Modelling & Simulation and Data Science to Support Commander's White Picture

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ABSTRACT

The white picture is in the current complex multi-domain operations the key enabler for a commander to understand threats and their consequences for his mission. Modelling and Simulation (M&S) together with Data Science (DS) can support a) up-to-date development of the white picture b) analytical work of SME's that estimate the related risk to military operation at any level of command. The paper discuss the NATO use case of M&S and Data Science implemented to support the SACEUR's Area of Responsibilities (AOR) resilience risk articulation. The Open Source data were analysed, structured and manipulated to generate in automated fashion and on demand, the geo- referenced data/information related to the Resilience 7 Baseline Requirements (7BLR) covering continuity of government, energy supply, movement of people, food and water, mass casualties, communication system and transportation system in the JFC's AOR. It serves as the input of the NATO resilience model that foresight the risk to SACEUR's operation. The system dynamics paradigm was used to develop the NATO resilience model as an ideal approach to deal with the mixture of qualitative and quantitative input data and abstract resilience language at the strategic level. Strategic shocks effect the current and close future of the white picture status. Machine Learning techniques were implemented to estimate the strategic shocks parameters. The prototype has been used in the experiment with the end-users and validation steps have been identified.

1.0 INTRODUCTION

The Common Operating Picture (COP) is the very fundamental command and control tool providing situational awareness to users at all levels of command. It enables informed decisions based on the actual data in the Area of Responsibilities (AoR) [1], [2]. The COP is composed of three components. The first one, the blue picture, provides data and information about friendly forces. The second one, the red picture, contains data and information about enemy forces. The last one, the white picture, provides the current situation in the civil domain within the AoR.

Uncertainty is a common denominator in the current and close-future complex multi-domains operations. It is mostly portrayed in the white picture with a great deal of unknowns. Therefore, approaches to better understand and represent the white picture are of an eminent importance. M&S and DS with their methodologies, methods, architectures and techniques are scientific disciplines well suited to reduce the uncertainty of the white picture. M&S together with DS can support a) up-to-date development of the white picture b) analytical work of SME's that estimate the related risk to military operation at any level of command. When dealing with the real time support of operations, M&S tends to be more used at the abstract level description of the AoR with what –if analysis capabilities, whereas DS covers the real time data gathering, analysis and manipulation with the varying levels of data granularity. M&S cannot be used isolated without having a connection to the real world data that is properly cleaned, verified and aggregated at the level needed by users of the white picture provided by DS.

2.0 NATO RESILIENCE

In the current NATO operations, the shocks from natural disasters of failures of the civilian critical infrastructures influence heavily the execution of any mission. NATO Resilience is about NATO countries being prepared for or absorbed any strategic shocks that can happen. Building resilience cannot be enforced; however, it is national responsibility to do all the steps needed to increase their capacity to deal with shocks and events that interrupt availability of basic national services. NATO agreed on Resilience through Civil Preparedness (RtCP) delivering understanding of civil environment and its impact on NATO military operations [3]. Despite its conceptual uncertainty, resilience is mostly about the measurement of capacities and availabilities [4]. NATO Resilience agreed terminology is expressed in seven Baseline Requirements (7BLRs) [3]. These create the following Resilience metrics used for expressing capacities and availabilities:

- Continuity of Government,
- Energy Supplies,
- Uncontrolled Movement of People,
- Food and Water,
- Mass Casualties,
- Communication and
- Transportation

NATO's approach to model a strategic shock (Figure 1) is described as an adaptive process in which resilience is exercised by capacities to absorb strategic shocks with minimal impact (C_{gap}) while maintaining essential functions at an acceptable level. Then system capacity needs to be recovered at a reasonable time (t_1) and at a reasonable cost. Well-designed system manages the local consequences of a shock or event and adapts, and increases its capacity (C_f) to withstand future shocks or critical events.

