

China - September 2011

Beijing: Beihang University, School of Automation and Electrical Eng.

Changsha: National Univ. of Defense Technology, System Simulation Lab.

China Lecture – 1b

Modeling and Simulation: Body of Knowledge

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Based on: (1/2)

- Ören, T.I. (2011). *A Basis for a Modeling and Simulation Body of Knowledge Index: Professionalism, Stakeholders, Big Picture, and Other BoKs.* SCS M&S Magazine, 2:1 (Jan.).
- Ören, T.I. and B. Waite (2010). *Modeling and Simulation Body of Knowledge Index: An Invitation for the Final Phases of its Preparation.* SCS M&S Magazine, 1:4 (Oct).
- Lacy, L.W., Gross, D.C., Ören, T., and B. Waite (2010). *A Realistic Roadmap for Developing a Modeling and Simulation Body of Knowledge Index.* Proceedings of SISO (Simulation Interoperability Standards Organization) Fall SIW (Simulation Interoperability Workshop) Conference, Orlando, FL, September 20-24, 2010.

Based on: (2/2)

- **2007 November 26-29, Orlando, Florida**
I/ITSEC - Interservice/Industry Training, Simulation Conference
Tutorial (with Bill Waite): [Need for and Structure of an M&S Body of Knowledge](#)
- Ören, T.I. (**2006**). Body of Knowledge of Modeling and Simulation (M&SBOK): Pragmatic Aspects. EMSS 2006 - 2nd European Modeling and Simulation Symposium, ISBN: 84-690-0726-2, pp. 327-336. 2006 October 4-6, Barcelona, Spain.
- **2006 September 22 - October 23, Barcelona, Spain**
University of Barcelona (Universitat Autònoma de Barcelona)
- Barcelona lectures – 1: Modeling and simulation (M&S): A comprehensive view and an introduction to the Body of Knowledge
- Ören, T.I. (**2005** - Invited Tutorial). Toward the Body of Knowledge of Modeling and Simulation (M&SBOK), In: Proc. of I/ITS (Interservice /Industry Training, Simulation Conference). Nov. 28 - Dec. 1, Orlando, Florida; paper 2025, pp. 1-19.

Additional reference:

➤ **2009 March 4 and 11**

Introductory Webinars: Modeling & Simulation

Body-of-Knowledge Index (M&S BOK Index)

- (Bill Waite and Tuncer Ören) [slides](#) (9.69 MB)

(from the M&S Body-of-Knowledge:

[BoK Sharepoint site](#))

MESSAGE (1/2)

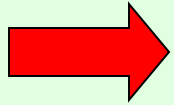
Simulation offers a very rich paradigm

1. to **perform experiments** with dynamic models &
 2. to **provide experience** either
 - 2.1 for **entertainment** or
 - 2.2 to **develop/enhance** three types of **skill**,
i.e., motor skills, decision making skills, &
operational skills.
- *Lack of an explicit consensus of an M&S Body-of-Knowledge inhibits its evolution.*

MESSAGE (2/2)

- Having M&S acknowledged as a distinct branch of knowledge is important in **advancing the profession, industry and marketplace.**
- **A concerted effort** will ensure that M&S as a profession evolves in a timely manner.
- This will **enhance its usefulness** in many complex problems.

OUTLINE



- I. INTRODUCTION**
- II. BOK *TECHNICAL CONCEPTS***
- III. M&S BOK *CONTENT***
- IV. M&S BOK *EVOLUTION***
- V. CONCLUSION**

INTRODUCTION



1. Thesis

2. Context / Circumstances

- a. Diversity M&S Practice**
- b. Comprehensive Scope of M&S**

3. Stakeholder Needs / Opportunities

Thesis

- Specifying the information that constitutes the M&S body of knowledge is:
 - essential to ***relating M&S to science and technology***
 - paramount in ***establishing the identity of M&S*** as a distinctive discipline
- Having M&S acknowledged as a distinct branch of knowledge is important in ***advancing the recognition*** of the profession, industry and marketplace.
- ***A concerted effort is needed*** to ensure that M&S as a profession evolves in a timely manner.

