The Richness of Modeling and Simulation & its Body of Knowledge

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http://www.site.uottawa.ca/~oren/
1. Introduction
2. Importance of M&S
3. M&S & Education
4. Richness of M&S
5. Professionalism in M&S
6. Stakeholders of M&S
7. M&S Body of Knowledge
8. Conclusion

Possible opportunities & challenges
Some Motivations to see the Big Picture:

“The smaller a man, the closer his horizon”
(John McLeod, founder of SCS)

“The greater a person, the larger his horizon”
(Tuncer Ören)
Having a large horizon is desirable; but not sufficient.

Two important factors (biases):

- **Where we are** (*local bias*): At the North Pole, all directions point out the South!
- **Our perspective** (*cultural bias*):
  - “Horizon” is relevant if we are outside of a sphere;
  - When we are within a sphere, our perspective (*point of view*) & our ability to discern are relevant.
Simulation has well over 100 definitions!


For any discipline, having that many definitions is not necessarily a testimony of richness.

Experiments and experience are the essence of modeling & simulation (M&S).

• Simulation is performing goal-directed experiments using a model of a dynamic system.

• Simulation is providing experience, by use of a representation (a model) of a system, to enhance any one of three types of skills (training):
  -- motor skills (by virtual simulation, or simulators),
  -- decision making and communication skills (by constructive simulation, gaming simulation),
  -- operational skills (by live simulation)
- for entertainment purposes (simulation games)
1. Introduction

2. Importance of M&S
   2.1 Simulation-based Science & Engineering
   2.2 Simulation-based Social Sciences
   2.3 Computational Neuroscience
   2.4 Impact of Extreme-scale Computing in M&S
   2.5
2. Importance of M&S

2.1 Simulation-based Science & Engineering

“Simulation-based engineering science (SBES) is a well established and important concept” (Oden et al., 2006).

"Meaningful advances in SBES will require dramatic changes in science and engineering education" (p. 56).

2.2 Simulation-based Social Sciences

Simulation-based social sciences include anthropology, archaeology, economics, geography, government, linguistics, management, political science, and sociology.
2. Importance of M&S

2.3 Computational Neuroscience

*Computational neuroscience* is a subfield of neuroscience that uses mathematical methods to simulate and understand the function of the nervous system (Scholarpedia).

"A *connectome* is a comprehensive map of neural connections in the brain" (Wiki-connectome).

"The *Human Connectome Project* aims to provide an unparalleled compilation of neural data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain" (HCP).

Advanced simulation is an integral part of the connectome project.
2. Importance of M&S

2.4 Impact of Extreme-scale Computing in M&S

Extreme scale computers are high-speed computers such as teraflop, petaflop, or exaflop computers. They perform, respectively, $10^{12}$ (i.e., one thousand times one billion), $10^{15}$ (i.e., one million times one billion), or $10^{18}$ (i.e., one billion times one billion) floating point operations per second.

Simulations performed on these types of computers are called, extreme-scale simulation, terascale simulation, petascale simulation, or exascale simulation.

USA is working to realize an exascale computer.
2. Importance of M&S

2.4 Impact of Extreme-scale Computing in M&S

As a practical importance of:

• **petascale simulation**, one can point out that, if one billion entities are represented in a simulation model, every second, over a million fp operations can be performed for each object represented.

• **exascale simulation**, one can point out that, if 100 billion entities (e.g., all neurons in a brain) are represented in a simulation model, every second, over 10 million floating point operations can be performed for each object represented.
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6. Stakeholders of M&S
7. M&S Body of Knowledge
8. Conclusion
3. M&S & Education

Education for simulation

For simulationists
- Degree programs:
  - bachelor, MS, PhD
- Professional training
- ...

Simulation for education

Practically in any field
- In Degree programs:
  - bachelor, MS, PhD
- Professional training
- ...

Uniform curricula

Benefits of M&S for Ed.

