Analysis and Evaluation

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The lecture will refer to the following subjects.

1. M&S supportable tasks and missions

(1) General missions in defense

(2) Subjects of analysis: Systems of Systems

(3) Tasks in further-development of forces

(4) Tasks in armaments design and realization

2. M&S based analysis

(1) Basic questions for analysis and evaluation

(2) Netted analysis: from performance to merit and vice versa

(3) Methods for analysis and evaluation

(4) Subjects and conditions of analysis

(5) Aims and benefit of simulation

(6) M&S analysis contribution during systems life cycle

3. M&S application

(1) Type of results produced

(2) Requirements related to analysis results and models

(3) Analysis of simulation results

(4) Building and validation of models

(5) Building federations of simulation systems

(6) Concept of Integrated Simulation Systems

(7) Example of Integrated Simulation Systems

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1. M&S SUPPORTABLE TASKS AND MISSIONS

1.1 General missions in defense

The general missions in defense which can be supported by Modelling & Simulation (M&S) are

- Forces analysis and planning
- Armaments planning and realization
- Education, training and exercises
- Support to operations.

The tasks are related to systems and scenarios at different system levels. These levels cover the strategic, operational, tactical and technical ones.

1.2` Subjects of analysis: Systems-of-Systems

The subjects of analysis and evaluation are systems. Systems are build based on systems. Therefore a "Systems-of-Systems" approach is required. Netted systems and netted capabilities, especially the use of netted capabilities are at the core of analysis and evaluation.

Different scales of space and time have to be used in doing analysis at those different system levels.

The analysis will not be restricted to military systems but has to take into account all "forces" contributing to defense and security. Beside military forces these are political, religious, social, economical and information forces as well as the general infrastructure.

1.3 Tasks in further-development of forces

The analysis tasks for the further-development of forces should be assigned to short-, mid- and long-term planning activities. Short term activities relate to ad hoc needs supporting currentlly on-going missions by referring to available technique. Mid-term activities relate to modernization in the tactical and technical area by referring to further-developed technique.

Long-term activities relate to the transformation of armed forces as well as to research and technological development. Both these last two activities refer to ideas and concepts especially based on expected technological possibilities. They will answer the question "What might be expected in the long-term future?", they will not answer the question "How will this what be generated?"

All those short-, mid- and long-term planning activities require the support by M&S and its tools.

1.4 Tasks in armaments analysis and planning

Tasks in armaments analysis and planning cover the whole life cycle of technical systems. They can be assigned to mainly three phases:

- Research & Technology Development (R&TD)
- Development & Procurement of Technical Systems (D&P)
- Satisfying Ad Hoc Needs.

Development & Procurement cover the sub-phases Analysis, Risk Reduction, Introduction and Usage.

The time horizons planned to be achieved are from

- From R&TD to D&P/Introduction: 10 – 15 years
- From D&P/Analysis to D&P/Introduction: 5 - 10 years
- For Satisfying Ad Hoc Needs: up to 2 years.

The analysis to be conducted in the D&P sub-phases are the following:

In the phase Analysis the military user has to define the required military capabilities he needs to fulfill his different tasks and missions. These requirements definitions will take into account technical restrictions and prognoses results from R&TD activities.

In the phase Design / Risk usually technical requirements are defined and feasibilties are tested. New in this phase, at least in Germany, is the testing of technical concepts and designs with respect to the expected fulfillment of required military system capabilities (aptitude testing).

In the phase Development beside the usual performance acceptance tests and live testings still, as in the phase Design / Risk, aptitude testing will be conducted.

In the phase Usage the maintenance of approved performances and of required military capabilities has to be tested.

All these analysis and testing activities require the support of M&S and its tools.

2. M&S BASED ANALYSIS

2.1 Basic questions for analysis and evaluation

Common to the different system levels (strategic, operational, tactical, technical) is that at each level the same type of questions have to be answered by analysis activities.

The very basic questions are:

- *Why* should forces be used?
- *What* are the tasks of forces to achieve the required "why"?
- *How* should the required "what" be achieved (by which forces conducting which missions)?

The questions related to the conceptual answers are:

- What are the definitions of systems, their elements and their relations which have to be analysed?
- What are the military capabilities to be required for the systems, their elements and their relations, given a certain system definition?

Here it is important to note that capabilities, being attributes, have to be assigned to something, here to systems and their components (elements, relations).

The questions related to the evaluation of a given system are:

- What is its merit?
- What is its effectiveness?
- What are its performances?

