

# A Snapshot of the Modeling and Simulation Community and Education

Mathias Kölsch

The MOVES Institute, Naval Postgraduate School, Monterey, CA

## Abstract

The Department of Defense's need for modeling and simulation (M&S) tools and professionals is growing at a rapid pace. From research to development, from training to acquisition, from requirements analysis to testing; M&S has become invaluable to achieve the best performance, lowest cost and risk, best-trained and best-prepared, adaptive and effective modern services. The demands on M&S professionals are constantly changing, adapting to different foci in application areas, shifting with increasing civilian workforce expertise and availability, and reallocating with budget priorities. Hence, instrumental to relevant education and training is adaptation to the current situation and setting sustainable long-term directions. We took a snapshot of the US Army M&S community and their education via a survey of senior personnel, querying the importance of M&S-related skills and the perceived proficiency of entry- and senior level professionals. The goal was to obtain validation for education and training programs, and to determine areas for improvement.

The most important skills were found to be communications, fundamental concepts of M&S, distributed simulations, training systems, computer networks, program management, and VV&A (Verification, Validation and Accreditation). M&S education seems to be on the right track since the greatest expertise was observed in the areas of greatest importance (highly correlated, Pearson 0.74). Disconcertingly, however, we also found *greater lack* in more important than in less important skills, particularly for entry-level professionals.

We propose a three-pronged approach for shaping the future of training and education in M&S that addresses the observed shortfalls: 1) proper focus of the technical education, combined with 2) stronger emphasis on communication (e.g., through completion of a technical thesis including oral defense), better system overview (e.g., training systems, the greater processes of program management, and VV&A), and stronger emphasis on the distributed and networked environment we live in. Finally, 3) conduct concerted, interdisciplinary research and education efforts in human, social, cultural and behavioral (HSCB) M&S.

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| 14. ABSTRACT<br><p><b>The Department of Defense's need for modeling and simulation (M&amp;S) tools and professionals is growing at a rapid pace. From research to development from training to acquisition, from requirements analysis to testing; M&amp;S has become invaluable to achieve the best performance, lowest cost and risk, besttrained and best-prepared, adaptive and effective modern services. The demands on M&amp;S professionals are constantly changing, adapting to different foci in application areas, shifting with increasing civilian workforce expertise and availability, and reallocating with budget priorities. Hence, instrumental to relevant education and training is adaptation to the current situation and setting sustainable long-term directions. We took a snapshot of the US Army M&amp;S community and their education via a survey of senior personnel, querying the importance of M&amp;S-related skills and the perceived proficiency of entry- and senior level professionals. The goal was to obtain validation for education and training programs, and to determine areas for improvement. The most important skills were found to be communications, fundamental concepts of M&amp;S, distributed simulations, training systems, computer networks program management, and VV&amp;A (Verification, Validation and Accreditation). M&amp;S education seems to be on the right track since the greatest expertise was observed in the areas of greatest importance (highly correlated, Pearson 0.74). Disconcertingly, however, we also found greater lack in more important than in less important skills, particularly for entry-level professionals. We propose a three-pronged approach for shaping the future of training and education in M&amp;S that addresses the observed shortfalls: 1) proper focus of the technical education, combined with 2) stronger emphasis on communication (e.g., through completion of a technical thesis including oral defense), better system overview (e.g., training systems, the greater processes of program management and VV&amp;A), and stronger emphasis on the distributed and networked environment we live in. Finally, 3) conduct concerted, interdisciplinary research and education efforts in human, social, cultural and behavioral (HSCB) M&amp;S.</b></p> |                      |                                                     |

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# 1 Introduction

Modeling and simulation (M&S) skills and tools and professionals in their mastery are in growing demand in many industry sectors and the military. According to Department of Defense (DoD) estimates, the M&S workforce is currently at least 10,000 people strong [3]. M&S has shown tremendous value for research and development, it has been applied to improve human training and the acquisition process, requirements analysis and product testing, to name just a few. The DoD calls for an educated and informed workforce and invests \$2.2 billion annually in joint M&S activities [2]. M&S is, in fact, necessary to achieve the best performance, lowest cost, fastest deployment, best training and best-prepared, adaptive and effective modern military force.