Thesis - Lemma

- M&S technology, profession, industry and market are evolving
- Lack of an explicit consensus M&S Body-of-Knowledge inhibits this evolution
- Broad-based collaboration to specify the M&S BOK is desired, and feasible
- An open-source program of activity can serve to achieve the objective BOK commensurate with stakeholder needs and interests particularly in M&S workforce development (e.g. BOK, curricular management, professional certification, etc.)
- Socialization of the topic across organizational constituencies and agendas is underway ... Prototyping is about to begin

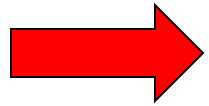
Your interest, participation, and influence **will** make a difference

INTRODUCTION

1.Thesis

2.Context / Circumstances

a. Diversity M&S Practice (*M&S 101*)



b. Comprehensive Scope of M&S

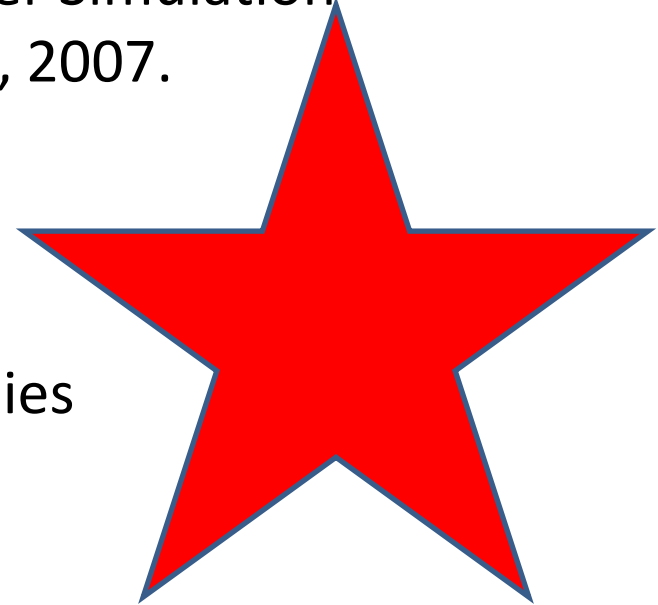
3.Stakeholder Needs / Opportunities

Comprehensive Scope of M&S:

Ören, T.I. (2007). The Importance of a Comprehensive and Integrative View of Modeling and Simulation. Proceedings of the Summer Simulation Conference. San Diego, CA, July 15-18, 2007.

Aims & importance :

- Explore different **perceptions** of M&S studies
- *Present them in a unified framework*
- Underline **advantages** of each perception
- Hence, **benefit from the rich paradigms** M&S provide



Possible perceptions of M&S studies

(Each perspective discriminate different types of simulation & has pragmatic consequences)

1. Purpose of use
2. Problem to be solved
3. Connectivity of operations of simulation and real system
4. Types of knowledge processing
5. Philosophy of science

According to Type of Knowledge Processing

Simulation is perceived as:

Computational activity (process)

Systemic activity (since 1960s)

Model-based activity (since 1970s)

Knowledge generation activity

Knowledge processing activity

Possible Stakeholders of M&SBOK:

Stakeholder

Possible uses

- Novice

- Explore the discipline
- Determine applicability

- Practitioner

- Expansion of knowledge
- Specific problem solving
- Identification and evaluation of techniques

- Learner

- Expansion of knowledge
- Verification of derived knowledge
- Accomplishment of corporate or certificate requirements

Possible Stakeholders of M&SBOK:

Stakeholder Possible uses

- Academia
 - Referencing
 - Expansion of knowledge
 - Curriculum/course development (including degree programs, academic/professional development courses)
- Industry
 - Marketing
 - Offering professional courses
 - Personal selection/training
 - Technical investment

Possible Stakeholders of M&SBOK:

Stakeholder

Possible uses

- Funding Agencies
 - Acquirer/User of Product/Service
 - Market
 - Policy Makers (National, International)
- Determine priorities
 - Source selection
 - Evaluation of products, services, techniques, vendors/providers
 - Formation of market, niche markets, and workforce
 - Set policies for the country/countries/region(s) to benefit from M&S

