Observations on the use of Modelling and Simulation for Advanced Planning in NATO

Dr. A. Tremori, Dr. P. Caamaño Sobrino, Mr. W. Buck and Dr. T. Mansfield

NATO STO CMRE
Viale San Bartolomeo 400
19126, La Spezia
ITALY

NATO/ SACT HQ
7857 Blandy Road, Suite 100
Norfolk, VA 23551-2490
USA

alberto.tremori@cmre.nato.int, pilar.caamano@cmre.nato.int,
wayne.buck@act.nato.int, thomas.mansfield@cmre.nato.int

ABSTRACT

NATO has recently employed a Modelling and Simulation (M&S) methodology to support advanced planning. This represents the first use of M&S for advanced planning in NATO, a step required due to an increase in the complexity of both the problem space and required responses. The event successfully modelled real world terrain and behaviours. This enabled the efficient and timely assessment of operational concepts and even more relevant, represented a first step toward a new approach to planning and decision making in NATO.

In this event, NATO utilised M&S tools and methodologies in two distinct stages. The first stage operated a stochastic simulator, provided by one Nation, to conduct experimentation at the operational level in order to understand the problem space and select specific vignettes of interest. A second process stage, with a simulator currently used in NATO for computer-aided exercises and planners involved in experimentation, allowed concepts to be run, understood and optimised in specific areas.

This paper presents observations, discussion and analysis on NATO's first use of M&S for decision support at the operational level. Key findings include a range of best practices and opportunities for improvement relating to event stakeholders, culture, materiel, data and process. These findings will be of particular interest to NATO teams looking to utilise M&S methodologies to reduce effort while optimizing the quality of a wide range of decision-making processes.

INTRODUCTION

For some time now, the political, economic and societal environment has experienced substantial changes with a huge impact to the military and informational aspects of the PMESII (Political, Military, Societal, Economic, Infrastructure and Information) framework dimensions. Because of this, the warfare paradigms, as they were understood in the past, are not valid anymore. The increasing number of non-state actors and the increased complexity of their organisations have led to the need for a change in military thinking, putting more demands on the level of readiness of NATO military forces, see [1] and [2].

A demand to increase the level of readiness, together with the required improvements to the level of agility and resilience of forces; increases the requirements on NATO planning capabilities. There is the need to plan for potential situations that may arise, taking into consideration the highly dynamics aspects of these potential situations.

Modelling and Simulation (M&S) has shown to be an appropriate methodology, that when effectively combined with other methods and techniques such as Operational Research and Analysis or Artificial Intelligence, can bring the capabilities required to enrich and enhance the NATO Planning Process to cope

with the currently highly contested environment. Thus, NATO recently employed a planning methodology supported and informed by M&S.

This simulation event put together stakeholders of three different communities: operational planners, operational analysts, and M&S experts and technicians. Two different simulators, one stochastic and one deterministic, were used at NATO and National level in a process to conduct experimentation at the operational level. This increased the understanding of the comprehensive problem space and allowed an in-depth analysis of specific vignettes and set of events.

The observation of this event has allowed the identification of key aspects, best practices and areas of improvement related to stakeholders, culture, materiel, data, and process. The present work describes these key observations and is structured as follows. Section 2 describes the planning and analysis process followed in this NATO Simulation Event. Section 3 provides details on each one of the areas of best practice identified with a summary of the proposed observations and recommendations. Finally, Section 4 closes this work drawing the conclusions.

It is important to remember that, due to the level of classification of the observed and analysed study, part of the content of the original reports has contributed to this paper.

OBSERVED PROCESS

The primary source of data for this work has been elicited by observing a NATO M&S based study process for decision support.

Description of the observed process and main roles

The design of the experiments that supported the simulation study leveraged on the well-established NATO Collective Training & Exercise process [3]. Based in this directive, the whole experiment was based on three main phases: the preparation phase, which lasted about one year; the execution phase that ran over about three months; and the staffing and reporting phase. Figure 1 shows a schematic view of the planned timeline of the event. The main elements of the process are represented: the blue elements represent the coordination meetings, information products including both inputs and outputs are represented in orange, the yellow elements are activities of the process; whilst the green elements represent the stages in which the experiments using determinist simulation with the planners in-the-loop were executed.

