Abstract: The Certified Modeling and Simulation Professional (CMSP) examination is a professional certification examination promoted and administered by the National Training and Simulation Association (NTSA). Award of the CMSP designation is intended to recognize individuals who have attained a significant degree of knowledge and experience in modeling and simulation. The examination was first developed and offered to the community in 2001. Recognizing the need for a renewal of the examination’s content, NTSA commissioned a community effort beginning in 2009 to develop a new version of the examination. That renewal has been completed. The new CMSP examination is based on a consensus-based topic index intended to cover the essential parts of the modeling and simulation body of knowledge. A set of approximately 2000 new questions was developed; the set includes questions for every topic and subtopic in the index and supports two different types of CMSP certification. Every question is explicitly traceable to a published source in the modeling and simulation literature. In parallel with the question development, a new on-line examination system was designed and implemented to allow CMSP candidates to attempt the examination conveniently and intuitively. This paper will detail the new exam’s types, topics, and structure, and will introduce the new on-line delivery system for the examination.

1. Introduction

This paper is organized into three main sections. This introductory section introduces the Certified Modeling and Simulation Professional examination, describing its intent, governance, and history. The second section details the new CMSP examination’s topical content, question characteristics, and examination instance structure. The third section describes the new on-line system that has been developed to administer the examination.

1.1 CMSP certification

An important milestone in the maturation of a professional discipline is the institution of a professional certification examination for practitioners within the discipline and the acceptance by the larger community of that certification as an indicator of expertise and competence by those who have attained it. Accepted professional certification examinations already exist for a range of disciplines, including aviation, law, medicine, project management, and finance.

The Certified Modeling and Simulation Professional (CMSP) examination is a professional certification examination for modeling and simulation professionals. The CMSP designation is intended to identify individuals who have attained a significant degree of knowledge and experience in modeling and simulation. As modeling and simulation matures as a discipline, it is anticipated that agencies seeking modeling and simulation professionals will recognize and prefer those who have attained the CMSP designation.

In the new version of the CMSP examination described here, two types of CMSP professionals are acknowledged and two types of certification are offered: User/Manager and Developer/Technical. The CMSP User/Manager examination is intended and designed to identify persons with the knowledge required to:

1. Employ and explain key terms, definitions, and concepts in modeling and simulation.
2. Apply important principles of modeling and simulation practice, including simulation ethics, business considerations, and related communities of practice.
3. Understand and work effectively within typical and important uses of modeling and simulation, including application areas and domains of use.
4. Identify, assess, and select relevant simulation technologies, including modeling paradigms and implementation architectures, for a specific application.

5. Determine whether the use of simulation is, or is not, appropriate for a specific application.

6. Plan, initialize, and execute simulation runs or trials to satisfy project requirements.

7. Analyze, interpret, and apply the results of simulation runs in the context of an application.

8. Manage aspects of projects involving the use or development of simulation models and systems.

The CMSP Developer/Technical examination is intended and designed to identify persons with the knowledge required to:

1. Employ and explain key terms, definitions, and concepts in modeling and simulation.

2. Apply important principles of modeling and simulation practice, including simulation ethics, business considerations, and related communities of practice.

3. Understand and work effectively within typical and important uses of modeling and simulation, including application areas and domains of use.

4. Design and develop simulation models of various types, including mathematical, logical, structural, and conceptual.

5. Identify the underlying mathematical issues associated with many simulation models, including numerical evaluation algorithms, digital discretization, and numerical precision.

6. Implement simulation models as executable software and verify those implementations.

7. Validate simulation models using suitable methods and assess the suitability of a model for a specific application.

8. Design and implement technical infrastructures needed to support simulation systems.

Note that the first three items in the two lists are common to the two certification types; the remaining items are distinct.

The overall goal of the examination is to ensure that successful candidates have a representative understanding of the full broad spectrum of modeling and simulation, i.e., that they have knowledge across the body of knowledge. It may be true that the CMSP examination is more challenging in some ways than other, more focused, professional certifications, but it is not true that a formal education in modeling and simulation is required. The overall goal of the examination renewal process is to better serve the M&S community, by helping to identify and differentiate those who are genuinely professional modeling and simulation practitioners.

1.2 Governance and history of the CMSP examination

Working under the sponsorship and oversight of the National Training and Simulation Association (NTSA), the CMSP examination is governed by the Modeling and Simulation Professional Certification Commission (M&SPCC), which consists of nine members (three each from industry, academia, and government). The M&SPCC is responsible for the development, provision, promulgation, and sustainment of the CMSP as a certification examination for modeling and simulation professionals.

