Proceedings of the 2011 Winter Simulation Conference
S. Jain, R.R. Creasey, J. Himmelspach, K.P. White, and M. Fu, eds.

EDUCATING THE WORKFORCE: M&S PROFESSIONAL EDUCATION

Margaret L. Loper

Georgia Tech Research Institute
250 14th Street, N.W.
Atlanta, GA 30332, USA

John W. Diem

Defense M&S Coordination Office
1901 N. Beauregard Street, Suite 500
Alexandria, VA 22311, USA

Amy Henninger

Center for Army Analysis
6001 Goethals Road
Fort Belvoir, VA 22060, USA

Mikel D. Petty

University of Alabama in Huntsville
301 Sparkman Drive, Shelby Center 144
Huntsville, AL 35899, USA

Andreas Tolk

Engineering Management & Systems Engineering
Old Dominion University, 241 Kaufman Hall
Norfolk, VA 23529, USA

ABSTRACT

As Modeling & Simulation (M&S) becomes increasingly important, there is a significant and growing need to educate and train M&S practitioners and researchers. The Department of Defense (DoD) has a growing need for an educated M&S workforce. This need includes users, developers, managers and executive-level personnel, which can effectively apply M&S to DoD requirements. While several universities offer academic M&S degree programs, the time and expense of earning these degrees often limit the number of people that go through these programs. Professional education is an alternative for gaining M&S skills and knowledge, and courses are offered by a range of university and commercial groups. The observations in this paper begin to outline both the need and available options for M&S professional education. This collection of position papers begins a conversation on the DoD's need for professional M&S education and how the M&S Body of Knowledge might fit within that strategy. These position papers are contributed in preparation of a panel discussion and edited for the supporting proceedings.

1 M&S EDUCATION: AN OVERVIEW

As Modeling & Simulation (M&S) becomes increasingly important, there is a significant and growing need to educate, train, and certify M&S practitioners, researchers, and faculty. Efforts to meet that need have taken a number of forms: academic degree programs, non-degree professional education, and professional certifications. In this context, academic degree refers to a bachelors, masters or Ph.D. programs, non-degree professional education refers to skills and knowledge attained for career advancement through facilitated learning, and professional certification refers to a designation earned to assure qualification to perform a job or task.

Only a few universities offer M&S as an academic discipline with a degree program. Graduate-level programs are currently offered by the University of Central Florida, Old Dominion University (ODU), the

University of Alabama in Huntsville (UAH), and the Naval Postgraduate School (NPS). These programs follow a traditional academic approach where students enroll in a graduate program and take a series of courses that lead to a degree. It is common for the curriculum to be based on the theory and science of the underlying subject area, and for the degree to culminate with a formal project, thesis or dissertation.

An alternate form of M&S training is professional (or continuing) education. These courses differ from academic degrees in that they focus on applied learning rather than theory. They may also focus on a more narrow area study. Professional education courses are taught by universities and industry, and come with differing levels of accreditation. In this context, accreditation refers to the standards against which the student's course performance was assessed, which is often measured by continuing education units (CEUs). There are more choices in this space than for academic M&S degrees. In addition to ODU, UAH and NPS, courses are offered by the Georgia Tech Research Institute, George Mason University, and the Army Simulation and Modeling School, to name just a few. These professional education programs serve an important role in M&S education. Many practitioners and researchers do not have the time nor desire to pursue a traditional academic degree program, however they need to learn new skills and knowledge to be effective in their jobs.

The Department of Defense (DoD) has a growing need for an educated M&S workforce. This need includes users, developers, managers and executive-level personnel, which can effectively apply M&S to DoD requirements. To support the range of professionals that need M&S education, the DoD published the M&S Workforce Body of Knowledge (BoK) (Department of Defense 2008). The development of the BoK was funded by the Modeling and Simulation Coordination Office (M&S CO). The BoK provides standardized language and associated knowledge base for users, developers, managers and executive-level personnel to effectively apply M&S to DoD requirements. The BoK is considered a starting point for defining the core knowledge and skills that a member of the DoD M&S workforce performs.