Opportunities & Challenges for both:
Plan

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### 3. Richness of M&S

Over 500 terms denoting several types of simulation:

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<th>C</th>
<th>D</th>
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<td>biologically-inspired simulation</td>
<td>continuous simulation</td>
<td>continuous-change simulation</td>
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<td>bio-nano simulation</td>
<td>continuous-system simulation</td>
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<td>academic simulation</td>
<td>bond-graph simulation</td>
<td>cooperative simulation</td>
<td>copetition simulation</td>
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<tr>
<td>accurate simulation</td>
<td>branched simulation</td>
<td>cooperative simulation</td>
<td>co-simulation</td>
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<tr>
<td>activity-based simulation</td>
<td>closed-form simulation</td>
<td>coupled simulation</td>
<td>coupled simulation</td>
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<tr>
<td>ad hoc distributed simulation</td>
<td>closed-loop simulation</td>
<td>credible simulation</td>
<td>coupled simulation</td>
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<td>adaptive simulation</td>
<td>cloud simulation</td>
<td>critical event simulation</td>
<td>critical event simulation</td>
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<tr>
<td>adaptive system simulation</td>
<td>cloud-based simulation</td>
<td>customizable simulation</td>
<td>customizable simulation</td>
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<tr>
<td>adiabatic system simulation</td>
<td>cluster simulation</td>
<td>customized simulation</td>
<td>customized simulation</td>
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<tr>
<td>advanced simulation</td>
<td>coercible simulation</td>
<td>data-driven simulation</td>
<td>data-driven simulation</td>
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<tr>
<td>advanced distributed sim.</td>
<td>cognitive simulation</td>
<td>data-intensive simulation</td>
<td>data-intensive simulation</td>
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<tr>
<td>advanced numerical sim.</td>
<td>cokriging simulation</td>
<td>decision simulation</td>
<td>decision simulation</td>
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<tr>
<td>agent simulation</td>
<td>collaborative component-based simulation</td>
<td>degree 1 simulation</td>
<td>degree 1 simulation</td>
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<tr>
<td>agent-based simulation</td>
<td>collaborative simulation</td>
<td>degree 2 simulation</td>
<td>degree 2 simulation</td>
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<tr>
<td>agent-based participatory sim.</td>
<td>collaborative virtual sim.</td>
<td>degree 3 simulation</td>
<td>degree 3 simulation</td>
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<tr>
<td>agent-controlled simulation</td>
<td>collaborative distributed sim.</td>
<td>demon-controlled simulation</td>
<td>decision simulation</td>
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<tr>
<td>agent-coordinated simulation</td>
<td>collaborative virtual sim.</td>
<td>descriptive simulation</td>
<td>degree 1 simulation</td>
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<tr>
<td>agent-directed simulation</td>
<td>collocated cokriging sim.</td>
<td>detached eddy simulation</td>
<td>degree 2 simulation</td>
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<td>agent-initiated simulation</td>
<td>collocated simulation</td>
<td>deterministic simulation</td>
<td>degree 3 simulation</td>
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<tr>
<td>agent-monitored simulation</td>
<td>combined continuous-discrete</td>
<td>detached eddy simulation</td>
<td>deterministic simulation</td>
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<td>agent-supported simulation</td>
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<td>digital analytic simulation</td>
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<td>aggregate level simulation</td>
<td>continuous simulation</td>
<td>discrete modeling</td>
<td>discrete event simulation</td>
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<td></td>
<td>continuous simulation</td>
<td>dynamic simulation</td>
<td>dynamic simulation</td>
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<td>continuous-time simulation</td>
<td>evolutionary simulation</td>
<td>evolutionary simulation</td>
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<td></td>
<td>continuous-time simulation</td>
<td>expert system</td>
<td>expert system</td>
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<td>continuous-time simulation</td>
<td>feedback simulation</td>
<td>feedback simulation</td>
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<td>continuous-time simulation</td>
<td>flow simulation</td>
<td>flow simulation</td>
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<td>continuous-time simulation</td>
<td>fuzzy simulation</td>
<td>fuzzy simulation</td>
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<td></td>
<td>continuous-time simulation</td>
<td>genetic algorithm</td>
<td>genetic algorithm</td>
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<td>continuous-time simulation</td>
<td>genetic algorithmic simulation</td>
<td>genetic algorithmic simulation</td>
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<td>continuous-time simulation</td>
<td>genetic algorithmic simulation</td>
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<td>continuous-time simulation</td>
<td>genetic algorithmic simulation</td>
<td>genetic algorithmic simulation</td>
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<td>Criteria</td>
<td>Types of understanding</td>
<td>Definitions &amp; (explanations)</td>
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<td>------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
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<tr>
<td>Directness</td>
<td>apprehension (direct understanding)</td>
<td>Apprehension is direct understanding or self-evidence.</td>
<td></td>
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<td></td>
<td>comprehension (indirect understanding) (mediated understanding)</td>
<td>Comprehension is indirect or mediated understanding.</td>
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<tr>
<td></td>
<td>- logical understanding</td>
<td>Logical understanding is indirect understanding where logical inference is used as a means for the attainment of an understanding.</td>
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<tr>
<td>Direction</td>
<td>top-down understanding</td>
<td>Top-down understanding starts with background knowledge (meta-model) about an entity to gather knowledge about it.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bottom up understanding</td>
<td>Bottom up understanding starts with an analysis or perception of an entity and maps relevant knowledge to a meta-model of it.</td>
<td></td>
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<tr>
<td>Precedence</td>
<td>sequential understanding</td>
<td>Understanding done in sequence.</td>
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</tr>
<tr>
<td></td>
<td>parallel understanding</td>
<td>Understanding done in parallel.</td>
<td></td>
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<tr>
<td>Understanding process modality</td>
<td>unimodal understanding</td>
<td>Understanding one modality at a time. (e.g., text, picture, or gesture.)</td>
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</tr>
<tr>
<td></td>
<td>multimodal understanding</td>
<td>Understanding more than one modality simultaneously.</td>
<td></td>
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<tr>
<td>Robustness</td>
<td>robust understanding</td>
<td>Understanding by a system that has the ability to recover gracefully from the whole range of exceptional inputs and situations in a given environment.</td>
<td></td>
</tr>
<tr>
<td>Dependability</td>
<td>brittle understanding</td>
<td>Understanding by a system which is functional but easily broken by changes in operating environment or configuration, or by any minor tweak to the software itself. (Also, any system that responds inappropriately and disastrously to abnormal but expected external stimuli.)</td>
<td></td>
</tr>
<tr>
<td>Accumulation of knowledge</td>
<td>tabula rasa understanding (re-initialized understanding)</td>
<td>Tabula rasa understanding does not depend on the results (products) of previous understanding process(es). (At the beginning of an understanding process, any remnant understanding from previous understanding process(es) is ignored.)</td>
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</tr>
<tr>
<td></td>
<td>cumulative understanding</td>
<td>Cumulative understanding builds up an understanding on top of previous understanding(s).</td>
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</tbody>
</table>
3. Richness of M&S