The CMSP examination was first developed and offered to the community in 2001. The initial examination’s questions were developed by a group of volunteer modeling and simulation experts, largely based on their personal expertise and experience. The examination covered many topical areas within the modeling and simulation body of knowledge by virtue of the range of backgrounds in the experts chosen to develop the questions. Since then over 200 individuals have been designated as Certified Modeling and Simulation Professionals.

Recognizing the need for a renewal of the examination’s content, the M&SPCC commissioned a community effort beginning in late 2009 to develop a new version of the examination. The new version would improve on the initial version in several ways:

1. It would intentionally attempt comprehensive coverage of the emerging modeling and simulation body of knowledge.

2. The questions in the new version would be updated to reflect advances in the field since 2001.

3. All questions in the new version would be based on authoritative published sources.

4. A distinction would be made between two different types of M&S professionals, defined earlier, with related but different examinations for each type.

The renewal process is emphasizing transparency and credibility. The redevelopment of the examination to provide traceability to a specific set of identified sources is a major part of that improvement.

2. New CMSP examination

This section details the new CMSP examination’s topical content, question characteristics, and examination instance structure.

2.1 Topics and subtopics

The new CMSP examination is based on a consensus-based topic index intended to cover the essential parts of the modeling and simulation body of knowledge. The topic index used was adapted and extended from the
SimSummit Modeling and Simulation Body of Knowledge Index. Some of the changes made to the topic index for the CMSP examination reflect the availability of published sources and the testability of the content for each topic.

The CMSP topic index, organized into topics and subtopics, is as follows:

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
   2.2 Analysis
   2.3 Experimentation
   2.4 Acquisition
   2.5 Engineering
   2.6 Test and evaluation
3. Domains of use of M&S
   3.1 Combat and military
   3.2 Aerospace
   3.3 Medicine and health care
   3.4 Manufacturing and material handling
   3.5 Logistics and supply chain
   3.6 Transportation
   3.7 Computer and communications systems
   3.8 Environment and ecology
   3.9 Business
   3.10 Social science
   3.11 Energy
   3.12 Other domains of use
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. Simulation implementation
   5.1 Modeling and simulation life-cycle
   5.2 Modeling and simulation standards
   5.3 Development processes
   5.4 Conceptual modeling
   5.5 Specialized modeling and simulation languages
   5.6 Verification, validation, and accreditation
   5.7 Distributed simulation and interoperability
   5.8 Virtual environments and virtual reality
   5.9 Human-computer interaction
   5.10 Semi-automated forces/computer generated forces
   5.11 Stimulation
6. Supporting tools, techniques, and resources
   6.1 Major simulation infrastructures
   6.2 M&S resource repositories
   6.3 M&S organizations
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
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

2.2 Question counts, sources, formats, and attributes

Approximately 2000 new questions were developed. On average, there are 40 questions for each subtopic in the topic index; every subtopic has at least 20 questions, and some subtopics have more than 100 questions. Every question is drawn from and explicitly traceable to a published, peer-reviewed, and publicly available source in the modeling and simulation literature. Over 175 different sources were used for the questions. Those sources include journal papers, conference papers, books, and book chapters. Despite their value in many situations, web pages, Wikipedia articles, presentations and technical reports posted on-line, and other similarly transient sources were not used as sources for the CMSP questions.

The majority of the questions are multiple choice, with four answers (one correct and three incorrect). A minority of the questions are True-False (which of course is a special case of multiple choice). No other types of questions are used. Some of the questions and/or the answers include diagrams, images, and mathematical formulas.

As of this writing (January 2012) three subtopics have no questions, due to an apparent lack of sources. Those problematic subtopics are 7.3 M&S workforce development, 7.4 M&S business practice and economics, and 7.5 M&S industrial development. Readers with recommendations for suitable sources (published, peer reviewed, publicly available, non-transient) are urged to contact the authors.
Figure 1. Example question with all attributes exposed.

In addition to the question itself and its answers, each of the new questions has several additional attributes; these are a unique identifying number, the source for the question, the specific page number within the source from where the question was drawn, and the question’s author. Moreover, each of the questions has been categorized in three ways:

1. Subtopic in the topic index (and thus implicitly also topic)
2. Certification type (User/Manager, Developer/Technical, and Core)
3. Difficulty (Very easy = 1, Easy = 2, Moderate = 3, Difficult = 4, Very difficult = 5)

Figure 1 shows an actual question from the new question set with all of the question’s attributes exposed. A candidate taking the examination will not see all of the supplementary attributes, just the question itself and its answers.