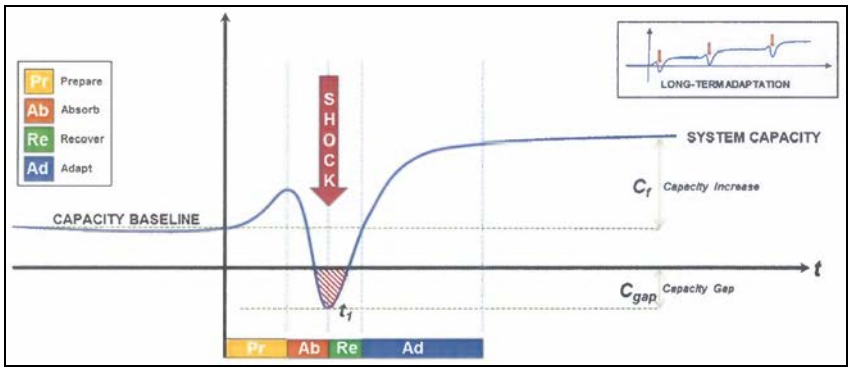

Figure 1: NATO approach to model a strategic shock.

3.0 M&S AND DS ARCHITECTURE SUPPORTING THE WHITE PICTURE

The overall architecture of M&S and DA support to the white picture (Figure 2) is founded in three main blocks. The first block, Resilience Data Analytics MVP, using DS techniques like Machine Learning and Big Data, scans in the real time real world Open source data and prepares the aggregated summaries metrics to define the Resilience Baseline situation describing Day 0 Civil Preparedness through 7BLRS lenses. The second block, Aggregated Resilience Model uses system dynamics as a modelling and simulation paradigm to understand most likely resilience behaviour with what-if analysis in the given time of 150 days. The third

blocks is executed in two modes that are used depending on the employed environment to describe strategic shocks or critical events to national Civil Preparedness. In the first mode called "Real world", it supports the white picture analysis in the real crisis by connecting to the real time real world Open Source data. This capacity provides automatic data collection from Open Sources with automatic and dynamic threshold determination used for prediction of strategic shocks and events. This block is fully automated and make updates every 24 hours. In the "Simulated world" mode, it is loaded by incidents and events that are pre-scripted in the form of Main Incidents List/ Main Event List (MEL/MIL). This third block serves as inputs to Aggregated Resilience Model to run the what-if analysis and estimate the capacities and availabilities of Resilience metrics.

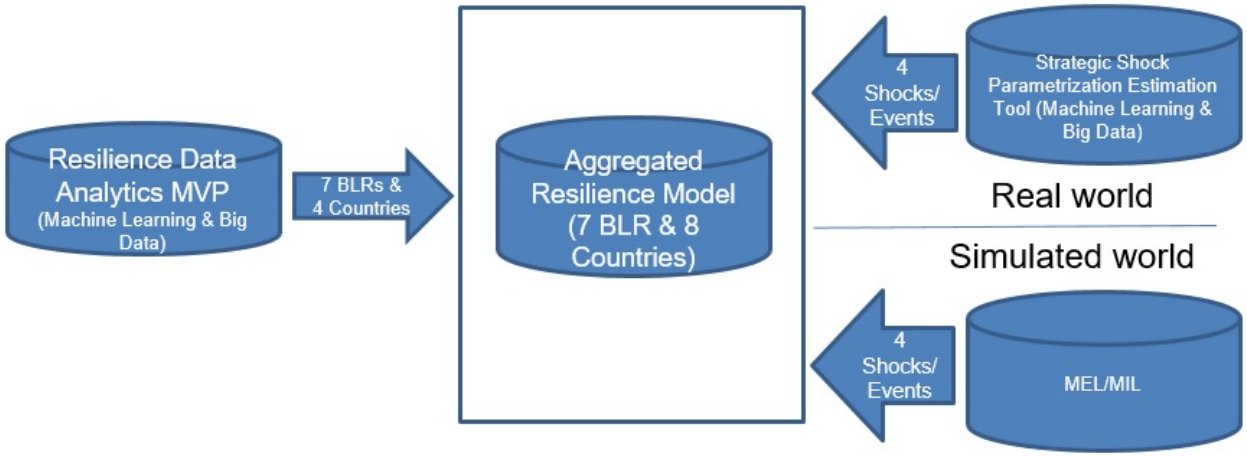

Figure 2: M&S and DS architecture for the white picture

The current Resilience Aggregated Model contains around 80 internal variables that are modelled in Casual Loops Diagrams (CLDs) (Figure 3) and Stocks and Flows Diagram (SFDs) following the system dynamics paradigm [5]. For each of 7BLRs there is one CLD and SFD created.