Possible Stakeholders of M&SBOK:

Stakeholder Possible uses

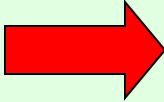
- Professional Societies*
- Guidance
- Serve the members properly

* 80 Civilian M&S Societies

and 25 Defense M&S Groups are listed at :

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

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 - II. BOK *TECHNICAL CONCEPTS*
 - III. M&S BOK *CONTENT*
 - IV. M&S BOK *EVOLUTION*
 - V. CONCLUSION

BOK Definition

Body of Knowledge is:

- "Structured knowledge that is used by members of a discipline to guide their practice or work."
- "The prescribed aggregation of knowledge in a particular area an individual is expected to have mastered to be *considered* or *certified as a practitioner.*"

BOK for M&S

- “The Body-of-Knowledge for M&S (M&S BOK) is the domain of knowledge (information) and capability (competency) that serves to provide identity to the M&S community-of-practice ... and subsequently the M&S profession, industry, and market. “
- “A pragmatic view is that: “M&S BOK is a stepping stone *to unifying the M&S community.*”

BOK as *Content* versus BOK as *Index*

- The content of the BOK is knowledge-information.
- BOK guide is an index to the BOK contents and their relationships - The *index* of a BOK is a set of pointers providing 'handles' whereby the subject information content may be denoted, identified, accessed and manipulated.
- Overloading terminology is common – context provides semantic discrimination.

BOK Attributes

- Include identification of :
 - *elements* of the M&S BOK and
 - *relationships*
 - among elements of M&S BOK and
 - between elements of M&S BOK and other BOKs
- Are Authoritative
- Are Comprehensive
- Are Discriminative
- Are Useful
- ...

OUTLINE

I. INTRODUCTION

II. BOK TECHNICAL CONCEPTS

III. M&S BOK CONTENT

- Three Aspects of Professionalism**
- Supporting Domains of M&S**
- Core Areas of M&S**

IV. M&S BOK EVOLUTION

V. CONCLUSION

3 Aspects of Professionalism in M&S (1)

1. Knowledge

To solve problems, i.e., knowledge of

- Application area(s)
- Supporting domains
- M&S core

To guide attitude in problem solving

- Code of professional ethics

3 Aspects of Professionalism in M&S (2)

2. Professional activities

- Knowledge generation and dissemination
(Academia, R&D)
- Application (generation of products/services)
(Industry)

3. Professional maturity/conduct

- Professional and ethical conduct
- Certification of professionalism

M&SBOK - Supporting Domains

Science

- Systems science
- Physics
- Differential equations
- Numerical analysis
- Probability
- Statistics
- Queuing theory
- Computer Science
- Artificial Intelligence
- Software agents

Engineering

- Systems engineering
- Software engineering

Management

- Enterprise mgmt
- Project mgmt
- Product mgmt

Systems Engineering

- **Systems Engineering ... interdisciplinary approach ... to enable the realization of successful systems. ... defining customer needs and required functionality ..., documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: (Concept, Design, Development, Operations, Performance, Test, Manufacturing, Cost & Schedule, Training & Support, Disposal)**
- **Systems Engineering integrates ... disciplines ... into a team effort forming a structured development process Systems Engineering considers ... business and technical ...**



Necessity and Sufficiency Criteria for M&S 'Core' Concepts

- Completeness
 - Comprehensiveness of scope
 - Detail of basis
- Definitiveness
 - Selective discrimination versus 'other' fields
 - Unique in ensemble, not individually
- Unitary Cohesion
- Correctness
 - Consistency
 - Truth

Desiderata for Specification of of M&S 'Core' Concepts

- Independence
- Minimalism
 - (therefore) Orthogonality
- Plausibility
- Richness
- Concreteness
- Provability ?