2.3 Question quality control

A group of external reviewers will review each of the new questions. All of the reviewers are knowledgeable in modeling and simulation, many of them have received the CMSP designation, and none were involved in the creation of the new questions. The reviewers will examine the new questions for correctness, clarity, and relevance, and they will determine if each question’s categorization for type, topic, and difficulty are appropriate. Based on their feedback, those questions needing revision will be revised before the new examination is opened to the public.

2.4 Examination instances

A unique instance of the examination is generated for each candidate by randomly choosing questions from the question bank. As mentioned earlier, there are two different types of CMSP certification, User/Manager and Developer/Technical. The candidate selects the type of certification he or she is seeking. In addition, the candidate may select up to one-third of the subtopics within each of four specific topics (Applications, Domains, Modeling methods, and Implementation) for exclusion from his/her examination instance.

With the candidate’s choices in mind, a generated examination instance will have this structure:

1. 100 questions total.
2. All questions from either from the candidate’s selected certification type or from “Core”.
3. No less than 10 questions from each of the 8 topics.
4. No questions from any of the candidate’s excluded subtopics.
5. Average difficulty of all questions in the instance no less than 2.5 and no greater than 3.5.

2.5 Degree of difficulty

As mentioned, the examination will be customizable to each candidate in two ways: (1) candidates select the type of certification they are seeking, and (2) candidates may exclude a limited number of subtopics from their examination instance. Nevertheless, an examination instance will have a broad scope, and it is unlikely that even a well-educated and experienced candidate will be able to simply sit down and answer the test accurately over a period of a few hours. It is for that reason that the examination is “take home”, and that candidates are

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2 This review process is ongoing as this paper is written (January 2012). It will likely be complete by the time the paper is published (March 2012).

3 This exclusion option is intended to compensate for the very broad nature of the modeling and simulation body of knowledge. The M&SPCC determined that candidates cannot reasonably be expected to have extensive knowledge in all aspects of modeling and simulation.
given a substantial amount of time to complete it. It is expected that each candidate will have to search for some of the answers. Candidates may also retake the examination (but not the same instance) if necessary.

The question development team has tried to establish a degree of difficulty such that it is reasonable to expect that a successful candidate has a broad understanding of modeling and simulation, with depth in some specific topics. The examination is meant to be difficult enough that the CMSP designation represents a noteworthy degree of knowledge and accomplishment, but not so difficult that experienced and knowledgeable modeling and simulation practitioners are unable to pass it.

3. Examination delivery

In parallel with the question development, a new on-line examination system was designed and implemented to allow CMSP candidates to attempt the examination conveniently and intuitively. This section describes the new website system for administering the examination. First, the examination procedure from the candidate's perspective is discussed. Then, the website's features are explored in more detail. Finally, the process of populating the question database is discussed.

3.1 Examination process from a candidate’s perspective

Initial payment for the examination occurs on an external website controlled by the CMSP examination administrators. After the candidate has paid the examination fee, an administrator creates an account for the user in the CMSP on-line system. The website automatically generates a random password for the user and sends him or her an email with login instructions.

Upon first logging in to the CMSP website, the candidate is prompted to provide some basic credentials, including their name, contact information, and type of certification sought (User/Manager or Developer/Technical). The candidate is then presented with a complete list of question subtopics and prompted to choose subtopics that he or she wishes to exclude from his or her examination (referred to as "exclusions"). Once the candidate has provided this information, he or she is presented with the “home” page to which he or she will return upon subsequent logins. The home page contains information and navigation links pertaining to the candidate and to his or her examination instance; this includes a link to start or resume the exam, the number of questions that he or she has answered thus far, and the amount of time remaining in the examination period.

Upon first starting the exam, the system creates an examination instance for the candidate. The system selects the questions for the instance in a process that implements logic specified by the M&SPCC. The database of potential questions is filtered to select Core questions and either User/Manager or Developer/Technical questions as appropriate for the candidate, then to remove questions in the subtopics provided as exclusions by the candidate. From this pool, 10 questions are chosen from each of the 8 topics in the topic index and 20 additional questions are selected "at large" from any non-excluded subtopic. The questions are then sorted by major topic. The average difficulty of the questions selected for an instance is also considered. If an instance’s average difficulty is not between 2.5 and 3.5 (inclusive), the examination instance generation process is repeated. Because the questions have been written collectively with varying difficulty in mind and the question set is large, this average difficulty test rarely fails; even when it does, examination instance generation is not computationally heavy and the regeneration is quick.