The "merit question" can not be answered by considering the system itself only. The merit of a system can only be answered in the context of another system which contains the considered system as an element.

The "effectiveness question" has to be answered at the system level the considered system is assigned to.

The "performance question" relates to the performances of the components of the considered system.

Additional to the above questions planners and operators have to answer another three important questions:

- What are the relative priorities they assign to systems and their capabilities?

- What are the estimated cost of the systems with their defined capabilities?
- What are the risks involved in the given answers related to systems, system capabilities and cost?

2.2 Netted analysis: from performance to merit and vice versa

From a forces planners and operators point of view the questions with respect to performances, effectiveness and merit have to be answered together.

The chosen approach for forces planning might start top-down or bottom-up. Important is that in a planning cycle one has to run both directions at least one time; normally it has to be done once and again.

The relations between the questions with respect to performance, effectiveness and merit again can be formulated in form of questions.

The question at the peformance level is:

- What are the performances assigned to defined systems and their components?

The question at the effectiveness level is:

- To what extend can users of those systems transform the systems performances into effectiveness of the users mission?
  (formulated another way: does the users system, in which the user itself is a component, reach its expected capabilities?)

The question at the merit level is:

- To what extend can the systems effectiveness contribute to the required capabilities of the system in which the considered system is a component?
  (formulated another way: what is the contribution of a systems component capability to the system capability?)

2.3 Methods for analysis and evaluation

Steps to be followed during analysis and evaluation are again related to three basic questions:

- *Why* doing an analysis?
- *What* has to be analysed?
- *How* should the analysis be conducted?

The “Why-Question” relates to the Users View. Its answer formulates the objectives, the usage of the analysis results and the insights which should be achieved.

The “What-Question” relates to the System View. It formulates questions to be answered and conditions to be taken into account during analysis. The conditions also include the scenarios to be considered. Finally the answer to this question are definitions of Systems-of-Systems to be analysed.

2.4 Subjects and conditions of analysis

Asking for capabilities of systems in action requires the introduction of the factor “*Time*”.

Therefore, operationalization of all the above described tasks yields the following:

- The subjects of analysis are *dynamic* systems.
- The conditions for analysis basically are also *dynamic* systems.
- Using those systems requires *command & control of dynamic systems*.

The task of command & control of dynamic systems is the controlled approach of *changes of the states of systems* to reach a defined goal. To enable the control of changes of states of systems it is necessary that those changes are measurable.

To enable system analysis and system synthesis of dynamic systems with unknown dynamics, with unknown ways to command and control and with the necessity to measure changes of states requires simulation systems.

2.5 Aims and benefit of M&S

The overall aim of military systems analysis is gaining insight into dynamic military systems and their capabilities. The sources for gaining this insight are either real missions or simulated missions.

The bandwidth of conducted missions is much smaller than the bandwidth of missions military forces should be prepared for.

The resulting gap can only be closed by using M&S.

Using M&S and its tools strives for gaining insight, not producing numbers.

The aims and benefits by using M&S can be summarized as follows:

- Identifying information
- Generating information
- Gaining knowledge
- Achieving understanding.

No NATO nation will go for missions alone. Therefore, military systems analysis and evaluation should be done in NATO teams or in multi-national teams. Using M&S in those teams especially will enhance mutual understanding among partners.

2.6 M&S portional contribution in analysis during systems life cycle

A systems life cycle runs from first ideas to real systems including its outphasing.

First ideas and concepts are based on expected technological possibilities. They contribute to the further-development of techniques and generation of real technical components. Finally, a real technical system is produced based on then available techniques.

First ideas and concepts of dynamic military systems can only be analysed by transferring them into models and conducting simulation-based analysis. At this stage only M&S tools can support analysis and evaluation.

As time goes by and real system components show up, they will be incorporated into the simulation environments for analysis purposes.

Finally, when the required systems have been produced, their performances and capabilities have to be tested in mission-relevant environments. These mission-relevant environments will be made available by M&S.

3. M&S APPLICATION

3.1 Type of results produced

The type of results produced by M&S based analysis are relative ones not absolute ones.

M&S applications aim at a comparative analysis of alternatives of systems.

Those comparisons refer to alternatives for:

- Technical concepts
- Proposals for technical solutions
- Military doctrines and missions
- Conditions and assumtions

Sensitivity analysis has to be conducted to enable the estimation of the risk included in analysis results.

The sensitivities of results are related to changes and / or uncertainties in:

- Concepts and proposals
- Doctrines and rules
- Conditions and assumptions.