Together with M&S application areas, the desired skills for M&S professionals are constantly changing. Hence, instrumental to relevant education and training in M&S are setting sustainable long-term directions and fine-grained adaptation to the current situation. This article reports on a survey of senior M&S personnel, both from the civilian (CP36) and military (FA57) sector that was conducted at a two-week seminar in April 2009. The survey provides a snapshot of the state of the M&S community in the US Army and the education. This is complementary to related efforts that aim to better define the discipline of M&S and it supports efforts to create well-formed curricula in academia and for training DoD personnel.

The article continues with a discussion of other work in modeling and simulation in general and in the US Army. We will then present the survey along with demographic information about the participants, followed by the result presentation and concluding with a discussion of their meaning.

## 1.1 What is Modeling & Simulation?

Modeling and simulation is a discipline that uses models – including emulators, prototypes, simulators, and stimulators – either statically or over time, to develop the data needed for making managerial or technical decisions. Such data and phenomena are often visualized in virtual and augmented environments, facilitating efficient data manipulation and the users’ perceptual immersion, all essential for effective analysis, training and operation. The taxonomic terms “Live, Virtual, and Constructive” are often used to classify M&S types: live refers to real people using real systems in a simulated mission, virtual refers to a simulated system, and constructive simulations involve simulated people. The M&S community has been actively constructing a “body of knowledge” (BoK) [3, 8], demonstrating the maturity of the discipline and furthering the standards of M&S education. The survey described here does not attempt to define a BoK, but instead to take a momentary snapshot and to discover training and education shortfalls. The pillars of M&S are commonly seen as: history and fundamentals of M&S, applied mathematics, computer systems, virtual environments, training and human systems, M&S systems life cycle management, and modeling. As of the last decade, simulation with graphical means, par-

ticularly immersing trainees in simulated worlds and scenarios, has become an integral part of M&S. A relatively new development is the desire to blend live, virtual and constructive simulations seamlessly and to immerse trainees in the half-real and half-realistic experience of augmented reality.

The Huntsville Simulation Snapshot [7] is a closely related attempt to discover the skills and needs that make a simulationist. Madewell and Swain focused on the mostly civilian and contractor need for simulationist in analyzing job ads. Our survey was specific to US Army needs and experiences.

## 1.2 US Army Modeling & Simulation and the Advanced Simulation Course

The US Army is grouped into branches, each fulfilling a major requirement. Additionally, officers may belong to a career field, or *functional area* (FA), which requires special skills and/or training. FA-57 officers are the simulation operations specialists, experts in modeling and simulation and in facilitating “the training and operational environment for commanders to conduct first class mission planning and mission rehearsal exercises.”[1] Army M&S is often grouped into three domains: Training, Exercises, and Military Operations (TEMO), Research, Development, and Acquisition (RDA) and Advanced Concepts and Requirements (ACR).

To join this career field, officers undergo a sequence of training programs, starting with a six-week Simulation Operations course. The Civilian Program (CP) 36 education is the equivalent for DoD civilians in this functional area. Once qualified, there is currently no standard, mandatory continued education for FA-57/CP 36 professionals. The two-week Advanced Simulation Course for Army M&S senior leaders, offered annually at the Naval Postgraduate School (NPS) since 2009, fills this need and provides continued education to these officers and civilians. It “covers the significant M&S issues and M&S activities throughout the Acquisition Life Cycle” [9]. It also brought 20 long-time practitioners and experts of M&S into the same room – a unique opportunity to learn more about the current state of the community, experiences and education.

## 1.3 Graduate-Level M&S Education

It is important to mention graduate education when discussing a discipline. Graduate-level education is necessary to drive the discipline forward, to provide the breadth and depth that go beyond what a six-week course can convey. Sarjoughian et al. [11] suggest that graduate education gives “in-depth technical knowledge to develop large, complex systems” and teaches “proven and new theories, approaches, and tools” - a necessity for continued progress that cannot be conveyed in short, non-technical courses. A 1996 panel on graduate education in M&S [10] can be considered the cradle for many M&S programs across the country. The panel members clearly saw the need for higher education in M&S that would pull other education and training efforts along. Desel [6] presents ideas for M&S curricula and for offering M&S aspects to non-majors. However,

