**Modeling and Simulation Body of Knowledge (M&S BoK)** – **Index**

This site reflects the work of:

the **SCS Technical Committee on M&S Body of Knowledge Index** (Tiger Team*)*

founded in 2016 with the authorization of Prof. Lin Zhang, the then President of the [SCS](http://scs.org/)

(The Society for Modeling & Simulation International)

updated by Dr. Tuncer [Ören](http://www.site.uottawa.ca/~oren/): 2017-04-18

ISO 8601: (yyyy-mm-dd)

* The [members](http://www.site.uottawa.ca/~oren/MSBOK/TT.pdf) of the Committee
* The **basic agreement** to develop the M&S Body of Knowledge Index
* **Status**:
  + Part 1 is under scrutiny [2017-04-18 -

**Index**

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| --- | --- |
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| Part 2. M&SBOK: | Core Areas |
| Part 3. M&SBOK: | Supporting Domains |
| Part 4. References: | M&S Portals, M&S Blogs, Google News on Simulation  References by Authors, Application Areas, Topics |

**Part 1. Background**

* 1. Preliminary
  2. Terminology
  3. Comprehensive View of M&S

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| **1.1** | **Preliminary** | | |
|  | 1.1.1 | [Recommendations](http://www.site.uottawa.ca/~oren/MSBOK/ComRecs.pdf) by Members of the Technical Committee | |
|  | 1.1.2 | Some [Vision Quotations](http://www.site.uottawa.ca/~oren/MSBOK/quotations.pdf) | |
|  | 1.1.3 | High level Recognition of M& | |
|  |  | 1.1.3.1 | US Congressional Modeling and Simulation [Caucus](http://soling.syr.edu/DestinyUSA/UpdateDocs/MSCaucus.htm) |
|  |  | 1.1.3.2 | US [House Resolution 487](https://www.congress.gov/bill/110th-congress/house-resolution/487) (introduced by  [Rep. Forbes, J. Randy [R-VA-4]](https://www.congress.gov/member/j-forbes/F000445) 2007 June 14) |
|  | 1.1.4 | [Stakeholders](http://www.site.uottawa.ca/~oren/MSBOK/stakeholders.pdf) and Possible Interests for M&SBOK | |
|  |  | 1.1.4.1 | M&S [Associations and Organizations](http://www.site.uottawa.ca/~oren/links-MS-AG.pdf) |
|  |  | 1.1.4.2 | For a comprehensive World Medical Simulation Centre Database  click [here](http://www.bmsc.co.uk/) then select the region on the map  (Maintained by [BMSC](http://www.bmsc.co.uk/) – Bristol Medical Simulation Centre)) |
|  |  | 1.1.4.3 | [Individuals, Certified Simulationists](http://www.site.uottawa.ca/~oren/MSBOK/individuals.pdf) |
|  |  | 1.1.4.4 | Workforce Development |
|  |  | 1.1.4.5 | Professional Certification for **CMSP** (Certified Modeling and Simulation Professional) designation: [M&SPCC](http://www.simprofessional.org/index.html) – M&S Professional Certification Commission |
|  | 1.1.5 | [Professional Concerns](http://www.site.uottawa.ca/~oren/MSBOK/proConcerns.pdf)  (**P**rofessionalism, **A**chievements, **P**rogress, and **C**hallenges) | |
|  |  | 1.1.5.1 | Why an M&SBOK? Rationale and Possible Usages – Some [Views](http://www.site.uottawa.ca/~oren/MSBOK/views.htm) |
|  |  | 1.1.5.2 | [Other BOK studies](http://www.site.uottawa.ca/~oren/MSBOK/refs-otherBOKs.pdf) and their presentation formats |
|  | 1.1.6 | M&SBOK | |
|  |  | 1.1.6.1 | [Early Studies](http://www.site.uottawa.ca/~oren/MSBOK/refs_MSBOK.pdf) |
|  |  | 1.1.6.2 | Tuncer Ören’s [publications and activities on MSBOK](http://www.site.uottawa.ca/~oren/pubsList/MSBOK.pdf) |