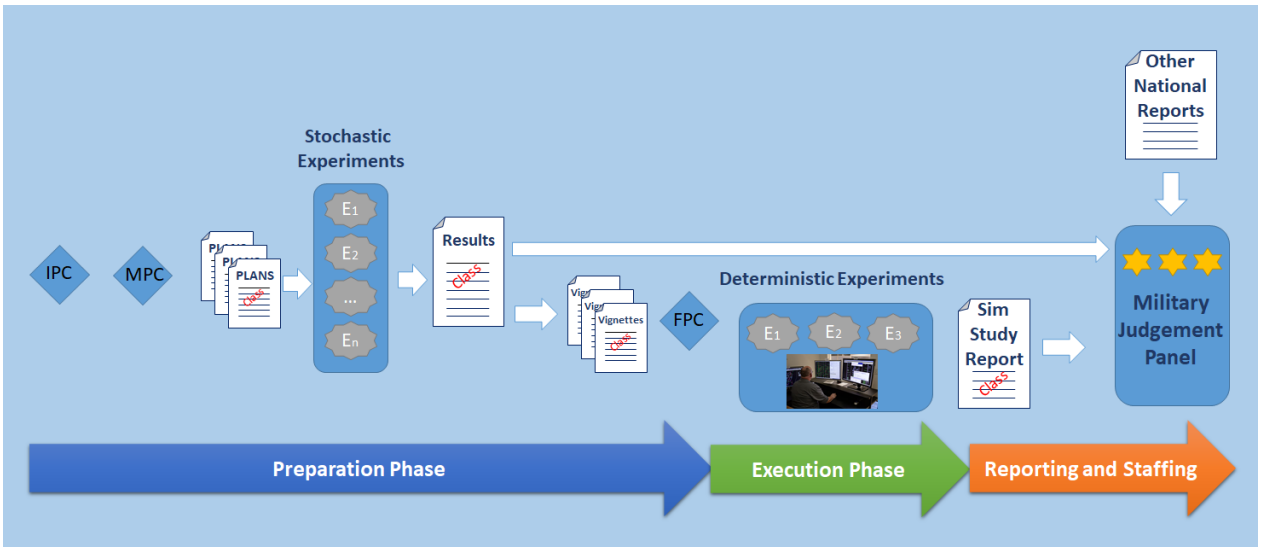

Figure 1: Timeline of the witnessed decision support process.

This paper presents the observations and the analysis collected by the CMRE M&S Team during preparation and execution.

The main actors of this process were a core team, for the coordination, three syndicates (data, experimentation and technical) and a panel composed by high ranking officers (military judgement panel) responsible for the final decisions.

During the preparation phase the core team refined the methodology of the study supported by SMEs on M&S and data analysis, while the data syndicate gathered, validated and input in the systems, the data required for the execution phase. In parallel NATO planners focused their efforts on the development of supplementary planning products such as the Blue Team ORBAT, the Red Team ORBAT, and the Courses of Action (CoAs).

The technical syndicate established and set up the facilities: including the simulation site and tools. Regarding the technical side, the process described used two main simulation tools. The first was a stochastic simulator provided and operated directly by one Nation, a campaign level tool that provided campaign outcome reports. The stochastic simulator was a closed model, meaning that it executed the courses of action without any additional interaction. Operational planners developed CoAs, which were agreed by the Military Judgement Panel (MJP). These CoAs were simulated by the stochastic simulator to produce a number of possible outcomes for a start state.

From the stochastic simulations, a set of reports was delivered to indicate possible vignettes. The military judgement panel analysed the vignettes prioritizing them for further analysis.

The selection and ranking of the vignettes marked the end of the preparation phase and the beginning of the execution one, where a deterministic simulator, currently used to run the main NATO computer aided exercises at operational level was used.

By this deterministic simulator, it was possible to perform further analysis on the scenarios with the planners involved in the simulation events to provide orders and feedback and observe the results. At this phase, the determinist simulator was used to further investigate a sub-set of CoAs and vignettes. An After Action Review (AAR) meeting was held after each run. The three syndicates, planners, analyst and technicians; together with the core team shared the outcomes of each run from the point of view of their specific area of

knowledge. This process allowed them to reach a better understanding of the situation leading to more informed planning products.