- **Number of terms in the M&S domain:**
  - An early (English-French-Turkish) M&S dictionary had about 4000 terms. 2006, Marseille, France.
  - The English-Chinese M&S dictionary has over 9000 terms. (In Press, Beijing, China) (with contributions of 30 Chinese scholars)
  - The English-French-Italian-Spanish-Turkish version which is being prepared has over 10000 terms and contributions of about 80 volunteers.
3. Richness of M&S

• There are many articles about comprehensive views of M&S.

  http://www.site.uottawa.ca/~oren/pubsList/MSBOK.pdf

• **Gaming simulation** can also be combined to explore experimentation for scientific research. An example is eyewire project of MIT which is gamified for crowdsourcing to have large cooperation of simulation game players to explore how connectomes of retina work (Anthony, 2012; eyewire).
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3 Aspects of **Professionalism in M&S**: 

1. **Knowledge:**
   - 1.1 To solve problems:
     - M&S BoK
     - Science, Eng., technology
     - Systems Eng., management
     - Application Area(s)
   - 1.2 How to behave as a simulationist
     - Code of Professional Ethics

2. **Activities:**
   - 1.1 Knowledge Generation & Dissemination:
     (Academia, R&D)
   - 1.2 Generation of products/services & solving problems:
     (Industry)
   - 1.3 Funding

3. **Monitoring:**
   - 3.1 Professional and Ethical Conduct
   - 3.2 Certification of Professionalism