Szczerbicka et al. [12] point out a few years later that the discipline is difficult to define - both a blessing and a curse. It is often the knowledge of tangential areas, some “soft” skills, and technical depth that are required to make a quality M&S professional and to creatively progress. However, the field’s flux requires frequent reassessments of direction and education. Four graduate programs currently offer Masters of Science degrees in M&S: the Old Dominion University (Norfolk, West Virginia), the University of Central Florida (Orlando, Florida), the California State University, Chico (suspended as of 2008), and the MOVES Institute at the Naval Postgraduate School (Monterey, California). Arizona State University and the Arizona Center for Integrative M&S offer a Master of Engineering in M&S. The Department of the Army created a detailed report of these programs [5] as well as a comprehensive survey of individual courses available at civilian and military US institutions [4].

## 2 Survey

The survey in form a questionnaire was designed to determine the importance and the observed proficiency of a variety of skills pertaining to M&S. The participants were first asked a few questions about their education and their current jobs. We then asked what the future role of the FA-57 officer should predominantly be, with respect to the three M&S domains:

- Training, Exercises, and Military Operations (TEMO),
- Research, Development, and Acquisition (RDA), and
- Advanced Concepts and Requirements (ACR).

The main part of the survey consisted of four repetitions of the same list of skills and areas that had to be rated on a five-point Likert scale. Two repetitions inquired about the *desired* level of skills, and the other two about the level of skills that the respondents are *observing* in M&S professionals they are working with or have worked with. The other independent variable was the seniority of the M&S professionals: respondents rated every skill once for entry-level and once for senior M&S professionals. For senior professionals, we expected higher observed skill levels and a shift in desired skills applicable to more managerial tasks.

Based on pilot study feedback, we gave participants the option to consider (desired as well as observed) skill levels with respect to only one of the three domains, TEMO, RDA or ACR, as this might allow them to give more precise answers. Table 1 lists the individual skills that the study participants had to rate, grouped by topic if possible. Note that the skills were not grouped in the actual survey, rather, the skills were presented as a flat list in no particular order.

The goal was to obtain validation for the current education and training programs, and to determine areas for improvement. One hypothesis was that the study participants (US Army) had more need for project management skills

Table 1: Skills queried in the user questionnaire. DoD=Department of Defense, HLA=High Level Architecture, DIS=Distributed Interactive Simulation, VV&A=Verification, Validation and Accreditation

|                          |                                                                                                                                                            |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| General topics           | Fundamental concepts of M&S<br>History of M&S, DoD M&S<br>Oral & written communications<br>Training systems<br>M&S for acquisition<br>Combat modeling      |
| Management               | Project management and leadership<br>Requirements analysis<br>Program management and policy<br>VV&A                                                        |
| Systems Engineering      | System modeling<br>Systems engineering management                                                                                                          |
| Simulation theory        | Continuous simulation<br>Discrete event simulation<br>Multi-resolution models and simulation<br>Distributed simulations (incl. HLA, DIS)                   |
| Human modeling           | Social and cultural modeling<br>Human behavior modeling<br>Human factors<br>Human performance evaluation<br>Human systems engineering                      |
| Games, graphics, physics | Game-based systems<br>Data visualization<br>Computer graphics<br>Virtual and augmented reality<br>Environmental models, GIS<br>Modeling physical phenomena |
| Computing foundations    | Databases<br>Operating systems<br>Software development<br>Data structures, algorithms<br>Programming (C++, Java)<br>Computer networks (excl. HLA and DIS)  |
| Experiments              | Stochastic modeling<br>Statistics<br>Data analysis<br>Experimental design                                                                                  |
| Mathematical foundations | Discrete mathematics<br>Linear algebra<br>Classification, machine learning                                                                                 |

rather than technical or application skills as industry [7]. We expected computing and math foundations to still be important but less so than “softer” skills. We expected entry-level professionals to lack experience and on-the-job training, but it was not clear in what particular skill sets. Strong discrepancies between desired and observed skill levels call for action to improve training and education.

### 3 Results

We received 20 responses to a first round of our questionnaire, and 14 to an improved repetition a few days later. The results are consistent where applicable but were not pooled. The following results are reported on the improved iteration unless otherwise noted.

