Annals of the Academy of Romanian Scientists
Series on Military Science
Volume 1, Number 1/2009

MODELING AND SIMULATION – FUNDAMENTAL ELEMENTS OF CONDUCTING MILITARY ACTIONS

Lieutenant-General Professor Teodor FRUNZETI, PhD
Commandant (rector) of "Carol I" National Defense University

"A rational man adapts to the world around him; the irrational man keeps on trying to adapt the world around him to himself. The consequence is that all progress depends on the irrational one."

"MAN AND SUPERMAN",
George Bernard Shaw, 1903

The global security environment essential changes, the modern battle content and physiognomy, the tactical echelons' new functional structure and their role in current conflicts and also in the future battlefield determine major transformations at all levels. The new military conflicts generate changes in military art, doctrines, organization, and training. With technology as a common element, all these changes are meant to improve the connection between man and technology given the digitization of the battlefield, with the fundamental goal of a potential successful conflict.

While the ongoing multifunctional and structural improvement of different echelons is a reality, while flexibility, maneuverability, high degree of action, adaptability and ability to act jointly are the current requirements of most modern army structures, while, in order to face the 21st century new challenges, NATO's transformation is a reality, we can easily perceive the modern armies' permanent concerns to increase efforts to improve their military technologies with similar efforts, at the analytical level by revigorating the operational research. The diversified concerns regarding the improvement of the quality of training, higher military education and also of the scientific research activities emphasize the modern armies' tendencies and orientations regarding the use of modeling and simulation as a viable and effective alternative in the field of conducting military actions, supporting decisions and assessing alternatives and results, implementing new techniques, tactics and procedures of troop conducting, achieving cooperation by conducting joint exercises using NATO, command and staff procedures.

In this context, military operations represent the main objective of the Modeling and Simulation domain (M&S), as results from the US and NATO master plans. Thus, NATO's opinion on Modeling and Shaping stipulates that *M&S will ensure the available, flexible and effective means to drastically emphasize all of NATO operations, defense planning, training, operational support, research, technological development and armament acquisition.*

Similarly, the modeling and shaping concept stipulates that it will support force training, the development of doctrine and tactics, assessment of units' performances, operational support to plan, execute and analyze operations and exercises, the possibility of conducting a general rehearsal in view of carrying out the missions and support analyses of the national security political, military and economic dimensions and developing the defense policy.

In general terms, modeling means representing a system or process through another system called model, with the same relevant characteristics as the original and is easier to study. The purpose of modeling is to obtain relevant conclusions about the original based on the model study. Modeling can be achieved analytically and experimentally. From this definition, we can state that, from the formal, mathematical point of view, modeling is an operation associating a certain model to a certain original and the content of the operation depends on the purpose of modeling which implicitly determines which characteristics of the original are relevant in connection with it; this introduces a new notion – that of *level of resolution.* Resolution[1] is the degree of details and specifications used in representing the real world aspects in constructing the model.

The model's definition used in NATO[2] was inspired by that used by the US Military according to which a model is *"a representation of a system, entity, phenomenon or process. The specific entities software models are made of algorithms and data."* An algorithm represents an established set of rules and processes well defined and less ambiguous in solving a problem in a finite number of phases; the data are traits of an entity expressed by the parameterized and discrete values describing their attributes. The model is objectively limited: it cannot encompass all the characteristics of the phenomenon. "The model's fundamental contradiction is that it does not coincide with the proposed purpose but serves to know it, which is done only through the model's ongoing improvement and a model's dialectical denial by another one."[3]

The concept of integrated modeling of the battle and operation is relatively recent in the field of military modeling and simulation and meets the master plans' fundamental demands, both from the perspective of aligning to the modeling and simulation common technical framework and also from the need to ensure the consistency of models representing the same reality (e.g. combat, operation), but has different purposes (i.e., assessment, planning, operational support).

The combat integrated modeling is an interactive process beginning with the conflict direct representation, continues by its assessment and simulation, comes back for an ongoing validation through a new direct representation, validated as a completely integrated model (a set of analytical and heuristic models of a conflict together with the associated tools of assessment and simulation), continues with overall assessment and optimization and a detailed simulation, stopping at the final applications.