The M&S BoK serves as a foundation for defining the core knowledge needed by the M&S workforce. However, most M&S courses (academic and professional) were created prior to the development of the BoK. This raises interesting questions about how it might be used in education. Since academic courses are governed by institutional procedures, the BoK might be used for reference but could not be required. However, the DoD could require professional education courses be assessed against the BoK to ensure a common level of education across the different options available to students. Is that a good idea? The DoD has some M&S programs it offers through the Defense Acquisition University (DAU) and through the U.S. Army FA57 and CP36 programs. Do these programs intend to use the BoK as a foundation for M&S knowledge? Do these programs provide adequate coverage for M&S professional education or do university-based and commercial M&S courses need to grow to support the expanding workforce?

This paper is the beginning of a case study to understand the DoD's need for professional M&S education and how the BoK fits within that strategy. The paper contains some description of the DoD's needs and current programs, and also includes a look at how three universities are addressing the need. This paper is not a comprehensive look at M&S professional education, rather observations by the following individuals:

- Diem discusses workforce development from the perspective of DoD M&S Enterprise.
- Henninger briefly describes the U.S. Army's M&S career titles to develop and train its workforce.
- Loper reports on the computational modeling degree program and the M&S professional education certificate offered at GT.
- Petty provides a case studying comparing content, delivery and purpose of the academic and professional educational programs at UAH.
- Tolk raises the issue of where the BoK falls short in education programs and need for M&S science.

2 MODELING & SIMULATION COORDINATION OFFICE WORKFORCE DEVELOPMENT (DIEM)

In its recent strategic planning session (May 2011), the DoD M&S Steering Committee (M&S SC) re-affirmed the vision and supporting goals originally established for the DoD M&S Enterprise in 2007:

> *M&S Vision:* Empower DoD with M&S capabilities that effectively and efficiently support the full spectrum of the Department's activities and operations. End State: A robust M&S capability enables the Department to more effectively meet its operational and support objectives across the diverse activities of the services, combatant commands, and agencies. A defense-wide M&S management process encourages collaboration and facilitates the sharing of data across DoD components, while promoting interactions between DoD and other government agencies, international partners, industry, and academia.
>
> *M&S Goals:*
>
> 1. Standards, architectures, networks and environments that:
>   - Promote the sharing of tools, data, and information across the enterprise
>   - Foster common formats
>   - Are readily accessible and can be reliably applied by users
> 2. Policies at the enterprise level that:
>   - Promote interoperability and the use of common M&S capabilities
>   - Minimize duplication and encourage reuse of M&S capabilities
>   - Encourage research and development to respond to emerging challenges
>   - Limit the use of models and data encumbered by proprietary restrictions
>   - Leverage M&S capabilities across DoD, other government agencies, international partners, industry, and academia
> 3. Management processes for models, simulations, and data that:
>   - Enable M&S users and developers to easily discover and share M&S capabilities and provide incentives for their use
>   - Facilitate the cost-effective and efficient development and use of M&S systems and capabilities
>   - Include practical validation, verification, and accreditation guidelines that vary by application area.
> 4. Tools in the form of models, simulations, and authoritative data that:
>   - Support the full range of DoD interests
>   - Provide timely and credible results
>   - Make capabilities, limitations, and assumptions easily visible
>   - Are usable across communities.
> 5. People that:
>   - Are well trained
>   - Employ existing models, simulation, and data to support departmental objectives
>   - Advance M&S to support emerging departmental challenges.

In doing this, the M&S SC once more established that a trained workforce – military, government civilian, contractor – with relevant skills and fully in tune with the department's current and emerging objectives are essential to achieving 1) an effective and efficient modeling and simulation capability and 2) the skills to manage and apply those capabilities. The annual reaffirmation of those vision and goals has, unfortunately, only generated a minimal investment at the DoD corporate level to establish a workforce development capability - and in the development of a strategy to put those capabilities and skills in place.

The lack of fiscal investment or planning energy doesn't mean that DoD's senior M&S leaders believe that a skilled workforce is not important. During the development of the most recent DoD M&S Enterprise strategy, many of the M&S SC members identified workforce development as a persistent gap. The strategic priority, as identified by numerous stakeholders, is the need for a competent, seasoned, career government and industry workforce. They identified a number of obstacles in the path of achieving resolution of this gap and thus solving the long-term professional recruitment and M&S career development issues:

- Some will say the problem begins in elementary or middle school with the lack of solid math, science, and engineering education that carries through to professional degree levels.
- A lack of standard M&S curriculum content at all levels.
- Designation of the work-force with a unique career code and the designation of core competencies in M&S.