#### 3.1 The Respondents

All respondents currently held a job as M&S professional either in or with affiliation to the US Army. They had received an average of 16.5 months of M&S training and education during their careers. 55% had received the FA-57 training (Simulation Operations Course, SOC), 10% the civilian CP-36 training, and 35% held a Masters of Science degree. The participants had, on average, 10.1 years of experience working in M&S and can undoubtedly be considered subject matter experts.

73% considered themselves part of the Training, Exercises, and Military Operations (TEMO) domain, 26% part of the Research, Development, and Acquisition (RDA) domain and 6.7% part of Advanced Concepts and Requirements (ACR). This was in contrast to the domain in which the respondents see the role of the future FA-57: TEMO 58.57%, ACR 19.64%, RDA 21.79%. Only one answer was possible for these questions. 15% considered themselves developers, 20% analysts, 70% managers, 10% “users” and 20% as working in training (multiple responses were possible).

#### 3.2 The Skills

All results were on a five-point Likert scale for desired and observed skills, respectively, as follows.

| <i>score</i> | <i>importance</i> | <i>observation</i>   |
|--------------|-------------------|----------------------|
| 1            | no need to know   | complete lack        |
| 2            | not important     | not sufficient       |
| 3            | good to know      | sufficient knowledge |
| 4            | important         | proficient           |
| 5            | very important    | highly proficient    |

The skills and knowledge areas that the respondents considered the most **important** overall were communication skills (4.80), fundamental concepts of M&S (4.73), distributed simulations (4.53), training systems (4.43), computer



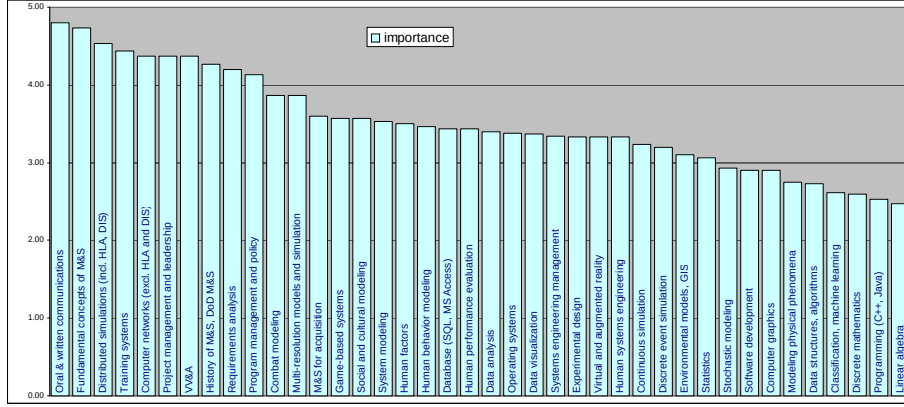


Figure 1: The importance of skills, 5=very important.

networks, program management, and VV&A (each 4.37). At the bottom end of the scale were linear algebra (2.47), programming (2.53), discrete math (2.6) and data structures (2.73). See Fig. 1 for these results.

Participants were given the option to consider skill levels specific to one domain. Most respondents chose to rate skills for the TEMO domain, four for the RDA domain, and none considered M&S from the ACR domain. Significant differences between TEMO and RDA were found for M&S for acquisition (0.78 points greater than average,  $p < 0.0084$ ) and systems engineering management (0.79 points greater than average,  $p < 0.0124$ ), which were regarded more important for RDA (see Fig. 2). As only four responses were RDA-specific, these comparisons need to be seen as trends.

Analyzing skill importance for entry-level versus senior M&S professionals revealed two areas of significant difference (with respect to the overall average): project management and leadership (entry-level: -0.37 with  $p < 0.0465$ , versus senior: +0.36 with  $p < 0.0084$ ) and program management and policy (-0.46 with  $p < 0.0134$ , versus +0.47 with  $p < 0.0021$ ), both being less important for entry-level, and more important for senior-level professionals (see Fig. 2).

