# Modeling and Simulation Body of Knowledge (MSBOK)

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## M&S: Perceptions from Different Perspectives

The way we perceive an entity affects our actions about it. Hence, it would be beneficial to have a systematic view of several possible ways M&S is perceived. Table 1 outlines perceptions of M&S from different perspectives.

Table 1. Perceptions of M&S from Different Perspectives

| Perception with respect to | Perceptions |
|---|---|
| 1. Purpose of use | • Imitation (fake)<br>• Provide **experience** for<br>○ Training<br>○ Entertainment<br>• Perform **experiments** for<br>○ Education<br>○ Understanding<br>○ Decision support |
| 2. Problem to be solved | • M&S as an infrastructure to support real-world activities |
| 3. Connectivity of operations | • Stand-alone simulation<br>• Integrated simulation |
| 4. Types of knowledge processing | • Computational activity<br>• Systemic activity<br>• Model-based activity<br>• Knowledge generation activity<br>• Knowledge processing activity |

### 1.1 Purpose of use

Table 2 highlights three purposes of use of M&S. As a process, the term simulation has a non-technical and two technical meanings. As a non-technical term, simulation means “imitation” or “fake” and has been used since 1340.

Table 2. Three Purposes of Use of M&S

| **Purpose of use of M&S** | **Type of simulation** |
|---|---|
| 1. Imitation (fake) | |
| 2. Provide **experience** (under controlled conditions) for: | |
| **Training** (gaining/enhancing competence): | |
| - motor skills | Virtual simulation |
| - decision and/or communication skills | Constructive simulation |
| - operational skills | Live simulation |
| **Entertainment** | |
| 3. Perform **experiments** for | |
| **Education** | |
| **Understanding** | |
| **Decision support** | |

As a technical term, two main types of usages of M&S can be identified. M&S is used: (1) to provide *experience* (for training and entertainment) through controlled conditions and (2) to perform *experiments* (for education, understanding, and decision support).

The technical meanings cover any type of simulation regardless whether simulation is computerized or not and whether it is carried out on pure software or hardware/software. Furthermore, both of the technical meanings allow top down decomposition of the entities and activities involved and thus enable their systematic and hierarchical elaborations.

**1.1.1 Experience:** In *training*, simulation is used to gain/enhance competence through *experience* under controlled conditions. Three major types of simulations corresponding to three types of training.

(1) *Virtual simulation* (i.e., use of simulators or virtual simulators) to enhance *motor skills* to gain proficiency of use of equipment(s).

(2) *Constructive simulation* (or *gaming simulation*: war gaming, business gaming, etc.) to enhance *decision making* and/or *communication skills*, and

(3) Live simulation to gain/enhance *operational skills* by getting real-life-like experience in a controlled environment.

In *entertainment* (simulation games, animation of dynamic systems), simulation provides experience under controlled conditions. “Getting experience under controlled conditions” is the common aspect using M&S for training (i.e., gaining/enhancing competence) as well as for entertainment purposes.

**1.1.2 Experiments**: In areas other than training and entertainment, simulation is used to perform goal-directed *experiments* with dynamic models. These areas include education, understanding, and decision support.

Table 3 highlights types of use of simulation for decision support.

Table 3. Types of use of simulation for decision support

| |
|---|
| *Use of simulation for decision support* is done for the following main categories of activities:<br>• *Prediction* of behavior or performance of the system of interest within the constraints inherent in the simulation model (e.g., granularity)<br>• *Evaluation of alternative* models, parameters, experimental and/or operating conditions on model behavior or performance<br>• *Sensitivity analysis*<br>• *Engineering design*<br>• *Prototyping*<br>• *Planning*<br>• *Acquisition* (or simulation-based acquisition)<br>• *Proof of concept* |

“Experimentation is one of the key concepts in scientific thinking since Francis Bacon (1561-1626) who advocated it in 1620 in his Novum Organum. (New Instrument). Bacon’s work was a categorical departure from and reaction to “Organon” (the Instrument) which was the title of logical works of Aristotle (384-322 B.C.) which itself had an ‘unparalleled influence on the history of Western thought.’” (Ören 2002b).

Hence, the technical definition also ties simulation to the origins of modern scientific thinking. However a programmer’s view of simulation would be biased to the execution of the simulation program and would hinder this important point. The superiority of performing the experiments on a model rather than on the real system is also well established. In the existing studies of M&SBOK several aspects of both of these meanings are used.