AREAS OF BEST PRACTICES

The observations collected by the project team were grouped in five areas of best practices: stakeholders, culture, material, data and process. This section provides a summary of each area with some recommendations identified for each group.

Stakeholders

This grouping of comments relates to the human factor in the observed experiment. The comments focus on the process stakeholders, including their roles, responsibilities and impact on the process, as well as the interactions among the syndicates and the continuity of the involved personnel.

While there is a methodology to support the decision making process, the decision maker is always a human or, more typically, a team of humans. The observed impact of the different layers of humans involved in the process is highly critical to producing a reliable and valid final product. This criticality is due to a set of different reasons, including among others the following ones:

- The current NATO planning process is based on the experience and skills of the officers more than on tools. The adoption of future process changes may be more effective if they are an evolution from existing, known and understood processes.
- The overall experimental approach used for this project requires human intelligence to fuse all the different sources of information used.
- The characteristics of the simulators used in the experiment and the way they were used, required continuous human intervention.

Observations

An area of existing best practice has been highlighted in the number of different stakeholders and multi-cultural approach of the witnessed process. According to the observations, the roles of the stakeholders refer to three main areas, which are aligned with the roles identified in the NATO M&S Master Plan [4]: customers, user and suppliers. Figure 2 describes how the three categories are linked and overlapped with the main stakeholders of the experiment: the three syndicate sessions (planners, analysts and simulation experts), the core team and the military judgment panel (MJP).

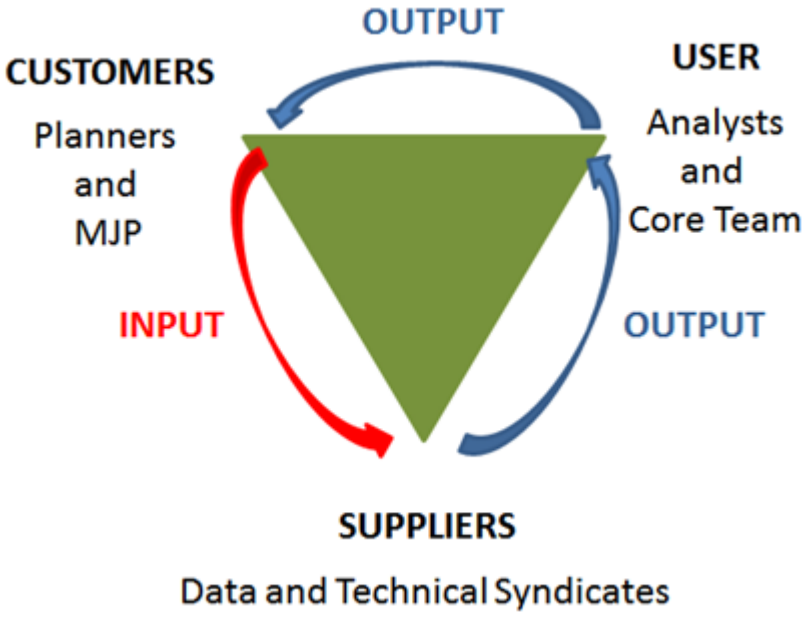

Figure 2: Simulation Study's Stakeholders roles and interactions.

The definition of the roles of the stakeholders brings to a critical concept in a simulation project: who is the customer? Any ambiguity in the identification of either the overall process customer or the customer for each syndicate may result in either an inefficient process or producing a result that does not achieve its maximum impact in the decision making process. In this specific case, care should be taken to ensure that the whole process and existing or future tools are designed to provide complete and clear information both to Planners and the MJP at all stages of the event. The involvement of the MJP throughout the process is vital to provide further soft data that can be used to correct any simulation biases and improve the quality of the result.

Regarding the identification of roles and the assignment of responsibilities to the stakeholders, one area of potential benefit highlighted by the comments could be provided by allowing the analyst syndicate closer operation of the simulation software. In this way the planners, via the analysts, could then expand upon a perceived tendency to mainly identify winning solutions and instead use simulation for a "what-if" analysis aiming at identifying weaknesses in plans and highlight areas for improvement.

Close interaction among the different syndicates is the second area of best practice identified under the Stakeholders category. Observations highlight that the close interaction of the syndicates throughout the process creates a beneficial, multi-cultural approach for decision making.