As a result, DoD finds itself in much the same position – at least concerning workforce development – as it was in 2007, or even earlier:

- No DoD-wide workforce development strategy.
- No DoD enterprise level investment in M&S-specific workforce development.
- A very limited DoD enterprise-level education foundation – primarily two very outdated Defense Acquisition University continuous learning modules, a Modeling & Simulation Information Analysis Center (MSIAC) M&S staff officers course with limited offerings, an outdated on-line Essentials of Modeling and Simulation Course, a handful of best practices guides on line that can be used for self-training, and occasional tutorials at semi-annual and annual professional gatherings.
- Only one service – the Army – with a fully resourced and managed plan to develop its military and civilian workforce; even there, however, many commands have not yet built this training into its human resource management processes.

Given recent budget cuts – and even more anticipated "efficiencies" in the very near-future – it is doubtful that a significant change to the situation described immediately above will take place. There are some relatively affordable steps that could be achieved. They would most reasonably begin with the establishment of a workforce development working group within the M&S SC and its integrated process team that is provided a charter, limited budget for some professional support and some aggressive, but reasonable, milestones. The three principal tasks for the workforce development team might be:

1. Work closely with DAU to fix the DAU continuous learning modules and find other means to leverage DAU's content and learning management infrastructure. Tackle the two existing courses initially, with the initial focus of updating the systems engineering and test and evaluation (T&E) modules that satisfy SPRDE and T&E curriculum requirements and add a Program Manager's (PM) module that addresses the decisions that PM staffs must make in applying and funding M&S throughout the program life-cycle
2. Establish an M&S workforce development Wiki site off of the M&S CO web site that would be updated as education and development opportunities are developed.
3. Identify if existing education opportunities – even if limited in number – could be expanded or opened to wider enrollment across DoD. These opportunities could include tutorials at SISO/SIW, I/ITSEC, ITEA LVC, NDIA SE Conferences, PEO/SYCON conferences, etc.; leverage of Army FA57/CP36 training; and re-purposing of the MSIAC staff officer's course as a centrally funded M&S 101 course that has an on-line distributed learning module as well as a site-delivered module. This final step could also involve leverage (with some updates) the current Essentials of Modeling and Simulation on-line course that is still in-demand but which can't be updated in terms of content or delivery software.

The highest priority effort would be beginning coordination with DAU to update the two continuous learning modules – CLE011 (M&S for Systems Engineering) and CLE023 (M&S for Test and Evaluation) and establish a reasonable date for having those modified courses on line – say October 2012. Ideally, a general purpose M&S training package would be established that could be shared by both CLE011 and CLE023. The community specific modules – for systems engineering and test and evaluation – would be updated as well to reflect recent, major, changes to acquisition policies and methods. The M&S SC might also re-establish an active and interested stakeholder process for both the M&S foundation and community-specific modules. This approach would allow a broader set of users across DoD to leverage the mature infrastructure of DAU continuous learning capabilities for course enrollment and content maintenance – and establish a means by which future modules (perhaps M&S for logistics, training M&S, etc.) could be crafted without having to redevelop the foundation material each time. The M&S foundation material would also be used as the basis for the M&S 101 training capability.

These are small steps with potentially huge payoff – especially in the context of broader M&S education efforts ongoing in current or evolving academic departments across the country or even within DoD STEM (science technology engineering and math) efforts. Doing nothing should not be an acceptable option – failure to educate the government M&S workforce (customers, managers, users, and developers) further impedes making significant progress in removing the many obstacles preventing interoperability and reuse of current and future M&S capabilities. These fledgling efforts must be constructed such that DoD policies, management process, standards and standardization support efforts, and core infrastructure for asset visibility and re-use are made visible through these workforce development efforts – and kept current and relevant to the demand of the workforce and the DoD.