For the purpose of risk minimization it is important not to neglect uncertainties.

3.2 Requirements related to analysis results and models

Analysis results must be:

- Understandable
- Reproducable
- Representative.

Models must be:

- Flexibly usable
- Adaptable
- Testable
- Continuously available for use.

The components for M&S-based analysis-subjects and –environments must provide the flexibility and adaptability necessary for above mentioned alternatives and sensitivities.

Summarizing all the requirements discussed up to now indicates that M&S requires more than simulation models. M&S requires simulation systems, which include models as a component.

3.3 Concept of Integrated Simulation Systems

Integrated simulation systems comprise application dependent components and application independent components. The application independent components are those which are principally necessary for any simulation and provide the general services of simulation technology.

The application dependent components are:

- Model functionalities
- Interactive Work-Place Functionalities
- Data bases

The application independent components are:

- Simulation frame
- External interfaces
- Data management tools

Models are abstractions or let's say "pictures" of something. Dependent on the purpose of the picture there might be many different pictures of the same thing. That means, models are application dependent.

3.4 Analysis of simulation results

The simulation results are the direct output of a simulation. The simulation results must be structured and analysed to identify the information they contain.

Having identified this information it needs experts with detailed knowledge about the models used and with experience in the analysis of the underlying subject matter to generate the analysis results. The analysis results and their explanations have to be based simply and solely on the content of the model functionalities.

This system analysis, professionally done, is scientific work. Scientific work is not restricted to basic research only.

Care must be taken not to confuse the simulation results with the desired analysis results. The simulation results are simply data.

One should remind here a remark made by Henry Poincare, Science and Hypothesis,1905:

"Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house."

Basic steps within analysis work are again described by a set of questions to be answered.

The "7+4 Questions":

Who was involved in what happened? *What* happened, *when, where and why*? *How* did it happen and *why* that how?

The "Why not? Questions" related to different aspects of the "simulation history":

- Why did events *not* happen?
- Why were decisions *not* been made?
- Why were orders *not* been given?
- Why did conditions *not* occur?

These "why not" questions are much more difficult to be answered than the "7+4" questions.

3.5 Building and validation of models

The following remarks should be taken into consideration when building and validating models:

- If reality is known and understood, then there is no necessity to build models for analysis purposes.
- A model is an abstraction not a representation of reality.
- The suitability of a model for its intended purpose is the decisive aspect.
- "Rules" for modelling:
    - Divide System into Sub-Systems ("analysis")
    - Maintain "important aspects" of the inteded purpose
    - Neglect "unimportant aspects" of the intended purpose
    - Integrate resulting Sub-Systems into overall System ("synthesis")

- There are no “A Priory“ rules to determine the “important aspects“.
- Normally not all the requirements resulting from the analysis task are known at the very beginning of modelling.

Due to the last two bullet it is common experience that the first approach in building a model is not the right one.

3.6 Building federations of simulation systems

The aspects to be considered during federation building are given as a prioritized list as follows:

- Building Federations *is building models* based on already available models.
- Main components of models are
    - Abstract pictures of systems and functionalities
    - Data models used by the abstractions
    - Data models used for data exchange with external federates
- Models related aspects to be considered during federation building are
    - Logical consistency between already available models related to
        - Abstractions of systems and functionalities in each model
        - Data models used by the abstractions
    - Modelling requirements for the new model (that is the federation) to be build
    - Necessary adaptations of the components of the available models
    - Requirements for the data model to be developed for the data exchange between the federates (this data model is the Federation Object Model (FOM / HLA) of the federation / model to be build).

This last bullet refers to the requirements which must be fulfilled by the application dependent FOM of the federation to be build. These are driven by the purpose of the analysis to be conducted and the content of the models to be coupled for that purpose.

3.7 Examples of Integrated Simulation Systems

The simulation systems and models developed by IABG on behalf of the German MoD show up in three different simulation system / simulation models families. These are:

- The simulation system family JASS
- The simulation system federation JOANA
- The simulation system KORA.

The members of the JASS family are:

- PABST (for ground units missions)
- HORUS (for ground forces missions)
- OSIRIS (for surveillance and reconnaissance missions)
- FIT (for command & control, communication & information)
- MUT (for missions in urban environment)

The JOANA federation comprises:

- ALICE (air forces operations)
- MEMO (naval forces operations)
- SimOF (ground forces operations)
- PSO (peace support operations)
- HORUS

Functionalities of the simulation system KORA cover all functional areas of ground forces. Examples are given in the lecture about CAX Planning & Execution.