Existence

- Existence – *a priori* assumption that the referent exists, *de facto* if not *de jure*
- The fundamental significance of existence for M&S is that one way or another, there is something that is being represented.
- Discriminating the referent is a profound challenge to practice
- Precision in referential specification is both necessary and uncommon

Intention

- Intention – purposeful, volitional assumption of specified consequence (versus ‘intentionality’)
- The intentional targets of the M&S asset are, after all, achievement of adequate representation and support of necessary inference
- Intention drives developmental implementation and grounds qualification

Causality and Determinism

- Causality - the guarantee that a given antecedent event or change-of-state in a system is a necessary and sufficient condition for some given subsequent event or change-of-state in the same system.
- Appreciating causality in referents and achieving effective complementary (dual) relations within the representation are key to representation and intention.

Representation

- Representation – where one entity or system (the representation) *stands in lieu of* another entity or system (the referent) for the purpose of being subjected to operations or observation which are not possible or desirable to apply to the original referent entity or system.
- Representation is the single concept that distinguishes modeling from most other disciplines and technical perspectives.

Representation - Relation

- Representation relation - where a represents b denoted aRb , and where what a 'says about' b may be made (and confirmed) to be (sufficiently) similar to what b really 'is'
- Intellectual Basis:
 - Logic of relations
 - Binary relations aRb
 - Similarity relations
 - Mapping relations
 - Symmetry, Conservation, and Invariance
 - Group Theory

Representation - Process

- Observation - (actually, or virtually) of the referent to appreciate its salient qualities
- Abstraction - The *conception* of the referent based on our *perceptual* observations... sufficient to support model implementation in its eventual representational milieu
- Quality management – determination and control of the adequacy of representational artifacts

Logical Inference

- Inference - achievement of new knowledge from available information by use of any of a series of eclectic techniques ... not unique to modeling
- Three fundamental modes of inference characterize M&S development and use:
 - abstraction via analysis
 - confirmation of representation-implementation
 - asset employment through inferential decision, understanding, or influence
- This specialized use-pattern of inference substantiates the demonstration of M&S as a specifically identifiable discipline

Core M&SBOK

Science & Technology

- Data, variables
- Models (Modeling formalisms, Model processing)
- Experimentation
- Model behavior (Types, Generation, Processing)
- M&S life cycle
- Types of simulation
- Agent-directed simulation

As a testimony of the richness of concepts in M&S: A list of over 100 Types of Variables (from the M&S dictionary) (Ören et al, 2006)

Across, Action, Activation, Algebraic, Allocated, **Antithetic**, Arbitrary, Argument, Artificial, Attached, Auxiliary, Behavior, Binary, **Boolean**, Bounded, Class, Constrained, Continuous, **Continuous-change**, Controlled, Coordination, Correlated, Decision, Declared, Declared Random, Dependent, Descriptive, Deterministic, Discrete, **Discrete-change**, Discrete-time, Discriminant, Dual, Dummy, Endogenous, Essential, Exogenous, Experimental, Experimentation, External, **Externally generated**, **Flow**, Formal, Free, **Fuzzy**, Gaussian, Global, Goal, Holistic, Independent, **Initialized**, Input, Instance, Instantiated, **Instrumentable**, Instrumental, Instrumented, Internal, Internally generated, Interpolated, Irrelevant, Key, Lag, **Lagged**, Latent, Lead, Level, **Linguistic**, Local, **Logical**, Monitored, **Nonnumerical**, Nonobservable, Numerical, Observable, **Output**, Qualified, **Qualitative**, Quantified, Quantitative, Random, Rate, Relevant, Run control, Simple, Slack, Stabilized, **State**, Statistical, Stochastic, Subscripted, Temporal, Temporary, **Through**, Time, Transition, Typed, Uncontrollable, Uninitialized, Yoked.