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**Knowledge Generation & Dissemination:**

- **Science**, engineering, technology
- **Systems engineering**, (project) management

**Application Area(s):**

- M&S BoK

**Certification of Professionalism:**

- (individuals, companies)

**Code of Professional Ethics**

**Generation of products/services:**

- (Industry)

**Funding**

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**Professional and Ethical Conduct**

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6. Stakeholders of M&S

Table 1: Stakeholders of M&S

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<thead>
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<th>Stakeholders of M&amp;S BoK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuals</td>
</tr>
<tr>
<td>- Researchers / educators</td>
</tr>
<tr>
<td>- Practitioners</td>
</tr>
<tr>
<td>- Experienced learners</td>
</tr>
<tr>
<td>- Novice learners</td>
</tr>
<tr>
<td>- Customers / users of products / services</td>
</tr>
<tr>
<td>- People (to be) affected by simulation projects (done or not yet done)</td>
</tr>
<tr>
<td>- Industrialists</td>
</tr>
<tr>
<td>Institutions</td>
</tr>
<tr>
<td>- Government organizations</td>
</tr>
<tr>
<td>- Non-profit organizations</td>
</tr>
<tr>
<td>- Agencies for licensing or certification (of individuals / organizations)</td>
</tr>
<tr>
<td>- Funding agencies</td>
</tr>
<tr>
<td>- Professional societies</td>
</tr>
<tr>
<td>- Standardization organizations</td>
</tr>
<tr>
<td>- Educational institutions</td>
</tr>
<tr>
<td>- Industrial / professional groups / centers</td>
</tr>
<tr>
<td>- Commercial organizations</td>
</tr>
</tbody>
</table>

http://www.site.uottawa.ca/~oren/links-MS-AG.htm

International Federation of M&S
SIEI (similar to DII)
(Simulation Industry Ethical Initiative)
Urgently needed
Importance of Modeling & Simulation (M&S)

USA
The Senate declared it as a critical technology

• High Level Recognition of M&S:
  US Congressional Modeling and Simulation Caucus (News) (Congressman J. Randy Forbes)

• As a testimony of high level recognition of M&S see:
  USA - House Resolution 487 (2007 July 16)
  USA - A companion bill - S. 616 (2009 March 17)
Since 1985, most universities in China have master and Ph.D programs on the direction of modeling and simulation technology under related discipline such as computer science, mathematics, mechanical engineering, and automation.

According to the investigation of CASS (China Association for System Simulation), during the last decade, there are 85,964 master students and 19,657 Ph.D students graduated from system modeling and simulation technology in the top 100 universities in China.

Modeling and simulation technology is being considered to be established as a first class discipline by the Ministry of Education of China under the proposal of most Chinese universities and CASS [1].

Bo Hu Li, Lin Zhang, Zongji Chen, Tianyuan Xiao and Jingye Wang (2010) 
Simulation Science and Technology in China
SCS M&S Magazine, vol. 1, issue 3 (July)
Stakeholders of M&S: Countries / Unions

USA: declared M&S as a critical discipline

China: acknowledges M&S’s importance

European Union may benefit from
- the declaration of M&S as a critical area for the well being of Europeans
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7. M&S Body of Knowledge (BoK)

7.1 Preliminary

• A body of knowledge (BoK) of a discipline is “structured knowledge that is used by members of a discipline to guide their practice or work” (Ören, 2006).
7. M&S Body of Knowledge (BoK)

7.1 Preliminary

• A BoK Index is a set of systematically organized pointers to the content of a BoK.

• Desired BoK Index features include:
  • Supporting a variety of users within the M&S Community of Practice (CoP)
  • Identifying and providing access to BoK topics/content
  • Providing configuration-managed views to content that changes over time"

(Lacy and Waite, 2011)
Among other benefits, M&S BoK would allow us systematic exploration of many opportunities and challenges. ✨

Cartesian approach may be useful!
Cartesian Approach: 

René Descartes: “Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences” (1637).

(However, when needed we can also be pragmatic. Remember for a camera, infinity is about after 20 meters.)

