History and Basic Concepts of M&S

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1.0 INTRODUCTION

1.1 Definition of M&S

The *NATO Modelling and Simulation Masterplan* defines model and simulation as follows:

> ***Model.***
> *A representation of a system, entity, phenomenon, or process.*
> *Software models of specific entities are comprised of algorithms and data.*
>
> ***Simulation.***
> *The execution over time of models representing the attributes of one or more entities or processes.*
> *Human-in-the-Loop simulations, also known as simulators, are a special class of simulations.*

Note: a simulation is kind of activity. A simulator is kind of system.

1.2 Benefits of M&S

The benefits of simulation can be described by the following examples:

1) Enhancement of Capabilities
   a. Analytical Assessment *(all possibilities can be explored and tested)*
   b. Mission Rehearsal *(practice improves success)*
   c. Experience Extension *(be prepared for all eventualities)*
   d. Situational Awareness *(critical factors are visualised and understood)*
2) Saving of Resources
   a. Life Cycle Savings *(simulation costs less to operate and maintain)*
   b. Reduced Training Time *(no lost time setting up and repeating activities)*
   c. Operational Efficiency *(efficient operating practices can be explored, tested and trained)*
   d. Asset Optimisation *(critical operational assets are not taken out of service for training)*

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3) Reduction of Risk

   a. Risk Awareness *(complete range of hazards can be experienced and tested)*

   b. Equipment / Life Preservation *(equipment wear and personnel harm is avoided)*

   c. Hazard Avoidance *(dangerous activities can be trained in safe environment)*

   d. Environmental Damage *(fragile environments are not compromised by activities)*

2. SHORT HISTORY OF M&S

Modelling and simulation well predates the computer. The most prominent example is the game chess. But there are more examples from ancient times:

- Figurine warriors replicating the art of battle have been dated as far back as 2500 BC in Egypt.
- Sun Tzu, a Chinese strategist and military philosopher, wrote about the game Wei Hei (or *encirclement*) around BC 500.
- Shataranja, the closest predecessor to the chess we play today, emerged in India circa 700 AD.

In the 1600s, in Germany the war game *Königsspiel (King's Game)* was created: on a large board, military details and terrain features (e.g. rivers or forests) were represented. *Königsspiel* advanced the notion that war can be reduced to distinct concepts and formal rules.

It is the 1800s where the basic concepts of M&S as we recognize them today become evident. In 1824, Prussian Baron von Reisswitz published the book *Kriegsspiel (Wargame).* He took account of a three-dimensional terrain. Dice decides the outcomes of fire. In 1879, in North America, Major Livermore added logistics and the quantification of fatigue to Kriegsspiel. A few years later, Lt Totten added layers to the game depicting the different levels of war: tactical, operational, and strategic. By 1887, wargaming becomes a permanent part of the curriculum at the U.S. Naval War College.

The beginning of the 20th century witnessed a proliferation of techniques. In Berlin, the WW I mobilization plan was developed by using wargaming. In Great Britain, Colonel Lanchester originated equations that codified firepower relationships. Prior to WW II, Japan wargamed its incursions into Manchuria and China.

In the 1940s, *Operations Research* was established in the U.S., Great Britain and Germany. The main use of Operations Research was during the planning processes for the employment of armed forces (example from Great Britain: the development of an efficient defence strategy against German submarines, using aircrafts). Operation Research uses a plethora of different scientific methods, mainly from the field of applied mathematics: probability theory, statistics, linear and non-linear optimization, differential equations, game theory, system dynamics, and (finally) simulation.

By 1950, wargaming is still large boards, playing pieces and push pins. Three significant occurrences changed the status quo: the transistor, integrated circuitry and commercially obtainable computers. Once this became available to the analysis community, M&S increased exponentially.

The 1960s saw the first computers capable of supporting simulations, e.g. IBM's 7070. Since then, the progress in M&S paralleled the enormous developments of computer science.

3. BASIC CONCEPTS OF M&S

3.1 Simulation Categories

Simulation is often categorised as being *Live, Virtual* or *Constructive*:

Live Simulation	A simulation that involves real people operating real systems (example: instrumented army training areas where the exchange of fire is replaced by laser shots).
Virtual Simulation	A simulation involving real people operating simulated systems (also called human-in-the-loop or man-in-the-loop systems, e.g. flight simulators or driving simulators).
Constructive Simulation	A simulation involving simulated people operating simulated systems (real people stimulate –make inputs– to such simulations but are not involved in determining the outcomes, e.g. wargaming simulations).