Next, we asked for the perception of actual, **observed** skill levels in M&S professionals (see Fig. 3). Overall, an average skill level of 3.47 was desired (based on “importance”, see above), but 2.73 was observed. Senior-level profes-

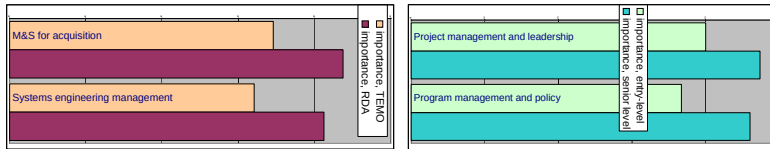


Figure 2: The importance of skills: significant differences between TEMO and RDA (left), and entry-level vs. senior-level professionals (right).

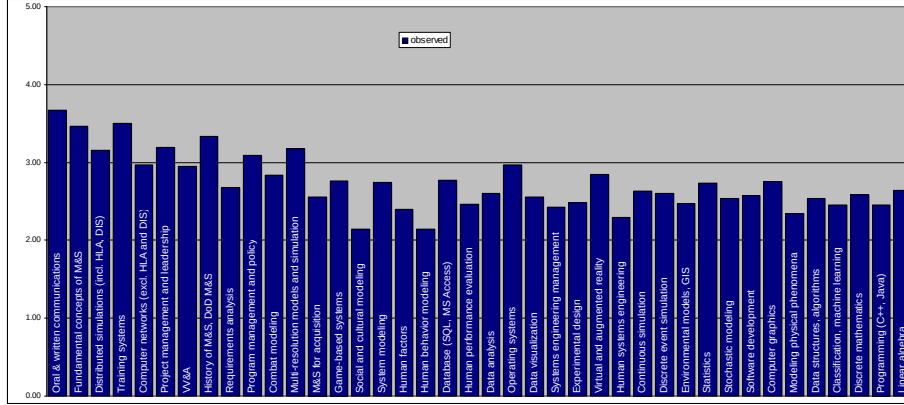


Figure 3: Observed skill levels.

sionals were considered to have a higher (2.93) degree of skills than entry-level (2.52). The subset of the RDA community observes balanced skill levels, 3.00 vs. 3.05 for entry- and senior level professionals. In general, importance and seen levels are closely correlated with a Pearson product-moment correlation coefficient of 0.74. Within the TEMO community, there is an even stronger correlation of 0.78. The four respondents from the RDA community reported a weaker correlation between importance and observation (Pearson 0.29); however, this is due to greater-than-necessary skills for less important areas, rather than a greater lack of more important skills (compared to TEMO).

The greatest skill levels are observed in the areas of greatest importance (communications, fundamentals). However, professionals seem to **lack** more important skills *more* than less important skills, as evidenced by a strong positive Pearson product-moment correlation of 0.85 between the importance of skills and the lack thereof. The average “discrepancy” is 0.74 points. Areas of greatest discrepancy are shown in Table 2, starting with requirements analysis (1.52 points discrepancy), social and cultural modeling (1.42), VV&A (1.41), and computer networks and distributed simulations (1.39). For entry-level professionals, the discrepancy is even more pronounced at an average of 0.92 points versus 0.56 points for senior-level professionals. Their skill level lacks particularly strongly in computer networks and distributed simulations (1.88) and fundamental concepts of M&S (1.80).

When we grouped several categories as in Table 1, we found a high correlation between the answers for the category’s individual skills, reported here as the average of category importance and observation, with their respective standard deviations: human aspects (importance:  $3.46 \pm 0.09$ , observation:  $2.29 \pm 0.14$ ), math (i:  $2.58 \pm 0.14$ , o:  $2.50 \pm 0.12$ ), experiments (i:  $3.18 \pm 0.22$ , o:  $2.59 \pm 0.11$ ), and management (i:  $4.27 \pm 0.12$ , o:  $2.98 \pm 0.22$ ).