## 1.2 Problem to be solved

A perception M&S is that it is as an infrastructure to support real-world activities**:** This *is the black box perception* by practitioners, for whom simulation is a tool to achieve other goals. This view allows to concentrate to the original problems they face; e.g., for NASA the goal is successful space missions and not simulation; for military, similarly and justifiably, goal is not simulation either. From this perspective, "simulation is perceived as not being the "real thing."

This view leads to successful applications of simulation in familiar areas. However, a broader view of M&S can lead to better appreciation of full scope of possibilities it offers. Hence, the limitations of this point of view are: (1) "not even knowing what one misses" and (2) to be obliged to have "patches" in the conception of M&S when need arises.

### 1.3 Connectivity of operations

As seen in table 4, two important categories of simulation can be distinguished with respect to the connectivity of operations. They are: stand-alone simulation and integrated simulation.

In *stand-alone simulation*, operations of the simulation and the system of interest are independent, i.e., are not connected.

In *integrated simulation*, operations of the simulation and the system of interest are interwoven. In *integrated simulation*, simulation *enriches* or *supports* real-system operation. To *support* real system operation, the system of interest and the simulation program operate *alternately* to provide predictive displays. To *enrich* the real system operation, the system of interest and the simulation program operate simultaneously to assure on-line diagnosis and augmented reality (enhanced reality) operation.

Table 4. Types of M&S with respect to the Connectivity of Operations

| **Type of connectivity -** operations of the simulation and the system of interest are | **Type of Simulation** |
|---|---|
| **not connected** | **Stand-alone simulation** |
| **interwoven** | **Integrated simulation** for:<br>***Enrichment*** of real system operation:<br>- simulation-based augmented/enhanced reality operation (for training to gain/enhance motor skills and related decision skills)<br>- on-line diagnostics<br>***Support*** of real system operations (The system of interest and the simulation program operate *alternately* to provide predictive displays)<br>- parallel experiments while system is running |

### 1.4 Types of knowledge processing

Simulation can be perceived as: computational activity, systemic activity, model-based activity, knowledge generation activity, and knowledge processing activity.

**M&S as a computational activity:** The emphasis can be at different levels from generation of model behavior to simulation-based problem-solving environments. This point of view is reflected in some definitions of simulation. e.g., "Simulation is the execution over time of models representing the attributes of one or more entities or processes." This *computational* view of execution of simulation program may hinder the high-level possibilities of computer aided problem solving environments such as problem specification, model specification (model synthesis, model composition), experimental frame specification (design of experiments), program gene-ration, and symbolic processing of problem specifications to assure built-in quality.

**M&S as a systemic activity:** "From a systemic point of view, simulation can be used to find the values of output, input, or state variables of a system; provided that the values of the two other types of variables are known" (Karplus, 1976). System sciences provide the basis for modeling formalisms as well as for symbolic processing of models, for a large variety of dynamic systems, including goal-directed systems, variable-structure systems, and evolutionary systems. (Ören, Zeigler, Elzas, 1984).

**Simulation as a model-based activity**: This approach allows construction of simulation-based computer-aided problem solving environments (advanced simulation environments) (Ören, Zeigler, Elzas, 1984).

In addition to generation of model behavior, the following can be considered:

- computer-aided modelling (model composability)
- model-base management (for reusability)
- parameter-base management (for example, in nuclear fuel waste management simulation systems, over a few thousand constants and parameters (some of them to be represented as probability distribution functions) have to be managed.
- symbolic processing of models

**Simulation as a knowledge generation activity:** From an epistemological point of view, simulation is a knowledge generation activity; more specifically, simulation is a goal-directed knowledge generation activity with dynamic models and/or within dynamic environments. This view allows advanced methodologists and technologists to integrate simulation with several other knowledge generation techniques. (Ören 1990). At this abstract level, the definition of simulation can be interpreted as follows: “Simulation is model-based experiential knowledge generation.” This abstraction facilitates the synergy of simulation with other knowledge generation (and processing) techniques such as: optimization, statistical inferencing, reasoning, and hypothesis processing.

**M&S as a knowledge-processing activity**: This view allows advanced methodologists and technologists to integrate simulation with several other knowledge processing techniques (Ören, 1990).