Recommendations

As already stated, the role of the human is the most a crucial aspect of the observed simulation informed decision making process. The following list summarises part of the recommendations related to this first set of observations:

- **Identify and support the customer:** Processes and tools should be designed around the end customer requirements and needs. MJP and Planners are the current customer of the results of the simulation process.
- **Encourage the multi-cultural approach:** Military, analytical and technical cultures (Planners,

Core Team, Analysts and Simulation Operators) provide a beneficial multi-cultural approach to the decision making process.

- **Facilitate the human interaction:** The process and the facilities have to encourage and support the human interaction in the current process.
- **Information flow:** MJP and Planners must be provided with the proper level of information during the whole process. Analysts have the responsibility to feed the customers.

Culture

In addition to the analysis on the role and interactions of stakeholders and syndicates, a more global grouping of observation comments is around the culture and knowledge on M&S of the people involved in the process, where M&S is a methodology that encompasses several concepts, such as tools, processes, modelling, design of experiment…. These observations relate to the leadership, levels of experience within the teams and prior M&S education levels, as well the approach to this kind of experiment.

Observations

Perhaps the most significant point raised by the comments in this grouping was that of creating a better knowledge about M&S and setting proper expectations on the usage of M&S as a methodology to inform and support decisions.

The expectations could be set by concentrating on developing knowledge of the strengths and limitations of the specific tools used: this should happen early in the process stages to align the syndicates and improve understanding. Specific examples could be the presentation by technical and data syndicates on the capabilities of the tools to the planning and experimentation syndicates. Another sample could be the explanation of the NATO planning process to the simulation operators to make them aware on the differences between the use of M&S for decision support, and their consolidated knowledge about the use of M&S for training.

A more generic comment, relates to the development of culture and knowledge on M&S in NATO and Nations. This would create a baselineto build upon to make the stakeholders aware of strengths, benefits and limitations of the M&S methodology. Particular emphasis may be given to generating a desire within the NATO leadership to use M&S processes to test and learn about key plan features, as opposed to the current observation, which indicates that the generation of a winning plan is prioritised as a main process output.

The use of M&S in a decision support process inherently allows a wide range of possible “what if” scenarios and situations: this potential has to be exploited, in particular by the Planners, to explore as many critical areas of the plan as possible. During the preparation of the experimentation and then during the Period Games the approach of the planners has evolved from the traditional and culturally rooted approach to “plan to win” into a more productive “plan (and simulate) to test”.

Recommendations

- **Education on M&S:** A general remark about the need for more M&S education in NATO at all levels.
- **Setting the expectations:** In the planning phase of the event, the syndicates must be aware of limitations and potential of simulation for supporting decision making. In general, it is important to understand goals, procedures and expected benefits of the study.
- **Planning to test and not necessarily to win:** The current, traditional, approach from planners is to develop sound, robust winning plans. The usage of simulation should encourage a more challenging

"what if" approach among planners.

Materiel

Material refers to the simulators used for supporting the experiment as well as databases and other tools for cross-syndicate support and meeting management. As usual, the technological strengths and shortfalls are the easiest to be identified, replicated (strengths) or mitigated (shortfalls).

Observations

The main tools used for the witnessed simulation-based process were the deterministic and stochastic simulators used during the study. These tools provide a wide range of outputs to the process stakeholders. Potential improvement could be achieved by an improvement or a different use of the M&S material to allow end users, mainly the analysis team, more direct access to the tool inputs and results. By allowing analyst and planers to work on the inputs, re-run the simulation and observe their effects, it would allow new ways of working within the syndicates and in the future a new planning process supported by M&S. The ability for the end customers, supported by the analysts, to observe different runs of the simulation in a rapid and dynamic sequence could open new possibilities for the decision support process. Further, the ability for the planning syndicates to witness the link between their decisions and the scenario outcomes could provide a powerful new informative process.

To support the above described enhanced process, the software should require a reduced time and effort to run the simulations (this includes also the effort related to data management described in the following section). Another challenge to allow new ways of working requires an improvement of the interfaces at the inputs and outputs of the tool to allow non-technical staff to interact with them in a more intuitive manner.