3 U.S. ARMY M&S DESIGNATIONS (HENNINGER)

Simulation Operations is the art and science of applying live, virtual and constructive simulation technologies in support of military operations, training and acquisition activities which include, testing, experimentation and analysis. (Department of the Army 2010) The U.S. Army has developed two M&S career titles to develop and train its workforce, the Functional Area (FA) 57 Simulation Operations designation for military officers and the Career Program (CP) 36 Analysis, Modeling & Simulation designation for civilians.

The *FA57* is an officer with operational experience who understands military operations and training. They develop, plan, coordinate, and execute exercises at all levels of command: battalion, brigade, division, combatant command, interagency and multi-national. FA57s are experts in modeling, simulation and Army Battle Command Systems (ABCS) and facilitate the training and operational environment for commanders to conduct first class mission planning and mission rehearsal exercises. FA57 currently has 217 authorizations in the Active Army and 209 in the Reserve Component (both in the generating and operational force) with ranks ranging from Captain to Colonel. The makeup of the FA57 officer population includes 87% from Maneuver, Fires, and Effects Branches with 35% of those officers having Combat Training Center Observer Controller experience.

FA57 training and education are among the best available in the Army:

- All FA57s attend the *Simulation Operations Course* which trains students on what simulations are and how best to utilize them in support of any organization.
- All FA57s attend the *Battle Command Officer Integration Course* which provides students with hands-on instruction on the ABCS. Students learn the inputs, outputs and architecture of this "system of systems" and how best to employ it during both training and operations in support of the Commander.
- *Army Knowledge Management Qualification Course* introduces students to knowledge management basic tools and techniques that they may apply in their units.
- The *School of Advanced Military Studies* (SAMS) is where an officer's planning skills are honed to perfection. SAMS graduates are given a special skill identifier and required to

commit to at least one payback tour as a planner within a military headquarters upon graduation.

- *Training with Industry* sends officers to work and train with an industry partner in the M&S field for up to one year.
- All FA57s attend the *Advanced Simulation Course* which introduces senior FA57 officers to cutting edge topics in the Modeling and Simulation career field. This course engages students on how to think and manage current and future challenges that await them as senior leaders of the FA57 functional area.
- All FA57s attend resident *Intermediate Level Education* (ILE) and the *Advanced Operations Warfighting Course* (AOWC) at Fort Leavenworth, Kansas. ILE prepares field grade officers with a warrior ethos and warfighting focus for leadership in Army and Joint, Interagency, Intergovernmental and Multinational organizations executing full spectrum operations. AOWC is designed to enhance students' understanding and skills in the Art of War and Battle Command.
- All FA57s are eligible to compete for fully funded *Advanced Civil Schooling*, which provides officers the opportunity to pursue a master's degree or Ph.D. from one of several universities, including the Naval Post Graduate School, Old Dominion University and the University of Central Florida.

The *CP36* is the Department of Army's civilian Analysis, Modeling and Simulation career program, for training, educating and developing civilian human capital in a systematic fashion. The CP36 Army Civilian Training, Education, and Development Systems (ACTEDS) was approved 15 April 2006. Analysis, modeling and simulation is pervasive throughout the Army, and is found in the Acquisition, Analysis, Operations, Testing, Training, Experimentation and Intelligence communities.

CP36 civilians work in a wide variety of organizations including program offices; research labs; technology, development and engineering facilities; analysis centers; test ranges; logistics centers; headquarters; and training centers and ranges. CP36 careerists support M&S activities throughout the acquisition life cycle and in the analysis, experimentation, intelligence, operations and plans, testing, and training communities. Dedicated educational programs and training enable M&S professionals to apply current and emerging technology with credibility and success.

CP36 training and education include the following options:

- *Army Simulation and Modeling School*, which includes the Simulation Operations Courses, Advanced Simulation Course, Battle Command Officer Integration Course, and the National Training Center Right-Seat-Ride Program.
- *Academic Degree Training* - A careerist may be approved to pursue a bachelor's or master's degree program funded by the career program, however, this must be approved by the ASA (M&RA) and must be related to current jobs. A careerist must be assigned to a permanent civilian position for three years before requesting this opportunity.
- *Developmental Assignments* - These assignments can vary in length from two weeks to 90 days, for the purpose of learning about a new organization, broadening understanding of Army analysis, modeling and simulation, or developing a specific skill or ability in a different analysis, modeling and simulation community. Organizations desiring to host developmental assignments should contact the CP36 staff for additional information.
- *Army Greening Assignments* - These assignments are intended to provide civilians opportunities to learn more about the operational Army.