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| **1.2** | **Terminology** | | |
|  | 1.2.1 | [Background](http://www.site.uottawa.ca/~oren/MSBOK/terminology-background.pdf): Definitions of "Definition" | |
|  | 1.2.2 | **Definitions** of simulation: | |
|  |  | 1.2.2.1 | Ören, T.I. (2011). [The Many Facets of Simulation through a Collection of about 100 Definitions](http://scs.org/wp-content/uploads/2016/12/2011-04-Issue06-6.pdf). SCS M&S Magazine, 2:2 (April), pp. 82-92. |
|  |  | 1.2.2.2 | Ören, T.I. (2011). [A Critical Review of Definitions and About 400 Types of Mode and Simulation](http://scs.org/wp-content/uploads/2016/12/2011-07-Issue07-7.pdf). SCS M&S Magazine, 2:3 (July), pp. 142-151. |
|  | 1.2.3 | Collections of Special Terms | |
|  |  | 1.2.3.1 | An Inventory of [over 8400 M&S Terms](http://www.site.uottawa.ca/~oren/MSBOK/terms-concepts.pdf)  (Currently, the list that I maintain has over 12 500 terms) |
|  |  | 1.2.3.2 | Terms and Concepts Related with [Similarity](http://www.site.uottawa.ca/~oren/MSBOK/terms-similarity.pdf) |
|  | 1.2.4 | [M&S Dictionaries](http://www.site.uottawa.ca/~oren/MSBOK/MSdictionaries.pdf) | |
|  | 1.2.5 | Ontology-Based Dictionaries | |
|  |  | 1.2.5.1 | Ontology-Based Dictionary of [V&V](http://www.site.uottawa.ca/~oren/MSBOK/terms-ob-dic-VV.htm) (rationale and an example) |
|  |  | 1.2.5.2 | Ontology-Based Dictionary of [Understanding](http://www.site.uottawa.ca/~oren/pubs-pres/2007/pub-ADS-07-understanding) |

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| **1.3** | **Comprehensive View of M&S** | | |
|  | 1.3.1 | **Challenges and Benefits of a** [Comprehensive and Consolidated View](http://www.site.uottawa.ca/~oren/MSBOK/MS-big-picture.htm) of M&S | |
|  | 1.3.2 | [Different perspectives](http://www.site.uottawa.ca/~oren/MSBOK/MS-big-picture-perceptions.pdf) | |
|  | 1.3.3 | [Domain-independent Application Areas](http://www.site.uottawa.ca/~oren/MSBOK/catSimApps.pdf) | |
|  | 1.3.4 | Tuncer Ören’s [publications and activities](http://www.site.uottawa.ca/~oren/pubsList/MSBOK.pdf) | |
|  | 1.3.5 | Other publications and activities | |
|  | 1.3.6 | Select articles: | |
|  |  | 1.3.6.1 | Ören, T.I. (2010). Simulation and Reality: The Big Picture. (Invited paper for the inaugural issue) International Journal of Modeling, Simulation, and Scientific Computing (of the Chinese Association for System Simulation - CASS) by the World Scientific Publishing Co. China. [Vol. 1, No. 1](http://www.worldscinet.com/ijmssc/01/0101/S17939623100101.html), 1-25. (Based on the keynote speech of the 2009 International Simulation Multiconference of SCS and SISO, July 13-16, 2009, Istanbul, Turkey. ([Presentation](http://www.site.uottawa.ca/~oren/pubs-pres/2009/pres-07-ISMC-keynote.pdf)) |
|  |  | 1.3.6.2 | Ören, T.I. (2009). [Modeling and Simulation: A Comprehensive and Integrative View](http://media.wiley.com/product_data/excerpt/12/35274078/3527407812.pdf). In L. Yilmaz and T.I. Ören (eds.). Agent-Directed Simulation and Systems Engineering. Wiley Series in Systems Engineering and Management, Wiley-Berlin, Germany, pp. 3-36. |
|  |  | 1.3.6.3 | Ören, T.I. (2007). [The Importance of a Comprehensive and Integrative View of Modeling and Simulation](http://www.site.uottawa.ca/~oren/pubs-pres/2007/pub-0706-SCSC-BigPicture.pdf). Proceedings of the Summer Simulation Conference. San Diego, CA, July 15-18, '07. |