Generally, a battle integrated model must allow for the model's entire theoretical and experimental variety (i.e., analysis, synthesis, assessment, optimization and simulations). However, this imposes the existence of a combat mathematic model, thus calling for the use of operational research. The question arises: is the mathematical modeling of any conflict possible? The answer is affirmative and triggers another fundamental question, apparently new: which are the relevant features of a conflict? A full answer to this question was given by the old but still up-to-date monograph by Colonel Dupuy, which presents a battle theory elaborated by the Historical Evaluation and Research Organization (HERO). He emphasizes the following components (submodels) of a combat model: *the model of combat potential, combat outcome, combat scenario procedures, rules for advance speeds, for personnel and armament losses (armored, artillery and others), air force and support exhausting rates.* According to HERO battle theory, these models are only heuristic, but each of them can be converted into an equivalent analytical model called dual model.

A separate discussion is necessary regarding the operational scenario analytical modeling inspired by the scenario's implementation in the Heuristical Combat Evaluator (HCE) component of the FORCES program. This was considered a game tree of the operation combat events ramification and was implemented within the Route Checker – the core of HCE technology – designed as a tool to support the interaction between soldier and machine and which ensures a simple but effective control of the game ramification under control of the responsible judge and which also ensures the feasibility of the course of actions.

This scenario representation suggests its modeling by means of graphs but the implemented model is not a tree, because it has a potential explosive ramification. Consequently, the implemented model is a multigraph having on each action direction an oriented, connected graph which modulates the program of action chaining on direction. Thus, the player's supervising control was shifted from the ramification process.

The development of the military operations' conceptual model of the mission space is a current issue which demands a periodic reevaluation of the development process in view of harmonizing it with the new objectives. *Elaborating a conceptual model of the mission space has as starting point the clear specification of the mission of the forces participating in the operation.*

In general terms, it can be represented as a list of essential tasks to be accomplished by the forces participating in the operation in accordance with the received combat orders. Almost always, this list has as major tasks destroying or annihilating the enemy forces, conquering the natural environment occupied by them and creating favorable conditions for the future operations. But the model's main content is the specification of forces participating in the operation and the actions and interactions used to accomplish the mission. The key notion here is "operation scenario" by means of which the operation concept is represented. In current simulations, the operation scenario is a logical model called "aggregated model" which represents the combat or support interaction; a more effective modeling can be accomplished through an oriented graph which gives the possibility to fulfil an adequate mathematic model of the operation.

The next step of modeling is the adequate representation of the operation actions and is in fact a process of reiterating the model, at the level of actions, that is achieving conceptual models of the mission space (MCSM) adequate for each planned action. Or, in other words, an operation MCSM is in fact a network of MCSMs associated to the operation actions and whose topology is determined by the operation scenario. Achieving an action MCSM necessitates the specification of the forces participating in the operation, the way they act to accomplish the mission, of the rules conducting the beginning and the end of the operation and also the way to assess the quantitative and qualitative (logical) results it ends with.

By correlating them with the operation mission, modeling must generally include an adequate representation of the losses and retrievals and, for land actions, the advancement paces. For this can be used both determinist analytic models of the Lancaster family or stochastic ones for small echelons or the presence of uncertainties about the parameters of determinist models, and heuristic, tactic and operational models based on war experiences, which provide greater credibility.

The last step of modeling is the adequate representation of the operation final results which are obtained by cumulating similar results of the actions and their importance for the overall operation, as well as their reference to the evaluation grid used to assess the level of the mission accomplishment.

In elaborating the conceptual model of the mission space there are two contradicting tendencies. The first one is achieving an accurate representation of the mission space and is justified by the wish to achieve high operational realism. The second tendency is simplifying the model with the purpose of obtaining a feasible model, able to solve the problems specific to its use: the development of doctrine and tactics, evaluating the unit's performances, operational support to plan, conduct and analyze the operation, support analyses of the national security for the defense policy development.