Skills for graphics were surprisingly diverse (i:  $3.17 \pm 0.31$ , o:  $2.62 \pm 0.20$ ). Computer networks and databases were regarded more important than basic

Table 2: Skill Discrepancy: a larger number indicates less-than-desired expertise.

| <i>skill area</i>                 | <i>discrepancy</i> |                    |                     |
|-----------------------------------|--------------------|--------------------|---------------------|
|                                   | <i>average</i>     | <i>entry-level</i> | <i>senior level</i> |
| requirements analysis             | 1.52               | 1.64               | 1.4                 |
| social and cultural modeling      | 1.42               | 1.26               | 1.59                |
| VV&A                              | 1.41               | 1.70               | 1.13                |
| computer networks, distrib. sims. | 1.39               | 1.88               | 0.90                |
| human behavior modeling           | 1.32               | 1.32               | 1.32                |
| fundamental concepts of M&S       | 1.27               | 1.80               | 0.73                |
| proj. management and leadership   | 1.17               | 1.14               | 1.2                 |
| communications                    | 1.13               | 1.33               | 0.93                |
| human factors                     | 1.11               | 1.19               | 1.03                |
| M&S for acquisition               | 1.05               | 1.09               | 1.00                |
| program management and policy     | 1.05               | 1.02               | 1.07                |
| human systems engineering         | 1.04               | 1.03               | 1.04                |
| combat modeling                   | 1.03               | 1.27               | 0.8                 |
| human performance evaluation      | 0.97               | 1.12               | 0.82                |
| <i>average (all areas)</i>        | <i>0.74</i>        | <i>0.92</i>        | <i>0.56</i>         |

computer skills such as programming, data structures, algorithms or software development.

## 4 Discussion

The overall most important skills for M&S professionals in the US Army were found to be communications, fundamental concepts of M&S, distributed simulations, training systems, computer networks, program management, and VV&A. Unsurprisingly, almost all skills received a “good to know” rating or above since the questionnaire only considered a pre-selected list of likely M&S-relevant skills. Reassuringly, the greatest expertise was observed exactly in these areas and the high correlation between skill importance and observation (Pearson 0.74) is encouraging as suggests good education in the right areas. Disconcertingly, however, there is also a strong correlation between the importance of skills and the lack thereof, that is, professionals seem to lack more important skills *more* than less important skills. This lack is particularly pronounced for entry-level professionals with respect to a rather diverse set of skills (for example, computer networks and VV&A). This was expected as senior professionals generally have greater skill levels, not merely due to better education but through training on the job and, realistically, also through natural selection.

Lessons for training and education in M&S need to be drawn from the observed shortfalls. Not every discrepancy can be addressed with the same kind of remedy: some can be taught better in the classroom, others better on the job,

and still others require adoption of thought practices that can only be acquired through long education. We propose a three-pronged solution to adequately address the diverse nature of the shortfalls.

1. The educational focus needs to adjust consistently where classroom solutions are immediately available, such as teaching more requirements analysis methods, computer networks and distributed simulations. Programs need to be flexible and fine-tune their curricula to every student's requirements. Yet merely teaching these technical aspects is insufficient.
2. Solid communication skills and a birds-eye view of processes have to be conveyed. Written and oral technical communication skills are essential for practitioners, particularly at the senior level. This can only be adequately taught once the technical aspects have been grasped in detail, and only through repeated practice and feedback. A written and orally defended Master's Thesis addresses this need well and teaches methodical thinking. Scaled-down versions should be employed where less time is available. Hand in hand with these skills goes understanding of the "big picture" of, for example, embedding of training simulations and other systems into the greater processes of program management and VV&A.
3. The lack in expertise in modeling human, social, cultural and behavioral (HSCB) modeling is largely due to the novelty of the field, particularly with respect to its application to conflict resolution. This can only be addressed through interdisciplinary collaboration and result dissemination, through bright individuals that can apply M&S principles to HSCB aspects, and, most importantly, through concerted and dedicated research efforts that help establish an accepted knowledge base in HSCB M&S.

The results of this survey provide insight into the US Army Modeling and Simulation community and their education and training. This information is crucial to shaping programs to educate the best-prepared and most effective M&S experts.

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## Author Biography

Mathias Kölsch is an Assistant Professor of Computer Science at the Naval Postgraduate School, Monterey, CA. In his role as Chair of the Academic Committee he shapes the Modeling, Virtual Environments and Simulation (MOVES) curriculum at the MOVES Institute to match the needs for modeling and simulation experts for the US Navy, Marine Corps, Army and Air Force. The MOVES Institute delivers world-class M&S education at the graduate level, through certificates and senior-level courses. Mathias holds a Ph.D. from UC Santa Barbara and conducts research in computer vision, augmented reality, and gesture recognition.