4 M&S EDUCTION AT THE GEORGIA INSTITUTE OF TECHNOLOGY (LOPER)

Georgia Tech (GT) supports M&S education through academic degrees, as well as professional education. The academic programs support the theoretical understanding of science and technology related to simulation, but GT does not actually award an M&S degree. One such program is computational science

and engineering (CSE). CSE is a discipline devoted to the creation, study, and application of computer-based models of natural and engineered systems. Such models are essential to the exploration and understanding of scientific phenomena as well as the design and analysis of modern, human-created systems. The CSE discipline draws on concepts from computer science, applied mathematics, science, and engineering in order to synthesize a cohesive body of knowledge concerned with the representation and manipulation of models. GT offers interdisciplinary M.S. and Ph.D. degree programs in CSE, where student are associated with a home unit from one of the following: Aerospace Engineering, Biology, Chemistry and Biochemistry, Civil and Environmental Engineering, Computational Science and Engineering, Industrial and Systems Engineering, Mathematics, and Biomedical Engineering.

GT also has an extensive program for M&S professional education. The M&S program is administered through the Distance Learning and Professional Education (DLPE) organization, as part of their Defense Technology certificate program. DLPE's professional education program focuses on life-long learning, and offers 9 professional certificates in defense technology. GT's M&S certificate program is unique as compared to other programs, as it recognizes M&S is vital to many fields such as health care, emergency response, transportation and defense. As a result, the certificate is based on the premise that M&S education should be a combination of foundation courses and domain courses. A common body of knowledge forms a foundation for any M&S education program, upon which domain specific courses are needed to introduce the application and implementation of M&S for a particular field. The GT certificate is based on 6 courses, 3 required and 3 electives. The required courses include:

- *Fundamentals of Modeling* – looks at the intuitive process by which scientist develop simulation models. The course examines topics such as theory, representations, data, model-based problem solving and conceptual modeling.
- *Modeling & Simulation for Systems Engineering* - explores simulation model and simulation implementation topics and covers how M&S is used in the systems engineering life cycle. The course examines topics such simulation methodologies, systems engineering concepts, optimization, design of experiments and surrogate modeling.
- *Distributed Simulation Fundamentals* – investigates the principles that enable the networking of simulations. The course examines topics such as distributed system science, standards for networking heterogeneous simulations, design issues, and interoperability.

There are currently 37 elective courses in defense electronic domain areas, including:

- Airborne/Space
- Antenna Engineering
- Conflict Modeling
- Electronic Warfare
- Information Technology
- Infrared & Electro Optical
- Network Centric Operations
- Radar Systems
- Systems Engineering
- Test & Evaluation

The foundation courses are not hands-on, i.e. students do not have labs where they work with specific M&S tools. However, these courses have in-class exercises and assessments that reinforce knowledge learned in individual lectures. Mapping to the M&S BoK, these courses apply to all usage levels (awareness, application, management and executive), but do not go into detail implementation issues. In contrast, many of the elective courses are hands-on, using relevant simulation tools such as SysML or MatLab. Those courses are most appropriate for the BoK application usage level. However, some domain electives are similar to the foundation courses that use in-classes exercises (e.g., statapult test) to reinforce learning. These would also be appropriate for all usage levels. How to choose the appropriate course is left to the student by reviewing the course prerequisites.

The GT M&S certificate program, which started in 2006, gives students enough flexibility to take the right courses to meet their needs in M&S education.

5 COMPARING THE M&S GRADUATE DEGREE AND PROFESSIONAL CERTIFICATE PROGRAMS AT THE UNIVERSITY OF ALABAMA IN HUNTSVILLE (PETTY)

In this brief case study, we compare and contrast the M&S degree and M&S professional education programs at the University of Alabama in Huntsville (UAHuntsville) and comment on how they relate to each other.