Simplifying means replacing some operation submodels through a system of parameters in the context with similar effects on the model to those of the replaced submodels.

Finally, we consider that each conflict can be represented by a set of models depending on the original traits which were ignored in the modeling process and that each model has specific advantages proportional with the model's objectives and thus achieving integration within the model. The combat integrated modeling can cover all the types of simulations presented, through appropriate dual models; the operational realism and the degree of abstractness will not be miscorrelated with positive consequences on the degree of meeting the user's demands for success.

It is well-known that preparing the military actions is a very important activity. The effective preparation proves in the first place the commands' ability to lead. They have to foresee, plan, organize and coordinate the actions of larger units (units), based on the principles of command unity and promoting teamwork, ensure harmony among the leadership subject, object and purpose, connect leadership to execution. As training means, the simulation technologies and adequate communications can significantly reduce the supervision and control activities, necessary in the case of operational experiments or exercises. Moreover, they can create the possibility to collect, process and automatically integrate the databases and also the information and conclusions about the experimenting activity; subsequently, they can be analyzed, criticized, interpreted or even re-simulated for maximum results.

The modernization of the combat equipment has determined, among others, the emergency of training techniques and means out of which simulation is widely used and agreed upon in many countries and stimulated by the advanced technologies. The simulation process has been adopted in many domains including the military one, due to its effectiveness. Nowadays, we can witness the shift from simulation for training to simulation for decision; by simulating a variable of the military actions we can assess their effects, respectively we can check if a decision can lead to the accomplishment of an objective. Necessary corrections can be made so that, before the decision becomes action orders, it can be successively improved till it reaches the optimum choice.

Using digital models and protocols in the simulation processes, those using the practical training models, simulating the possible consequences of several planned actions but still not executed, could permit combined operational training (through simulation, true and virtual reality) to integrate all the weapons and services and also components from different countries. This system can allow for the subunits' combined training in different areas or training means, irrespective of their displacement, and also modeling the equipments and materials most adequately for different types of possible missions and situations.

The experimental study of a model is called simulation and is preferable in cases when the analytical study is impossible or too difficult. The studied system model or process is called simulation model and is, in most cases, a mathematical model. Hence the organic unity between modeling and simulation and the fact that simulation always ensures the possibility to study a model when its analytical study is not applicable.

The word simulation derives from the Latin word "*simulatio*" meaning the ability to reproduce, represent or imitate something. In science, the word simulation was used for the first time by J. von Neumann and S. Ulam between 1940-1944 during the research on nuclear physics made in the US by a group of scientists of the 'Los Alamos' school who made the first atomic bomb. The use of the word simulation is justified here given the particular purpose of modeling, reproduction in time using the simulation model, the original relevant behavior.

We can state that simulation is the experimental study technique of an operational model with the purpose of drawing relevant conclusions about the original, by imitating the operation by means of model and observation and by collecting, recording and processing data. As a reality method of study, simulation has its place in the process of selecting the decision-making methods, between intuitive and analytical methods, and can be used separately or along with any other method.

Operation simulation is the technique of experimentally studying an operation model with the purpose of getting to relevant conclusions about the original by means of model and observation and by collecting, recording and processing data. The use of simulation here is the direct consequence of the model's characteristics.

Military simulations have been classified in accordance with different criteria depending on the nature of the original, the simulation purpose, the characteristics of the simulation model and the constructive characteristics of the simulation technological support. From the simulation purpose viewpoint, we can perceive the following types of use: individual training or in groups of different sizes supporting training in the combat organization and providing opportunities for staff skills; research and analysis of complex military problems; planning the missions and systems for the general rehearsal in view of its achievement; simulating weapon systems for the operators training.