Once an examination instance has been generated for the candidate, he or she is then directed to the examination. This interface, shown in Figure 2, is intended to be as intuitive and unrestrictive as possible while providing necessary and otherwise beneficial functionality. The website assumes that each question is either True/False or has four potential responses. The order of the responses is randomized when presented to the user. The website also displays any images or equations associated with each question. Questions not yet answered by the candidate are noted with a red bar and asterisk, and the website also shows the number of questions left unanswered in each topic using a dropdown list. The candidate can navigate to any major topic using the arrow buttons or the dropdown list. The candidate is free to respond to questions in any order and can change answers at any time. Once he or she provides a response to a question, whether or not it has been answered previously, the response is automatically recorded by the system.

The candidate must answer all 100 questions on the examination in order to proceed. He or she may log out and later resume the examination as often as desired during the examination period, which starts when the examination instance is created and lasts for 14 days. This period can be extended by website administrators if approved by the M&SPCCI on a case-by-case basis.

Once all of the questions have been answered, the “Submit Exam” button located near the bottom of the page becomes active. When the candidate presses this button, the examination is submitted for grading, and he or she is directed to an optional comment form where he or she can submit feedback regarding the examination. Once the examination has been submitted, it is marked as such on his or her “home” screen, and the candidate may not return to the examination unless allowed access by a website administrator.
Upon submission, the website system emails the administrators, informing them how many questions the candidate answered correctly and whether he or she passed or failed the examination. At least 85 of the 100 questions must be answered correctly to pass the examination. The administrators then inform the candidate of his/her status manually.

3.2 Examination website system structure and administrative features

The website is constructed using the PHP and JavaScript scripting languages, the MooTools AJAX framework, and standard technologies such as HTML and CSS. The Subversion version control system and a set of custom scripts allow development versions of the website system, which may contain experimental and not yet thoroughly tested features, to coexist alongside the website system used by candidates and administrators.

Aside from the features already mentioned, the website also contains an administrative frontend that allows website administrators to add or modify users, examination instances, and questions in the question database. The frontend provides an instant search feature, which allows administrators to dynamically filter the list of questions to find questions of interest to them. The frontend also allows administrators to export the entire set of questions in the standard comma separated value (CSV) format. It also provides aggregate reporting of question statistics, including the number of times each question has been given in an examination instance and the number of times each answer has been selected by a user. These features are intended to support question auditing and categorization.

3.3 Question bank and database format

The question database used by the system is intended to be the official version of the question bank for the M&SPCC's purposes. Data items associated with each question, such as the question text, identification number, correct answer, incorrect answers, source, and author, are...
stored in mySQL format; images and equations are stored in a directory. Question text is written and displayed using a sanitized HTML markup, which allows questions to reference images, italicize appropriate key words such as "not", and display subscript and superscript as necessary. Together, the mySQL database and images directory constitute the entirety of the question bank. The version control scheme for the question bank stores both, and scripts allow images and the database to be rolled back to previous versions if necessary.

To allow question authors to work in a familiar environment, questions are originally written and stored in Microsoft Word documents. The website administrative frontend provides the ability to import questions into the question bank using an import script. This script parses Word documents, extracting fields associated with each question in the process, and populates the bank with questions provided in the Word format.

4. Future work

Future work related to the new CMSP examination includes the following:

1. Questions will be developed for the three problematic subtopics identified earlier.
2. As candidates attempt the examination, correct/incorrect statistics will be accumulated for each question, and questions that prove to be unduly troublesome will be revised or replaced.
3. The topic index will be extended and new questions will be developed as the modeling and simulation body of knowledge expands.

5. Acknowledgements

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6. Authors’ biographies

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William V. Tucker has applied systems and software engineering, engineering management, and program management to M&S technology and applications across aerospace during his 34 year tenure with Boeing. His publications relate to M&S architecture, standards, education, and professional development. He has long been active in the M&S industry, and in industry groups including the Simulation Interoperability Standards Organization and the International Society for Modeling and Simulation, and the Modeling and Simulation Professional Certificate Council, National Training and Simulation Association, Alabama Modeling and Simulation Council, and National Defense Industry Association. He is married to the former Mary Davis. They have four children. She, like their two oldest children, holds an engineering degree, demonstrating real commitment to technology education. Their third child is currently studying engineering, while the fourth is wondering where she go to study bio-chemical engineering.