In a program that was initiated in the summer of 2010, UAHuntsville offers M.S. and Ph.D. degrees in M&S. The program has a conventional academic structure in terms of course requirements, thesis and dissertation requirements, and examinations. The curriculum of the UAHuntsville program was consciously based on the successful M&S degree programs at Old Dominion University (Norfolk VA) and the University of Central Florida (Orlando FL), but has been customized to meet the needs of the Huntsville technical community, which is heavily oriented towards engineering and aerospace applications of M&S. Students completing degrees in the program will have been educated in multiple areas of modeling and simulation, including fundamental concepts, modeling paradigms and methods, verification and validation methods, mathematics and statistics, visualization and graphics, simulation system architectures and implementation, and application-specific modeling and simulation practices.

The UAHuntsville Division of Professional and Continuing Studies offers a professional certificate program in M&S. To earn a certificate, a student must complete four courses in M&S, each consisting of 14 hours of instruction. The four courses and their content are:

1. *Fundamentals of modeling and simulation.* Core concepts, applications and processes, common tools, fidelity and credibility, and technology trends.
2. *Developing simulations.* Projects, processes and standards, conceptual modeling, model design, and implementation techniques.
3. *Simulation verification, validation, and accreditation.* VV&A concepts, credibility and risk, verification and validation methods, verification and validation in M&S projects.
4. *Systems analysis, modeling, and simulation.* Systems analysis methods, systems models, development tools, and uses of M&S in systems engineering.

The four courses may be taken in the classroom with a live instructor or via asynchronous on-line delivery of recorded lectures. In both cases students must complete required exercises.

The UAHuntsville M&S degree and professional certificate programs are consciously aimed at different audiences. The degree program seeks to provide broad and pedagogically complete education, with some intent of covering the full range of the emerging M&S "Body of Knowledge". Students in the degree program are likely to go on to be leading practitioners, researchers, and faculty in the M&S discipline. The certificate program instead is aimed at providing practical, hands-on skills to meet the immediate needs of working M&S practitioners. Students in the program are typically those who have entered M&S from other disciplines and seek to quickly become familiar with the most important M&S concepts, techniques, and methods that they can apply in the workplace.

Although the programs have important differences in intended audience, scope, and extent, there is nevertheless significant crossover and cross-fertilization between them, to their mutual benefit. Instructors in either of the programs often teach in the other. Moreover, content developed for one program can be reused for the other. For example, a portion of the content from the certificate class on verification, validation, and accreditation is the basis for series of lectures on the same subject in the degree program's introductory course. Finally, students in the professional certificate program may become interested enough in M&S to pursue a full-scale graduate degree; to encourage that, UAHuntsville is working towards offering academic credit equivalent to one semester course to students who complete the professional certificate.

6 M&S PROFESSIONAL EDUCTION: SCIENCE AND ENGINEERING (TOLK)

For several years now, the M&S community tried to establish the M&S BoK in form of a comprehensive and concise representation of concepts, terms, and activities as it is needed that make up a professional M&S domain. Such M&S BoK shall represent the common understanding of relevant professionals and professional associations. However, although the discussion on the necessity to create the M&S BoK was initiated more than a decade ago (Szczerbicka et al. 2000), we still did not reach an agreement that can be used to drive common curricula, aligned professional education, or generally accepted professional certificates. Without this core, however, we do not have a set of core competencies well defined that every M&S professional needs to be able to handle. The dangers were already addressed in the WSC panel discussion on *Sustaining the Growth and Vitality of the M&S Discipline* (Yilmaz et al. 2008): We have no common definition for M&S professionals or M&S experts, so that everybody can claim to be one without an option to be held responsible this claim.

One of the main reasons may be the failure of academia to recognize M&S as its own discipline and drive the development of the M&S BoK more actively. The reason for this reluctance may be that every traditional discipline already applies the one or other form of M&S as a tool to drive the own discipline forward. This viewpoint is also reflected in the academic journal environment: the majority of M&S journals focus on applications within hosting disciplines. We have biologists with M&S application knowledge, military training specialists with M&S application knowledge, transportation experts in civil engineering with M&S application knowledge, aerospace experts with M&S application knowledge, and more. However, while these discipline-driven viewpoints on M&S as an engineering approach in their own discipline is without question justified – M&S applications methodologically helped to drive solutions in many disciplines – they fall short when it comes building a basis for professional education.