An authorized classification[4], widely used, of models and simulations includes three types of simulations: real, virtual and constructive. However, it is problematical because the borderlines between its categories are not clear and it excludes the simulation category which involves simulated personnel operating with real equipment. In other words, the three categories are described like this: real simulation is a simulation involving real personnel operating with real systems; virtual simulation is a simulation involving real personnel operating with a simulated system (this introduces the concept 'Human' in the loop – playing a central role in the simulation by controlling the operational, decisional and communication procedures); constructive simulation is the simulation involving simulated personnel operating with a simulated system; it also has real personnel stimulating the simulation (i.e., introduces stimuli) but which is not involved in determining its response. This taxonomy was also adopted by NATO[5]. The constructive simulation provides abilities for concept analyses and prognosis of possible results and demands large organizations. Its strength consists in providing opportunities to measure, generate statistics and conduct analyses.

Simulation can replace certain training environments, increase the value, quality and veracity of training and amplify the training process. The activities can be developed within the simulation system, without interruptions due to the safety provided by the information environment. At the same time, we should also take into account the simulation limitations which refer mainly to the training which takes place outside the real battlefield, with no real ammunition – aspects which lead to certain limitations of the training.

We seek to maintain a balance between real and simulated training using their best advantages. In certain situations, training by simulation can be independent within the integrated training cycle or can be used sequentially on certain levels of training. Using simulators at the level of individual and team training can sometimes create premises for their use within the collective training or, circumstantially, in other training environments.

An illustrative example is operation "Iraqi Freedom" where, according to General Franks, before the hostilities, the troops had a significant number of major exercises in the field preceded by several computer-assisted exercises followed by several rehearsals, all this allowing the staffs to work together for a longer period. Harmonizing the work within the units and large units' commands should be one of our priorities. At the same time, we should be aware of the fact that "operations are operations", the others are nothing but "administrative operations" which overwhelm the commands and place the commanders in unpredictable situations. In fact, what we wish is that for each bit of intelligence, for each proof of refinement of tactical thinking we should have a means to analyze and assess the results.

Simulation provides means to reduce the budgetary pressure and the possibility to improve, exploit and improve certain equipment by ensuring a better quality of them and also of the training system together with determinations on the quality of the army as a whole. This ongoing tendency characterizes most modern armies and we can see a real development of the simulation implementation in the new equipment and installations and the use of simulation software within the operational systems.

One of the current tendencies is using the simulation networks where the equipments are connected to simulators. This technique has already been used successfully both in the US army and other armies and permits the personnel to train in their places of residency and avoid troop deployment for training needs. Research in this domain requires multiple knowledge, in particular in the fields of: automatics, computer science and information technology, military sciences, geography, etc. Our country has verified experimentally the possibility to distribute simulation; in the army there is a working group preoccupied with the achievement of the functional model and identification of the technologies necessary to distribute simulation to the applications using different protocols.

The great demand for the current military modeling and simulation has become increasingly obvious, resulting from the need of total integration of all the military users' systems (i.e., sensors, command and control systems, weapon systems, training, planning and operational support systems). Thus, it is necessary to integrate the M&S systems within the set of the user's analytical and informational tools. Implementing the distributed simulation will increase trust, the participants' mutual support and real-time overall performance. On the other hand, the use of distributed simulation programs must be transparent for all the users.

The first settlement of the Common Technical Framework (CTF) for M&S was achieved in the US Department of Defense Modeling and Simulation Master Plan, with the purpose of ensuring the effective use of models and simulations by facilitating interoperability and reuse.