Models

Detailed taxonomies exist (even since 1970s)

Some classifications are based on:

- nature, existence & trajectory of variables
- functional relationships of variables
- formalisms used to describe the models
- intended use
- disposition of submodels
- organization of submodels
- goals to be pursued

Models - Fundamental issues

Complexity, Model taxonomies, ontologies

Systems science, systems approach,
systems view

Modeling approaches for decomposition of
problems

Conceptual modeling

Experimentation

Simulation run

Length of the run, Number of runs, Warm-up period
Steady-state period
Antithetic run

(Automation of) Statistical design of experiments

Specification of experimental conditions

Experimental frame
Applicability of experimental frame to a model
Scenario specification
Composable and synthesizable scenarios
(Composable/ Reconfigurable) Synthetic environments

Analysis of simulation results

Post simulation analysis and report
Post live/virtual/constructive simulations reports

Multisimulation

(to experiment with several aspects of reality simultaneously)

Core M&SBOK

Technology

- Languages, tools, toolsets
- Comprehensive simulation-based problem solving environments
- Infrastructure
 - Standards, repositories, libraries

Standardization ([Rationale](#), [Mailing List](#))

[ANSI/ANS-3.5-1993;W1998](#): Nuclear Power Plant Simulators

[IEEE](#) Computer Simulation Standards

[IEEE](#) Learning Technology Standards Committee

[ISO](#) TC 163/WG2 - Simulation Standards

NIST [SSC](#) Simulation Standards Consortium

NTSA [SSC](#) Standards Standing Committee

[SAE](#) - Human Biomechanics and Simulation Standardization Committee

[SISO](#) - Simulation Interoperability Standards Organization

[System Biology Standards](#)

[TARDEC](#) - US Army Tank-Automotive Research Development Center

[Techstreet](#) - Available Simulation Standards (search with: simulation standard)

[US Army](#) Model and Simulation Standards

US Army: AMSO [SNAP](#) (Army Model and Simulation Office Standards Nomination and Approval Process)

US Army: [ASTARS](#) (Army Standards Repository Systems - Army M&S standards)

[US Army](#)'s Approach to Modeling and Simulation Standards for C4I Interfaces

[US Navy](#) (NMSO) SNEACRS: Standards Nomination, Evaluation, Advocacy and Central Repository System

Repositories

- Data bases for:
constants, parameters, auxiliary parameters
data for model identification, model fitting
- **Specifications** of:
models **Model bases** and **model repositories**,
physical environments, synthetic environments,
scenarios, experimental frames, studies
- Simulation components
(*not just program components*)
(reusable, extensible, [dynamically] composable)

Core M&SBOK

- Reliability and quality assurance
 - Errors
 - Validation
 - Verification
- Professional Ethics for simulationists

M&S: Ethics

- http://www.site.uottawa.ca/~oren/SCS_Ethics/ethics.htm
- <http://www.scs.org/ethics/>

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
- Ottawa Student Chapter of the SCS.
- NATO Modeling and Simulation Group
- DLM

Core M&SBOK

- History
 - Lessons learned (Best practices)
- Trends, challenges, desirable features

- Maturity of
 - Individuals
 - Organizations

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)

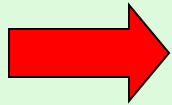
Early applications: Space flight simulations

Techniques:

Visualization for simulators, synthetic environments

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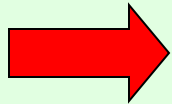


Intended Uses (cases) and Characteristics

- Academia
 - Curricular Development
 - Disciplinary Identification...
- Industry
 - Personnel Hiring, Training
 - Technical Investment
 - Marketing...
- Government
 - Planning
 - Investment
 - Policy...
- Professional Society
 - Guidance...

WE HAVE SEEN HIGHLIGHTS OF

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CONCLUSION / MESSAGE (1/2)

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CONCLUSION / MESSAGE (2/2)

- Having M&S acknowledged as a distinct branch of knowledge is important in **advancing the profession, industry and marketplace.**
- A **concerted effort** will ensure that M&S as a profession evolves in a timely manner.
- This will **enhance its usefulness** in many complex problems.

You are welcome to contribute to this “Open Source” Activity.

Publications, Presentations and Other Relevant Activities of Dr. Tuncer Ören on:

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

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

A large tree with pink and white blossoms is the central focus of the image. The tree is in full bloom, with many flowers visible. The background shows a brick building with several windows. The ground is a green lawn. Two semi-transparent red banners with white text are overlaid on the image. The top banner says "Thank you for your attention" and the bottom banner says "Q & A".

Thank you for your attention

Q & A