• The **first** was *to never accept anything as true which I could not accept as obviously true*; that is to say, to carefully avoid impulsiveness and prejudice, and to include nothing in my conclusions but whatever was so clearly presented to my mind that I could have no reason to doubt it.
Furthermore, *avoid the trap of single-vision understanding* which may lead to *dogmatic understanding*.

(More on several *types of understanding*:

Cartesian Approach:

- The **second** was to **divide each of the problems** I was examining in as many parts as I **could**, as many as **should** be necessary to solve them.

- The **third**, to **develop my thoughts in order**, beginning with the simplest and easiest to understand matters, in order to reach by degrees, little by little, to the most complex knowledge, assuming an orderliness among them which did not at all naturally seem to follow one from the other.
Cartesian Approach:

• And the last resolution was to make my enumerations so complete and my reviews so general that I could be assured that I had not omitted anything.
7. M&S Body of Knowledge (BoK)
   7.1 Preliminary
   7.2 BoK of Other Disciplines
   7.3 Previous & On-going Studies/Activities
   7.4 Being developed by the author
7. M&S Body of Knowledge (BoK)

7.2

Body of Knowledge of Other Areas

Business/Management
BA - Business Analysis Body of Knowledge
EA - Guide to the Enterprise Architecture Body of Knowledge
IT - Information Technology Body of Knowledge
UR - Utility Regulation Body of Knowledge

Civil Engineering
CE (Civil Engineering) Body of Knowledge

Database
Towards a Database Body of Knowledge

Family and Consumer Sciences
Body of Knowledge for Family and Consumer Sciences

Geography
Geographic Information Science and Technology Body of Knowledge

Mechanical Engineering
Body of Knowledge for Mechanical Engineering

Medicine
Guide to the Body of Knowledge for Medical Practice Management
Building the Drug Safety Body of Knowledge
7.2 BoK of Other Disciplines

Project Management
NPD - New Product Development Body of Knowledge
PM - Project Management Body of Knowledge
PM-APM - Project Management Body of Knowledge (APM)
PM - Project Management Body of Knowledge: Guide

Quality
Q - Body of Quality Knowledge
QPI - Body of Knowledge in Quality and Performance Improvement (database)
NBICE - Body of Knowledge for National Board Inspector Commission Examination
ASQ (American Society for Quality) Six Sigma Body of Knowledge
ASQ (American Society for Quality) Quality Technician Certification Body of Knowledge
TT - Towards Building a Solid Body of Knowledge in Testing Techniques
7.2 BoK of Other Disciplines

**Safety**
Beginning of Define a Body of Knowledge for Safety Practitioners
White Paper of the Body of Knowledge of the American Society of Safety Engineers Council on Practices and Standards

**Software Engineering/Computer Science**
SE - Guide to Body of Knowledge of Software Engineering
PSP (Personal Software Process) Body of Knowledge
SQM - Body of Knowledge for Software Quality Measurement
SA - Creating a Software Assurance Body of Knowledge
CST - Common Body of Knowledge for the Certified Software Tester
SRT - Replicated Studies: Building a BOK About Software Reading Techniques
CS - Overview of the Computer Science Body of Knowledge

**Systems Engineering**
SE - Guide to Systems Engineering Body of Knowledge
ISE - Towards an Information Systems Engineering Body of Knowledge
DISE - (US Department of Energy) Departmental Information Systems Engineering (DISE):
   Lifecycle: **vol 1**, Guidance: **vol 2**
ISSEP (Information Systems Security Engineering Professionals Body of Knowledge

**Usability**
Usability Body of Knowledge

**Utility Infrastructure**
BoKIR - Body of Knowledge on Infrastructure Regulation
7. M&S Body of Knowledge (BoK)

M&SBoK: Early and Contemporary Studies

Due to its importance and timeliness, several studies on M&SBoK preparation have been underway. Some of them are:

An early study was developed by the Technical Committee on Simulation of the IEEE Computer Society (CS-TCSim-BoK). However, this study did not have an impact on the discipline.

One of the on-going efforts is the establishment of a clearinghouse as well as contribution to the M&SBoK studies by an avid supporter of the M&SBoK studies, i.e., B. Waite (Aegis Docushare). Many Workshops are organized (e.g., Waite and Skinner 2003, Waite 2004).