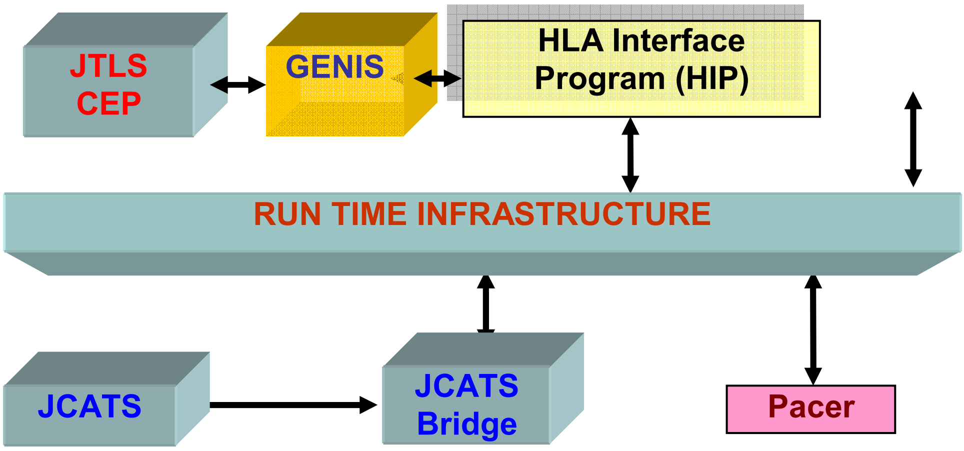
According to this objective, CTF represents: a high level architecture HLA encompassing all the models and simulations; the conceptual models of the mission space – CMMS – which should ensure the basis for the development of several simulation consistent and authorized representations; data standards which should ensure a common representation of data for all the models, simulations and C4I systems they interact with.

As for HLA, this is a developed technical architecture meant to facilitate the interoperability of the simulation systems. It allows for the simulation distribution to different simulation systems for a wide variety of applications to be elaborated and executed in a standardized way. For instance, these applications can support the analyses, experiments, the technical and technological acquisitions, training and education.

It also allows for the combination of the existent simulation systems with new ones, mixing different programming languages and operating systems. The architecture was inspired by some former simulation protocols such as DIS – Distributed Interactive Simulation – and ALSP – Aggregate Level Simulation Protocol. These individual technologies played an important role within different simulation domains but they were not totally able to meet the requirements of the M&S community, especially the simulation interconnection.

We can exemplify this by presenting the federation of a High Level Architecture (HLA), JTLS federation (Joint Theater Level Simulation) – JCATS (Joint Conflict and Tactical Simulation), representing the main constructive simulations within NATO. Their prime objective was to support the joint training for multiple echelons, a requirement which addresses the Multi-Resolution Module – MRM while administering limited resources.

The development of the conceptual model was decisive for reaching the federation objectives, the latter being based on scenarios describing the “real world”. The JTLS – JCATS federation architecture is presented below.



JTLS – JCATS Federation Architecture

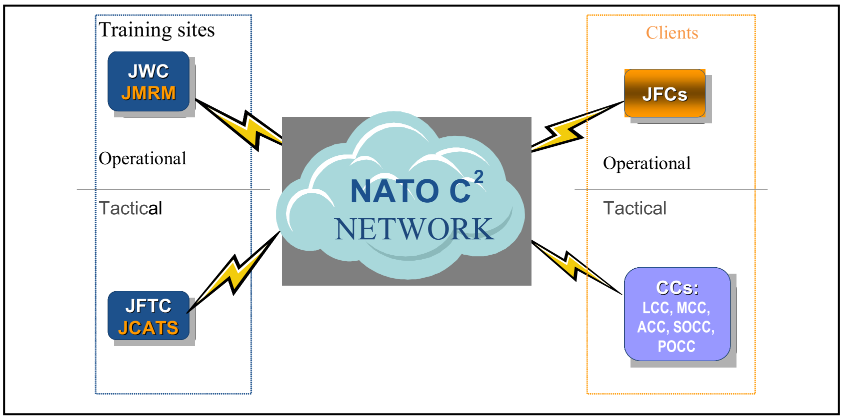
The events and incidents are produced by a Combat Events Program – CEP in JTLS which serves as an "engine" for war games and communicates with the GENIS system, component of the Graphical Input Aggregate Control System – GIAC.

The HLA interface sends and receives data bases for the war game for and from the federation by means of Run Time Infrastructure – RTI. RTI has six categories of services: federation management for larger architectures, such as the creation and combination with other federations; protocol management, to send and receive specific database classes; entity management, to send and receive the existent database and the wanted events and incidents; managing activities in time ensuring the causality conditions between systems; managing the property right to transfer attributes from one federation to another; managing the database distribution to ensure optimum filtration of information beyond the services provided by the protocols between interconnected applications.