An important remark related to material is linked to a cultural lack of trust and understanding of benefits and limitations of M&S, that has been already described in the previous best practices. This is particularly relevant for stochastic simulation, which is still, often, considered as a "black-box" that provides uncertain results. There was not a problem of clarity for deterministic simulation outcomes, considering the continuous exposure of the end users, the planners, to the simulation runs and results. Nevertheless, the possibility to observe and manage a huge number of details, which are sometimes at a too high level of resolution can be misleading or could even lead to the perception that quality of the results is low, in particular in the early phases of the experimentation.

Additional material observations have been made about the limitations in the geographic, functional and time simulation capabilities of the existing tools. The simulation was observed to be limited in its considerations to both the geographic window that represents the Joint Operational Area (JOA) and to a subset of domain effectors, excluding effectors such as electronic warfare or logistics.

In addition to the geographical and domain restrictions, the current material does not encourage the investigation of non-military 'white' and 'grey' actions such as civilian movements. An opportunity exists to expand the tools to consider the wider and more diverse military and non-military picture that would be present in real operational scenarios.

A more effective analytical process based on M&S may be obtained, in the future, by creating a multi-layered simulation architecture, the concept of which is shown in Figure 3

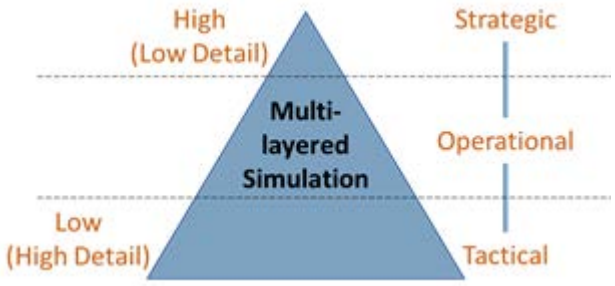

Figure 3: Multi-layered approach concept

This approach would allow models with high level of detail to be used where required, for example in tactical level simulations observing specific geographical areas, or events or specific tactical events with an operational relevance (e.g. Cyber-attacks, CBRN[1] incidents, ASW[2], MCM[3], SOF[4], etc). Models with lower level of detail may be used for higher level simulations such as, strategic level simulations or for analysis covering wider scenarios for geography space (out of the area of operations) and time (future impacts of the current events).

This observation is strictly linked to a need related to data and database management in particular: different simulators would allow exploring different levels of detail but this would require a modular database.

Additionally, and considering the importance and value gained from the interaction among the different stakeholders involved, tools for "Cross-syndicates" management are strongly suggested.

Recommendations

- **Improvements on the usage of existing tools and acquisition of new ones:** Provide a more efficient and effective support to the analyst and planners in terms of an easier access to data and a more dynamic use of simulation. Also, provide a more exhaustive coverage of the problem space, in terms of time, geography and functional areas.
- **Capability to run multi-level simulations:** Run multi-level, multi-dimensions simulation to support different level of planning and analysis (strategic, operational, and tactical).
- **Event Management:** The interaction among syndicates is a crucial factor of this kind of experiment, there is a need for "cross-syndicates" management tools (data management, event management).

Data

Data are a critical asset for this experiment, but they have to be collected, managed and provided as the final output. This grouping of observations has been made around the availability, level of detail and maturity of the data used by and produced by the simulation process.

[1] Chemical, Biological, Radiological and Nuclear.

[2] Anti-Submarine Warfare

[3] Mine-Counter Measures

[4] Special Operation Forces

Observations

Analysis of the observations has highlighted a potential risk that current simulation inputs may contain both too much information in areas that are not critical to the outputs of the simulation and too little detail in areas that may affect the final outputs of the process. Similar effects are also possible on the outputs of the process, where more depth of knowledge and further information could be provided in areas that are critical to the decision-making teams.

A method for determining and validating the correct data content, with the correct level of detail could potentially bring further improvements to the observed process. At the same time, a high granularity of data is required by the current systems and, even more important, it has an important cultural impact on the planners who are likely to not trust a simulation with aggregated information.

Of course, the availability of data is an area under continuous internal review in NATO.