Fairchild (2002) presented his version of M&SBoK by partitioning it in four areas:

1. Simuland: What is simulated,
2. Purpose: Why it is simulated,
3. Technique: How it is simulated (solution method, execution control, interfacing –inputs and outputs–, classical mathematics, and soft computing),
4. Programmatics: How it is controlled (technology and management).

Birta published an M&SBoK (Birta, Birta 2003) which caused Elzas to publish a critique (Elzas).

Studies elaborating on an “ideal simulationist” such as reports (Madewell and Swain 2003, Rogers 1997) and their critiques also contain valuable information.

A section at the references –titled M&SBoK – Early Studies & Other Contributions– is dedicated for this purpose.
7. M&S Body of Knowledge (BoK)

M&SBOK - Early Studies & Other Contributions


IEEE CS – Technical Committee on Simulation. *Body of Knowledge*

Loftin, B.R. et al. (2004). Modeling and Simulation Body of Knowledge (BOK) and Course Overview.


7. M&S Body of Knowledge (BoK)

7.3 Previous & On-going Studies/Activities


- Interwoven with Bloom’s taxonomy of learning.
- Limited usefulness
7. M&S Body of Knowledge (BoK)

7.4 Being developed by the author

- Background
- Core Areas of the M&S BoK
- Supporting Domains
- References
7. M&S Body of Knowledge (BoK)

7.4 Being developed by the author

• Background

Publications, Presentations and other relevant activities of Dr. Tuncer Ören on:

• Modeling and Simulation *Body of Knowledge* (M&S BoK) &
• *Comprehensive and Integrative View* of M&S (Big Picture)

(Since 2005, 20 publications & 14 presentations)
# Modeling and Simulation Body of Knowledge (M&S BoK) - Index

Draft Version 11b  
(In version 11, major changes have been made; 
In version 11b, some minor changes are made and some links are updated)  
updated and © by: Dr. Tuncer Ören - 2012-04-03 (yyyy-mm-dd)  
(The format is especially chosen to reveal the structure and the content of the M&SBOK index)

Please also consider:  
[Modeling and Simulation Body of Knowledge Index: An Invitation for the Final Phases of its Preparation](http://www.site.uottawa.ca/~oren/MSBOK/MSBOK)  
M&S Magazine of SCS, Vol. 1, Issue 4 (October 2010), by Tuncer Ören and Bill Waite  
Publication and Presentations of Dr. Tuncer Ören on [M&SBOK](http://www.site.uottawa.ca/~oren/MSBOK/MSBOK)

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Part 1. Background
(Preliminary, Introduction, Terminology, Comprehensive View)

1.1 Preliminary

M&SBOK Development Project
Version History and Milestone Reports
Members of the Review Committee
Recommendations by Members of the Review Committee

1.2 Introduction

Some Vision Quotations
High level Recognition of M&S
  - US Congressional Modeling and Simulation Caucus
  - M&S in China
Stakeholders and Possible Interests for M&SBOK
  - M&S Associations and Organizations
  - For a comprehensive World Medical Simulation Centre Database
    click here then select the region on the map
  - Individuals, Certified Simulationists
  - Workforce Development
- Professional Certification for:
  --CMSP (Certified Modeling and Simulation Professional) designation:
    M&SPCC – M&S Professional Certification Commission

Professional Concerns
   (Professionalism, Achievements, Progress, and Challenges)
Why an M&SBOK? Rationale and Possible Usages - Some Views
M&SBOK: Early and Contemporary Studies
Presentation Formats of: Other BOK studies, as well as M&S BOK studies
1.3 Terminology

**Background:** Definitions of "Definition"
Some **M&S Definitions:** On Internet:

From Defense-Related Sources and From Civilian Sources, Suggested in this Study

SCS M&S Magazine, 2:3 (July), pp. 142-151.

