), 82-92.

Ören, T. (2012). The Richness of Modeling and Simulation and its Body of Knowledge. Paper presented at the SIMULTECH, Rome, Italy.

Ören, T. (2014). The Richness of Modeling and Simulation and an Index

of Its Body of Knowledge. In Simulation and Modeling Methodologies, Technologies and Applications (pp. 3-24). Switzerland: Springer International Publishing.

Ören, T. (2018). Modeling and Simulation Body of Knowledge (MSBOK). Retrieved from http://www.site.uottawa.ca/~oren/MSBOK/MSBOK-index.pdf

Ören, T., Mittal, S., & Durak, U. (2017). The Evolution of Simulation and Its Contribution to Many Disciplines. In S. Mittal, U. Durak, & T. Ören (Eds.), Guide to Simulation Based Disciplines - Advancing Our Computational Future (pp. 3-24). Cham, Switzerland: Springer International Publishing.

Ören, T., & Waite, B. (2007). Need for and Structure of an M&S Body of Knowledge. Paper presented at the Interservice/Industry Training, Simulation Conference (I/ITSEC), Orlando, FL.

Ören, T., & Waite, B. (2010). Modeling and Simulation Body of Knowledge Index: An Invitation for the Final Phases of its Preparation. SCS M&S Magazine, 1(4).

The Organization for Developing and Providing Professional Certification. (n.d.). Retrieved from http://www.simprofessional.org/index.html

Padilla, J. J., Diallo, S. Y., Lynch, C. J., & Gore, R. J. (2018). Observations on the Practice and Profession of Modeling and Simulation: a Survey Approach. Simulation: Transactions of the Society for Modeling and Simulation International, 94(4), 493-506. doi:10.1177/0037549717737159

Padilla, J. J., Diallo, S. Y., & Tolk, A. (2011). Do We Need M&S Science? SCS M&S Magazine(n4), 161-166.

Paulo, E. P., & Few, S. (2009). Leveraging the DoD M&S Education Project for Specialized Army M&S Education. Paper presented at the Winter Simulation Conference.

Petty, M. D., Reed, G. S., & Tucker, W. V. (2012). Topics, Structure, and Delivery of the New Certified Modeling and Simulation Professional Examination. Paper presented at the Spring 2012 Simulation Interoperability Workshop, Orlando, FL.

Petty, M. D., Reed, G. S., & Tucker, W. V. (2017). The Certified Modeling and Simulation Professional Certification and Examination. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 109-128). Hoboken, NJ: John Wiley & Sons, Inc.

Professions, A. C. o. (2018). What is a Profession? Retrieved from http://www.professions.com.au/about-us/what-is-a-professional

Rogers, R. V. (1997). What Makes a Modeling and Simulation Professional? The Consensus View from One Workshop. Paper presented at the Winter Simulation Conference (WSC), Atlanta, GA.

Salas, E., Prince, C., Bowers, C. A., Stout, R. J., Oser, R. L., & Cannon-Bowers, J. A. (1999). A Methodology for Enhancing Crew Resource Management Training. Human Factors, 41(1), 161-172.

Sarjoughian, H. S., & Zeigler, B. P. (2001). Towards Making Modeling & Simulation into a Discipline. Paper presented at the Winter Simulation Conference.

The Society for Modeling and Simulation International (SCS). (2018). Retrieved from http://scs.org

Sokolowski, J. A., & Mielke, R. R. (2017). M&S as a Profession and an Academic Discipline: A Contemporary View. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 55-86). Hoboken, NJ: John Wiley & Sons, Inc.

Swenson, S., Gravitz, R. M., & Lightner, G. M. (2017). Modeling and Simulation for the Enterprise: Integrating Application Domains for the M&S Professional. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 183-207). Hoboken, NJ: John Wiley & Sons, Inc.

Szczerbicka, H., Banks, J., Ören, T., Rogers, R. V., Sarjoughian, H. S., & Zeigler, B. P. (2000). Conceptions of Curriculum for Simulation Education (Panel). Paper presented at the Winter Simulation Conference (WSC), Orlando, FL.

Tolk, A. (2010). M&S Body of Knowledge: Progress Report and Look Ahead. SCS M&S Magazine, 1(4).

Tolk, A. (2017). An Introduction to the Facets of the Profession of Modeling and Simulation. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 3-9). Hoboken, NJ: John Wiley & Sons, Inc.

Tolk, A., Balci, O., Combs, C. D., Fujimoto, R., Macal, C. M., Nelson, B. L., & Zimmerman, P. (2015). Do We Need a National Research Agenda for Modeling and Simulation? Paper presented at the Winter Simulation Conference.

Wiegand, P. R. (2019) UCF's School of Modeling, Simulation, and Training/Interviewer: J. Lord. School of Modeling, Simulation and Training.

Wu, W., Mayo, G., McCuen, T. L., Issa, R. R. A., & Smith, D. K. (2018). Building Information Modeling Body of Knowledge. I: Background, Framework, and Initial Development.

Journal of Construction Engineering and Management, 144(8), 1-9. doi:10.1061/(ASCE)CO.1943-7862.0001518

Yilmaz, L. (2017). A Complexity and Creative Innovation Dynamics Perspective to Sustaining the Growth and Vitality of the M&S Profession. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 211-222). Hoboken, NJ: John Wiley & Sons, Inc.

Yilmaz, L., Davis, P., Hu, X., Ören, T., Sarjoughian, H. S., Fishwick, P. A., . . . Tolk, A. (2008). Panel Discussion: What Makes a Good Research in Modeling and Simulation: Sustaining the Growth and Vitality of the M&S. Discipline. Paper presented at the Winter. Simulation Conference.

Zhang, L., Wu, Y., & Yang, G. (2017). M&S as a Profession and Discipline in China. In A. Tolk & T. Ören (Eds.), The Profession of Modeling and Simulation: Discipline, Ethics, Edcuation, Vocation, Societies, and Economics (pp. 167-181). Hoboken, NJ: John Wiley & Sons, Inc.