3.2 Main Usage of Simulations

The main application areas for simulation are:

1. Training *(routine development of skills)*
2. Mission Rehearsal *(mission specific training)*
3. Conduct of Operations *(decision support during military operations)*
4. Crisis Management and Planning *(planning for potential/plausible future crisis scenarios)*
5. Force Assessment *(decision making in the areas of capability and force structure analysis)*
6. Experimentation *(exploration of concepts, testing of doctrine and tactics)*
7. Research and Development *(operational and technical analysis in design and development)*
8. Acquisition *(determination of user requirements, prototyping, system testing and evaluation)*
9. Life Cycle Management *(resource planning, encompassing logistics and maintenance)*

3.3 Approval of a Simulation

Usually, each proposal to develop a simulation needs an assessment made against the following criteria:

User requirements:	Who wants the simulation? For what exactly?
Representations:	How are people and things with their dynamic behaviours and interactions going to be represented inside the simulation?
Data availability and reliability:	Does the necessary data exist?
Technology:	What are the appropriate technologies?
Confidence building approaches:	How can the overall credibility of simulation outcomes be established?
Cost / benefit:	How are the returns on investment to be determined in order to secure the resources to build and use the system?

3.4 Implementation of a Simulation

To implement a simulation, you need:

data	about the thing you are simulating,
models	to be executed dynamically,
presentation	a means to present the simulation outcomes to the user.

3.5 Specific Simulation Concepts and Definitions

Some more specific simulation concepts are:

Fidelity:	The accuracy of the representation when compared to the real world. (A simulation generally involves a fidelity compromise, because of data and costs issues.)
Resolution:	The level of detail used for the representation of processes or objects.
VV&A:	Verification, Validation and Accreditation.
Verification:	Answers the question: "Was it built right?"
Validation:	Answers the question: "Was the right thing built?"
Accreditation:	The official certification that a simulation is acceptable for use in relation to a specific purpose.
Agent:	A software module that models the behaviour of objects or the reasoning of humans.
CGF:	Computer Generated Forces: application of Agents for the simulation of military units.
SAF:	Semi-Automated Forces. See CGF.
Monte Carlo Simulation:	A simulation in which random statistical sampling techniques are employed such that the result determines estimates for unknown values.
Deterministic Simulation:	A simulation which, for a given set of inputs, produces an identical set of outputs, each time the simulation is run.
Stimulation:	The use of simulation to provide an external stimulus to a system or subsystem.
Emulation:	A simulation methodology in which the same inputs are accepted and the same outputs are produced as a given system.
Synthetic Environment:	A representation of the real world generated by simulation systems, people (real or simulated), and equipment (real or simulated).

3.6 Linkage of Simulation Systems

Simulation systems may operate in isolation, or be linked together. There are two main standards for the linkage of simulation systems:

DIS: Distributed Interactive Simulation. DIS was developed in the US mostly from 1990-96. It consists of a prescriptive protocol of the contents of Protocol Data Units (PDUs). It is defined in the IEEE 1278 standard.

HLA: High Level Architecture. In HLA several simulation systems, called "federates", are combined to form a larger simulation system, called a "federation". This requires:

a. Specifying the information that will be exchanged in a Federation Object Model (FOM).

b. A means of exchanging information between the participating federates, using software called the Run-Time Infrastructure.

3.7 Common Problems in Defining and Implementing Simulation Systems

Some of the most significant problems with defining and implementing simulations are the following.

3.7.1 Data

Data issues often encountered are:

a. Level of Detail
b. Standards
c. Consistency
d. Currency
e. Classification
f. Validation

3.7.2 Latency

Latency (or transport delay) is related to the length of time it takes simulation systems to react from the time of operator input until the system starts to present a response to that input.

3.7.3 High level interoperability

Full interoperability of simulation systems has to go far beyond the usage of the linking standards DIS or HLA. Missing are standards for establishing semantic, dynamic and conceptual consistency in simulation networks.

3.7.4 Verification and Validation

The main problems in doing verification and validation for a simulation system are connected to the development process of the simulation system itself:

- no use of proved development process,
- missing or sloppy documentation of the development process.

3.7.5 Sensory Disorientation

Variations in human sensory stimulation can lead to disorientation, which manifests itself as vertigo or motion sickness. The most common circumstance causing vertigo is inconsistency between visual and motion perceptions. Especially moving virtual simulators (e.g. flight simulators) are affected by this problem.

Literature:

[1] NATO Modelling and Simulation Masterplan 1.0, AC/323(SGMS)D/2, August 1998

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[3] Little, D.: History and Basics of M&S, RTO-EN-MSG-043, 2006