Collections of Special Terms
- An Inventory of **over 8400 M&S Terms**
- Terms and Concepts Related with **Simulation and Similarity**
- Terms Related with **Experiment, Experience and Training**

**M&S Dictionaries**
- List of **M&S Dictionaries**
- M&SNet's **M&S Dictionary Project**
  -- version 1: English-French-Turkish (over 4000 terms)
  -- version 2: English-French-Italian-Spanish-Turkish
    (over 10 000 terms, in preparation)
  -- version 3: English-Chinese (about 9000 terms, in press)

**Ontology-Based Dictionaries**
- Ontology-Based Dictionary of **V&V** (rationale and an example)
- Ontology-Based Dictionary of **Understanding**
- Ontology-Based Dictionaries of Other M&S Terms
1.4 Comprehensive View

Challenges and Benefits of a Comprehensive and Consolidated View of M&S

Different perspectives. Domain-independent Application Areas


Simulation and Reality: The Big Picture and Challenges

Keynote of ISMC'09 (International Simulation Multiconference) Sponsored by SCS and SISO, 2009 July 13-16, Istanbul, Turkey

Part 2. M&S BOK Core Areas

Science / Methodology
Types of simulation
Life cycles of M&S
Computers & Computation
Technology
Infrastructure
Reliability
Ethics,
Maturity

History
Trends
Challenges, and Desirable Features
Enterprise
2.1 Science / Methodology

Data

Issues (types of data and terms related with data)
Variables (types of variables and terms related with variables)
-- Input Variables (types of inputs and terms related with inputs)
Values (types of values and terms related with values)

Models & Modeling Formalisms

Models (types of models and terms related with models)

Issues: Reusability, Interoperability, Composability, Dynamic composability
Conceptual models and Conceptual modeling
Taxonomy of simulation models
Modeling formalisms (list of modeling formalisms)
Modeling physical systems

(By Prof. Dr. François Cellier (in English, in German, in Spanish)
Modeling qualitative systems

Model Building

Modeling
Model composition (and dynamic model composition)
Model-base Management
  Model search, semantic model search
  Model integrity

Model Parameters and Parameter-base Management
  Parameters, Auxiliary parameters
  Deterministic parameters, Stochastic parameters

Model Characterization (Descriptive model analysis)
  for Model comprehensibility
    -- Model documentation (static and dynamic documentations)
    -- Model ventilation (to examine its assumptions, deficiencies, limitations, etc.)
  for Model usability
    -- Model referability

Model Evaluation (Evaluative Model Analysis)
Model evaluation with respect to:
  A Modeling Formalism (Consistency of model representation)
    Evaluation of:
      (Static structure of: component models, Coupled models, Models of system of systems)
      (Dynamic structure of: state transitions, Output function(s),
        Structural change, Dynamic coupling)
    Model robustness
Another Model (Model Comparison)
Structural model comparison
-- Model verification (Types of and techniques and tools for model verification)
-- Model checking (for homomorphism, isomorphism, endomorphism)
-- Model equivalencing
Behavioral model comparison (under same or different scenarios)

Real System (For Analysis Problems)

Technical System Specifications (For Design and Control Problems)
Model qualification (model realism, model adequacy, model correctness analysis)
Model validity
(Types of and techniques and tools for model validity)

Goal of the Study
Model relevance (domain of intended application(s); range of applicability of a model)

Model Transformation
Types of model transformation (copying, reduction, pruning, simplification, elaboration, isomorphism, homomorphism, endomorphism)
Experimentation (Main issues related with experimentation)
(types of experimentation and terms related with experimentation)
Statistical Design of Experiments
Computer-Aided Systems for Design of Experiments
Computer-Aided Systems for Execution of Experiments
Data compression techniques (deterministic, stochastic)
Analysis of simulation data

Model Behavior (Main issues related with model behavior)
(types of model behavior and terms related with behavior)
Types of Model Behavior
Generation of Model Behavior
Processing of Model Behavior

2.2 Types of Simulations (types of simulation and terms related with simulation)
2.3 Life Cycles of M&S
   for Experimentation
   to Gain Experience for Training to enhance
   motor skills (virtual simulation: simulators, virtual simulators)
   to Gain Experience for Training to enhance:
   decision-making and communication skills
   (constructive simulation - serious games: business gaming, war gaming, peace gaming)
   to Gain Experience for Training to enhance:
   operational skills (live simulation)
   for Entertainment (simulation games)