The advantage of the JTLS – JCATS federation is its ability to send the control of simulated entities from one simulation to another thus permitting the entities to be modeled at any level of resolution.

Multi-resolution Modeling – MRM is necessary to assess the differences between the two simulations. This model represents in fact an integrated system able to support the integration of multi-echelon exercises at the theater level, with small structures and individual combat actions, being therefore improved. This is not only an object representation function. The JTLS and JCATS' functionality is not the same in different domains and this provides opportunities for the multi-resolution modeling implementation, while - more importantly - it provides increased functionality for the user. The objectives of multi-resolution modeling are: the forces' simultaneous training support within complex scenarios, at several levels, in a joint context; the detailed presentation of JTLS and JCATS models; ensuring the possibility to conduct exercises using distributed simulation; ensuring low costs for the exercises; supporting both the exercises using classified databases and also those using unclassified databases; ensuring complementary functionality; ensuring control of the federation configuration for users.

At NATO level, through the SNOW LEOPARD (SL – below) project, it is necessary to create a NATO Joint network for education and training, with strategic, operational and tactic capabilities, by connecting the existent national networks and capabilities. This project is a network distributed among NATO organizations, nations and partners in order to participate in increasing the training, education and distributed experiments.



SNOW LEOPARD project architecture

The NATO SNOW LEOPARD capability is being set up and will be able to provide training to NATO's Rapid Reaction Force, joint multinational commands and also NATO member states in accordance with the whole spectrum of missions, using real, virtual and constructive training methods and procedures and also the environment specific for the exercises to rehearse the missions.

In conclusion, we can state that both in the field of military leadership, technical and technological creation and also in the action-related one, the specialized human resource must make a permanent intelligence investment, acting creatively and innovatively. Troop training must complete some operation concepts emphasizing any contingency and its counteraction. During training, the troops and staffs must be faced with less familiar situations and thus forced to think creatively. Even if man is the one who decides, technology and particularly simulation help him to master the reality virtually until he engages real forces and means. While we can state that science is concentrated in the simulation programs, we can also state that the latter cannot replace man's art and imagination. One of the most important elements of training is, in fact, caring for people, seeking to identify the most realistic procedures to avoid fratricide.

In order to achieve a proper quality of simulation, it is necessary to introduce war experience into the model. The war experience[6] is stored in the commanders and staff's personal experience; data recording former wars; war documents; the studies and analyses specific to the operational research; military archives. It is introduced into the model through its appropriate structure followed by an adequate process of "adjusting" and "calibration".

Career soldiers are still skeptical about the ability of computer simulation to represent correctly the combat processes. It undoubtedly has an active role in increasing the quality of modeling in order to obtain the best possible models. For this, career soldiers must be convinced by the advantages provided by simulation and to realize that simulation is not an impediment but an enabler in their activity. On the other hand, model-creators must refrain from achieving "elegant" but unrealistic models in favor of "dirty" models reflecting the professional experience. Sooner or later, we might realize that, for us, military men, everything but the war is simulation.

Bibliography

1. DOD 5000.59-MODELING AND SIMULATION (M&S) MASTER PLAN, DoD, October 1998
2. NATO MODELING AND SIMULATION MASTER PLAN, Version 1.0, Document AC/323 (SGMS) D/2,7-2004
3. Cam.(r) dr. Vasile GRAD, Ion Stoian, Emil-Carol KOVACS, Vasile DUMITRU, CERCETARE OPERATIONALAIN DOMENIUL MILITAR, (Editura Sylvi, Bucuresti, 2000), p.78
4. DOD 5000.59-MODELING AND SIMULATION (M&S) MASTER PLAN, DoD, October 1995
5. NATO MODELING AND SIMULATION MASTER PLAN, Version 1.0, Document AC/323 (SGMS) D/2,7 August 2004
6. Ben-Itzhak, U. – Introducing War Experience into Staff Trainer, NATO PfP/PWP "Simulators and Simulation – Powerful Means Enabling Allied Forces To Reach Interoperability", Brno, Czech Republic, May 5-7, 1999.