Maybe a good comparison to identify the shortcomings is having a look at *Computer Science* and *Computer Engineering*. As a general rule, science tries to discover knowledge while engineering creates solutions. In the continuum of theoretic insights leading to applicable methods that produce useful solutions, the scientist tends towards the theory, the engineer towards the solution. In computer science, theory of artificial languages, decidability of questions, computational complexity, and more builds the core elements of the theoretic foundation. Computer engineering uses this foundation to look for solutions. Even if a problem is generally not decidable, heuristics can still help to find acceptable solutions under given constraints. If a problem is generally too complex to be solved, computer engineering looks for constraints that allow to come up with a recommendation that at least is better than guesswork. However, computer science and computer engineering are going hand in hand.

Our current curricula as well as the majority of M&S research fall into the categ*ory of M&S Engineering*. That is only natural, as research funding tries to support finding of solutions. In addition, the professional associations nearly exclusively grew out of the computer engineering domain from the fields that applies simulation to create solutions: American Statistical Association (ASA), Association for Computing Machinery (ACM) Special Interest Group Simulation (SIGSIM), Institute of Electrical and Electronics Engineers (IEEE), Institute for Operations Research and the Management Sciences (INFORMS), Institute of Industrial Engineers (IIE), and National Institute of Standards and Technology (NIST). An exception is the Society for Modeling and Simulation International (SCS), but even this professional group started as the Society for Computer Simulation originally. This is not a bad thing per se, but if everybody focuses on the engineering side, where does *M&S Science* come from and takes care of solid common theories?

Simulation was perceived a success story in so many application domains so rapidly, that academia did not find the time to deal with the scientific basis before solving problems. The M&S community was so busy cutting down the woods that they had no time to sharpen their axes, and M&S academia participated in this ride on the wave of success instead of focusing on ontological and epistemological foundations and a solid canon of M&S science. In order to continue to grow we need this common M&S theory that is application independent. While the focus of M&S has been simulation in the past, what makes M&S really special and distinguishes it significantly from other software engineering disciplines is the

modeling part. Solving problems on the conceptualization level in a common theory has the potential to drive new methods and results in new solution in several traditionally independent application disciplines. University-based M&S continuing education programs must help to educate professionals in such M&S specific thinking resulting in new solutions, not in application discipline specific point solutions. A common M&S theory developed, maintained, and extended by a community of M&S science will allow the academically meaningful transfer of solutions between different application disciplines. Try and error, which is the only approach when engineering solutions are not rooted in a common theory, will be replaced by academic rigor based on scientific insight.

DoD sponsored programs will benefit from these approaches as well. An example is the current discussion on how to apply DoD M&S approaches in support of Human, Social, Cultural, and Behavioral (HSCB) modeling challenges (Tolk et al. 2011). A naïve approach would be to simply apply the lessons learned from physical-technical models, as very successfully done for military training federations, to this new domain of socio-psychological models. After all, both are simulation systems and should follow the guidelines of simulation interoperability standards resulting in interoperable simulation systems. However, the epistemological foundations of these two model categories are fundamentally different, so that the blind application of simulation standards must lead to wrong results. M&S science education of professionals will help to avoid costly and potentially even deadly mistakes.

7 SUMMARY

The DoD needs a trained workforce – military, government civilian, contractor – with relevant skills and fully in tune with the department's current and emerging objectives. This is essential to achieving an effective and efficient modeling and simulation capability. While several universities offer academic M&S degree programs, the time and expense of earning these degrees often limits the number of people that go through these programs. Professional education is a viable alternative for gaining M&S skills and knowledge. Since these courses are offered by a wide range of university and commercial groups, there is a growing need to have a foundation against which courses can be assessed. The DoD M&S BOK may provide one such measure. The observations in this paper begin to outline both the need and available options for M&S professional education.

REFERENCES

Department of the Army. 2010. FA57 Simulation Operations. FA57 Brochure. http://www.ms.army.mil/fa57/FA57_Brochure_web.pdf.

Department of Defense. 2008. Modeling and Simulation Body of Knowledge (BOK). Final Report. http://www.msco.mil/msLibrary.html.