2.4 Technology
   M&S languages
   M&S tools and environments
   Computer-Aided Problem Solving Environments
   (for Modeling, Model Processing, Program Generation, Experimentation, and Problem Solving)
2.5 **Infrastructure**
   - Standards
   - Code of Best Practice
   - Lessons Learned
   - Resource Repositories

2.6 **Reliability** & QA of M&S and types of:
   - Errors ([types of errors and terms related with errors](#))
   - Validation ([types of validation and terms related with validation](#))
   - Verification ([types of verification and terms related with verification](#))
   - Built-in Quality Assurance
   - Failure Avoidance

2.7 **Ethics**
   - ([at SCS](#)) ([at Tuncer Ören's site](#))

2.8 **History**

2.9 **Trends, Challenges, and Desirable Features**

2.10 **Enterprise**

2.11 **Maturity**
A Code of Ethics (by SCS) for Professional Simulationists exist. The Code is adopted by:

- Society for Modeling and Simulation International
- Mcleod Institute of Simulation Sciences
- McLeod Modeling and Simulation Network
- Simulation Interoperability Standards Organization
- Alabama Modeling and Simulation Council
- Student Chapters of the SCS
- NATO Modeling and Simulation Group
- DLM . . .
M&S: History

Hardware:
- Analog simulation: Differential analyzer
- Hybrid simulation
- Digital simulation

Software: languages, tools, techniques, environments
- M&S languages: Early languages and their critique
- M&S environments: Conventional, AI support

Applications
- Canon ball problem
- Simulators: First pilot trainer of Link (1929)
- Early applications: Space flight simulations

Techniques:
- Visualization for simulators, synthetic environments
Part 3. M&S BOK:
Supporting Domains (Independent of the Application Areas)

Computers and Computation, Science Areas, Engineering Areas, Management Areas
Mutual Contributions of M&S

3.1 Computers and Computation
Impact of Computers
- Digital, hybrid, analog; mobile, cloud
- Extreme scale computers (petascale simulation, exascale simulation)
Synergies Soft Computing and M&S
- Fuzzy logic and simulation
- Neural networks and simulation
Synergies of Artificial Intelligence & M&S
Agent-Directed Simulation
- Agent-based models
- Agent simulation (and agent-initiated simulation)
- Agent-supported simulation
- Agent-based simulation
3.2 Supporting Science Areas
Systems Science
Physics
Mathematics (Differential Equations, Numerical Analysis, Probability, Statistics)
Queuing Theory

3.3 Supporting Engineering Areas
Systems Engineering
Visualization

3.4 Supporting Management Areas
Enterprise Management
Project Management
Product Management

3.5 Education
Education
Part 4. References

(See also: M&S BoK Sharepoint of SimSummit)

M&S Portals
Social Network - Ning by Prof. Dr. Gabriel Wainer
M&S Blogs
Google News on Simulation

References by Authors
References by Application Areas
References by Topics including:

Body of Knowledge
- BOK of Other Areas
- M&SBOK - Early Studies & Other Contributions
- M&SBOK - Recent Contributions
- Dr. Tuncer Ören's publications and activities on M&SBOK

M&S
- Master Plans
- Dictionaries
- Epistemology
- Ontologies
- Taxonomies
- Standards

- Composability
- Reusability
- Interoperability
- Conceptual Models

M&S &
- Systems Engineering
- Simulation Professionals & Needed Qualifications
1. Introduction
2. Importance of M&S
3. M&S & Education
4. Richness of M&S
5. Professionalism in M&S
6. Stakeholders of M&S
7. M&S Body of Knowledge
8. Conclusion
8. Conclusion

M&S offers many opportunities & challenges to solve problems of unprecedented complexities.

As simulationists, we can continue to:
1. sharpen our tools,
2. abide by ethics, &
3. offer our services.
1. Introduction
2. Importance of M&S
3. M&S & Education
4. Richness of M&S
5. Professionalism in M&S
6. Stakeholders of M&S
7. M&S Body of Knowledge
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Thank you for your attention!

Q & A