**Part 2. M&S BOK Core Areas**

2.1 Science / Methodology

2.2 Types of simulation

2.3 Life cycles of M&S

2.4 Technology

2.5 Infrastructure

2.6 Reliability

2.7 Ethics

2.8 History

2.9 Trends, Challenges, and Desirable Features

2.10 Enterprise

2.11 Maturity

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| * 1. **Science / Methodology** | | |
|  | **Data** | |
|  |  | [Issues](http://www.site.uottawa.ca/~oren/MSBOK/core-sci-data.pdf) |
|  |  | ([types of data and terms related with data](http://www.site.uottawa.ca/~oren/MSBOK/terms-data.pdf))                                 (over 260 terms) |
|  |  | Variables ([types of variables and terms related with variables](http://www.site.uottawa.ca/~oren/MSBOK/terms-variables.pdf))     (over 160 terms) |
|  |  | -- Input Variables ([types of inputs and terms related with inputs](http://www.site.uottawa.ca/~oren/MSBOK/terms-inputs.pdf)) (over 110 terms) |
|  |  | Values ([types of values and terms related with values](http://www.site.uottawa.ca/~oren/MSBOK/terms-values.pdf))                 (over 90 terms) |
|  |  | |
|  | **Models & Modeling Formalisms** | |
|  | **Models** ([types of models and terms related with models](http://www.site.uottawa.ca/~oren/MSBOK/terms-models.pdf))                  (over 1100 terms) | |
|  | Issues: Reusability, Interoperability, Composability, Dynamic composability | |
|  | Conceptual models and Conceptual modeling | |
|  | Taxonomy of simulation models (some [M&S taxonomies](http://www.site.uottawa.ca/~oren/pubsList/taxonomies.pdf)) | |
|  | Modeling formalisms (list of modeling formalisms) | |
|  | Modeling physical systems  (By Prof. Dr. Fançois [Cellier](http://www.inf.ethz.ch/personal/fcellier/index_engl.html) (in [English](http://www.inf.ethz.ch/personal/fcellier/Lect/MMPS/Ppt/mmps_ppt_engl.html), in [German](http://www.inf.ethz.ch/personal/fcellier/Lect/MMPS/Ppt/mmps_ppt.html), in [Spanish](http://www.inf.ethz.ch/personal/fcellier/Lect/MMPS/Ppt/mmps_ppt_cast.html)) | |
|  | 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 | |