In addition to the presence, level of detail and consistency of the data used in the simulation inputs and outputs, the availability of reliable and accurate verification, validation and accreditation (VV&A) information is also important, see [5] for details. Observations identify that the capabilities and limitations of the process inputs and outputs are not clearly available, well communicated or understood by all relevant stakeholders. The involvement of the customers, mainly the planners, in the VV&A process is fundamental for the development of trust in the process and for the improvement of the quality of the final results.

The potential future opportunity to manage different levels of simulation to support other experiments or an innovative planning process, described in previous section, requires a capability to manage aggregated data to serve the different layers of aggregation of the models.

Recommendations

- **Maintenance, improvement and availability of the database:** Allow a more efficient access to data for future experiments/training events. Hold regular events to maintain and improve the current databases.
- **Manage the level of detail of data:** Considering that the current level of detail is really high and represents a cost in term of resources and time, it has to be investigated how much this effort is required by the simulation tools or it is a cultural need from the planners.
- **Manage aggregated data:** Being able, in the future, to generate data to support a multi-layer, simulation.

Process

Process group includes all the observations related to the doctrine and methodology, the organization and management of the experiment that have been used to evolve and generate the process briefly described in this paper.

Observations

This area represents a probable gap in the NATO doctrine for M&S based decision support processes. The development of the witnessed M&S based decision support process is currently linked to the NATO doctrine on collective training and exercise (CT&E). This was, probably, the best possible decision when the simulation study was set up, because the exercise organization is a well-defined and solid process, which allows NATO to deliver several, complex collective training events and exercises every year. Then many of the early stages of the decision support process are closely aligned with CT&E activities and the Collective

Training and Exercise Directive (CT&ED) [3].

As the process continues, the CT&E and decision support processes diverge. The main reason for this divergence is that, in CT&E, the end state and final deliverable content is known. This is not the case for decision support processes meaning that the use of a CT&E doctrine becomes inefficient. To resolve this, a NATO doctrine for M&S based decision support processes could be generated.

Benefits may also be achieved if the developed M&S based decision support doctrine were well aligned with the planning doctrine and planning schedules. Effort in this area will encourage the use of M&S as a core part of the planning process and this, on a long term could lead to a new planning process supported by quantitative methodologies such as M&S.

An additional key section within any new doctrine could also be a discussion around methods to preserve valid results in the process where, in the current experiment, validity is maintained by a number of complex human and simulation interactions as a result of the best practice of a close and collaborative working environment between the syndicate teams.

Another area of best practice has been highlighted in the potential to maintain a high pace throughout the event. Focus on planning and preparation of the event have to minimize periods of inaction of planners and analysts.

Recommendations

- **Develop a specific doctrine for M&S based decision making process:** The usage of the CT&E process is valid but decision making and analysis based on M&S require a specific approach.
- **Planning the resource allocation**: Resources (human and budget) must be properly allocated. The inclusion of future experiments in the calendar of current exercises and training events could be a solution.
- **Organization of the experiment:** A complex event requires proper management of each step to maximise the results. A clear leadership should provide guidance during the event (management of time, rooms, personnel, communications, etc.). The battle rhythm must be intense to keep all the teams focused on the work and on the objectives.

CONCLUSIONS

NATO is a conservative and, sometimes, not so fast organization in the approach to new steps: participation in an event that occurs for the first time in the Alliance is a great privilege and a very rare opportunity. The simulation study described in this paper represents the earliest step of a new process for planning and decision making. Including initial planning this process ran over a period of twenty-sixmonths. And even when the final analysis and assessment have not been yet published, the achievements made so far have shown the potential of M&S to provide support and to contribute to a new approach to decisions and analysis.

As a final analysis and a window towards future activities, the results of a DOTMLPFI analysis carried out over the groupings of identified best practice are shown in Table 1. The analysis provides an idea of the future required effort estimated to consolidate or implement each of area of best practice against the eight spaces of the DOTMLPFI framework.

Table 1: Observation Groupings DOTMLPFI Analysis
(Note ranking based on 3-level scale where red=high expected effort to implement, yellow=medium and green=low expected effort to implement)

Observation Grouping	D Doctrine	O Organisation	T Training	M Material	L Leadership	P Personnel	F Facilities	I Interoperability
Stakeholders								
Culture								
Material								
Data								
Process								

Notice that the content of this analysis represents the views of the authors of this work and it has not been validated with other stakeholders of the process.

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