Szczerbicka, H., J. Banks, R.V. Rogers, T.I. Ören, H.S. Sarjoughian, and B.P. Zeigler. 2000. Conceptions of curriculum for simulation education. *Proceedings of the Winter Simulation Conference*, edited by J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, Orlando, FL, Volume 2, pp. 1635 – 1644

Tolk, A., S.Y. Diallo, J.J. Padilla, and C.D. Turnitsa. 2011. "How is M&S Interoperability different from other Interoperability Domains?" In *Proceedings of the Spring Simulation Interoperability Workshop*, 11S-SWI-008, Boston, MA, April

Yilmaz, L., P.K. Davis, P.A. Fishwick, X. Hu, J.A. Miller, M. Hybinette, T.I. Ören, P. Reynolds, H.S. Sarjoughian, and A. Tolk. 2008. "What makes Good Research in Modeling and Simulation: Sustaining the Growth and Vitality of the M&S Discipline." In *Proceedings of the 2008 Winter Simulation Conference*, edited by S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, and J. W. Fowler, 677-688. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

AUTHOR BIOGRAPHIES

MARGARET L. LOPER is the Chief Scientist for the Information & Communications Laboratory at the Georgia Tech Research Institute. She holds a Ph.D. in Computer Science from the Georgia Institute of Technology, a M.S. in Computer Engineering from the University of Central Florida, and a B.S. In Electrical Engineering from Clemson University. Margaret has twenty-five years of experience in Modeling & Simulation and her technical focus is parallel and distributed simulation. She is a member of ACM SIGSIM, SCS, SISO and IEEE. Her research contributions are in the areas of temporal synchronization, simulation testing, and simulation communication protocols. Her email address is <margaret.loper@gtri.gatech.edu>.

JOHN W. DIEM is)Deputy Director, M&S CO. He is M&SCO's principal staff member for M&S LSA functions and chairs the Information Technology Standards Committee M&S TWG. Mr. Diem has served in a variety of Army simulation, training, and operational and developmental testing positions over the past 30 years. Recent assignments include Simulation and Integration Division Chief for the Army Operational Test Command, G3 of the III (US) Corps, and the Director, Plans, Training, and Security for Fort Hood.

AMY HENNINGER is a Highly Qualified Expert (HQE) serving as the Technical Advisor, Center for Army Analysis, in the area of Modeling and Simulation (M&S). In this position, she provides technical expertise, guidance and coordination of Army and DoD policies, procedures, and objectives for the execution of all emerging activities that are the responsibilities of the Army M&S community; makes recommendations on new policies, resources, resource application, and performance in support of Army M&S; and evaluates and advises on M&S input for The Army Plan, Defense Planning Guidance, Army Campaign Plan, and POM Technical Guidance memorandum. Dr. Henninger has worked for the Institute for Defense Analyses, Soar Technology, U.S. Army Research Institute and Science Application International Corp. She received her Ph.D. and M.S. in Computer Engineering from the University of Central Florida; a M.S. in Engineering Management from Florida Institute of Technology and several B.S. degrees in Industrial Engineering, Psychology and Mathematics from Southern Illinois University. Her email address is <amy.henninger@us.army.mil>.

MIKEL D. PETTY is Director of the University of Alabama in Huntsville's Center for Modeling, Simulation, and Analysis. He received a Ph.D. in Computer Science from the University of Central Florida in 1997. Dr. Petty has worked in modeling and simulation research and development since 1990 in areas that include simulation interoperability and composability, human behavior modeling, multi-resolution simulation, and applications of theory to simulation. His email address is <pettym@uah.edu>.

ANDREAS TOLK is a Professor for Engineering Management and Systems Engineering of Old Dominion University. He is also a Senior Research Scientist at the Virginia Modeling Analysis and Simulation Center. He holds a M.S. in Computer Science (1988) and a Ph.D. in Computer Science and Applied Operations Research (1995), both from the University of the Federal Armed Forces of Germany in Munich. He is senior member of IEEE and SCS and member of ACM, ASEM, MORS, NDIA, and SISO. His area of expertise is interoperability and composability and modeling and simulation based systems engineering. His e-mail address is <atolk@odu.edu>.