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|  | **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](http://www.site.uottawa.ca/~oren/MSBOK/core-sci-exp.pdf))     ([types of experimentation and terms related with experimentation](http://www.site.uottawa.ca/~oren/MSBOK/terms-experiment.pdf)) (over 100 terms) | |
|  |  | 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](http://www.site.uottawa.ca/~oren/MSBOK/core-sci-behavior.pdf))     ([types of model behavior and terms related with behavior](http://www.site.uottawa.ca/~oren/MSBOK/terms-behavior.pdf))  (over 120 terms) | |
|  |  | Types of Model Behavior |
|  |  | Generation of Model Behavior |
|  |  | Processing of Model Behavior (Analytical, Statistical) |
|  |  | Visualization of Model Behavior (3-D, animation) |
|  |  |  |
| **2.2 Types of Simulations** (types of simulation and terms related with simulation)(over 850 terms) | | |
|  |  | For over 500 types of simulation, see the appendix of the article at: [link](http://www.site.uottawa.ca/~oren/y/2012/-08-MS-BOK.pdf) |
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| **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**](http://www.site.uottawa.ca/~oren/MSBOK/core-technology.pdf) | | |
|  | 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**](http://www.site.uottawa.ca/~oren/MSBOK/core-infrastructure.pdf) | | |
|  | [Standards](http://www.site.uottawa.ca/~oren/MSBOK/refs-standards.pdf)  Code of Best Practice  Lessons Learned  Resource Repositories | |
|  |  |  |
| **2.6** [**Reliability**](http://www.site.uottawa.ca/~oren/MSBOK/core-reliability.pdf) **& QA of M&S and types of:** | | |
|  | Errors ([types of errors and terms related with errors](http://www.site.uottawa.ca/~oren/MSBOK/terms-errors.pdf))                            (over 200 terms) | |
|  | Validation ([types of validation and terms related with validation](http://www.site.uottawa.ca/~oren/MSBOK/terms-validation.pdf))             (over 50 terms) | |
|  | Verification  (types of verification and terms related with verification) | |
|  | Built-in Quality Assurance | |
|  | Failure Avoidance | |
|  |  |  |
| **2.7 Ethics** | | |
|  |  | (at [SCS](http://www.scs.org/ethics/)) (at Tuncer Ören's [site](http://www.site.uottawa.ca/~oren/SCS_Ethics/SCS_Ethics.pdf)) |
|  | | |
| **2.8** [**History**](http://www.site.uottawa.ca/~oren/MSBOK/core-history.pdf) | | |
|  |  |  |
| **2.9** [**Trends, Challenges, and Desirable Features**](http://www.site.uottawa.ca/~oren/MSBOK/core-trends-challenges.pdf) | | |
|  |  |  |
| **2.10** [**Enterprise**](http://www.site.uottawa.ca/~oren/MSBOK/core-enterprise.pdf) | | |
|  |  | Business practice: |
|  |  | Economics of M&S: [SISO](http://www.sisostds.org/StandardsActivities/StudyGroups/EconomicsofMSSSG.aspx), [Bill Waite](http://www.sim-summit.org/simsummit/0311/0311e.pdf) |
|  |  | Enterprise infrastructure |
|  |  |  |
| **2.11** [**Maturity**](http://www.site.uottawa.ca/~oren/MSBOK/core-maturity.pdf) of | | |
|  |  | Individuals |
|  |  | Organizations |
|  |  | Educational programs (individual courses, as well as undergraduate and graduate degree  programs and professional development seminars). |

**Part 3. M&S BOK:**

**Supporting Domains (Independent of the Application Areas)**

3.1 Computers and Computation

3.2 Supporting Science Areas

3.3 Supporting Engineering Areas

3.4 Supporting Management Areas

3.5 Education

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| **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](http://www.agent-based-models.com/ABM_Lab/Home.html) |
|  | -Agent simulation (and agent-initiated simulation) |
|  | -Agent-supported simulation |
|  | -Agent-monitored simulation |
| **3.2 Supporting Science Areas** | |
|  | Systems Science (a historic ref by [Ören & Zeigler](http://sim.sagepub.com/content/88/9/1033.abstract?etoc)) |
|  | Physics |
|  | Mathematics (Differential Equations, Numerical Analysis, Probability, Statistics) |
|  | Queuing Theory |
| **3.3 Supporting Engineering Areas** | |
|  | [Systems Engineering](http://www.incose.org/) |
|  | Visualization |
| **3.4 Supporting Management Areas** | |
|  | Enterprise Management |
|  | Project Management |
|  | Product Management |
| **3.5 Education** | |
|  | [Education](http://www.site.uottawa.ca/~oren/MSBOK/simEd.htm) |
|  |  |

**Part 4. References**

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| M&S [Portals](http://www.site.uottawa.ca/~oren/MSBOK/refs-MS-Portals.pdf) | |
| Social Network | |
| M&S [Blogs](https://www.google.ca/search?hl=en&ie=UTF-8&q=simulation&tbm=blg#hl=en&tbm=blg&sclient=psy-ab&q=%22blog+simulation%22&oq=%22blog+simulation%22&gs_l=serp.12...44781.50464.0.53094.7.7.0.0.0.3.1501.3543.0j1j6-1j1j1.4.0.les%3B..0.0...1c.1.Ew--SlPb4Qs&pbx=1&bav) | |
| Google [News on Simulation](http://news.google.ca/?hl=en&q=simulation&ie=UTF-8&client=blogsearch) | |
|  | |
| References [by Authors](http://www.site.uottawa.ca/~oren/MSBOK/refs-byAuthors.pdf) | |
| References [by Application Areas](http://www.site.uottawa.ca/~oren/MSBOK/refs-byApps.pdf) | |
| References [by Topics](http://www.site.uottawa.ca/~oren/MSBOK/refs-byTopics.pdf) 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 |
|  |  |