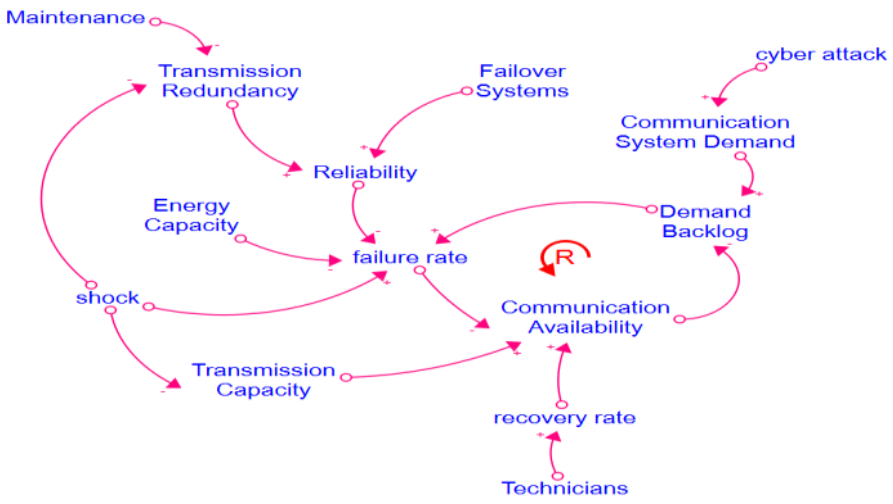

Figure 3: Communication model - CLD

SFDs' variables' parameters needs to be set up to for each country in AOR to define the Day 0 7BLRs Resilience capacities for each nation involved in the AoR. It is done by the export function from Resilience Data Analytics MVP. There is the difference in the granularity of data in Resilience Data Analytics MVP and Aggregated Resilience Model; therefore, there is an implemented interface that transforms high-level granularity data into the abstract level parameters in the system dynamics based model.

The abstract level parameter Energy Redundancy can be taken as an example. It represents the level of readiness for "alternative energy resources" in the event of energy supply disruption. This value ranges between [0,1]. Here, 1 stands for a very reliable alternative means that are fully operational while 0 means that there is no alternative way to reach the energy resources or they are not reliable. So it is expressed as the percentage of total electricity import in total electricity supply coming from Resilience Data Analytics MVP:

Energy Redundancy = (Electricity Import)/(Electricity Import + Electricity Production).

The four strategic shocks (electricity blackout, cyber-attack, big human movement and pandemic) are modelled with their parameters (start, end, magnitude). These parameters need to be previously set up by already described third block in the architecture. There is also a need to define the effects of strategic shocks on each country in the AoR following the Aggregated Hierarchy Process methodology [6]. Strategic shocks influence the availability parameters of each 7BLRs in the time of 150 days; see Figure 3 and Communication Availability parameter.

There is an event concept introduced into the Aggregated Resilience Model. Any generic event can cause decrease in capacities parameters of 7BLRs; see Figure 3 and Transmission Capacity variable, and consequently in availabilities parameters. There is a need to set up the generic event parameters (start, end, magnitude and effects to BLRs capacities parameters) before the model can be executed and effects of that event can be portrayed in the form of 7 BLRs' availabilities and capacities parameters.

4.0 CURRENT VISUALIZATION AND WHAT-IF CAPACITY TO SUPPORT THE WHITE PICTURE

When bringing the results of what-if analysis to the strategic military level, there needs to be an aggregation mechanism involved, otherwise, there is a high risk of getting too much data and information to the decision makers.

NATO aggregates this 7BLRs into more generic categories allowing describing Civil Preparedness at strategic level. It is Continuity of Government (GOV), Continuity of Essential Services (POP) and Civil Support to Military (MIL) that are expressed as 3 Core Civilian Functions. Further, the risk to military operation is articulated through 4 Risk Military Functions, namely Command and Control, Manoeuvre, Sustain and Protect. Based on Resilience SMEs knowledge there was an upper layers of CLDs created describing dependencies and interrelations among 7 BLRs, 4 Risks Functions and 3 Core Civilian Functions.

The results of the aggregation process of what-if analysis are then visualized through a strategic dashboard that is used to communicate the Civil Preparedness further as directed by NATO Crisis Response System. The strategic dashboard accumulates 3 Core Civilian Functions and 4 Military Risk Functions over the AoR (Figure 4). In this case, the outer circle describes a magnitude of availabilities of 3 Core Civilian Functions and outer circle describes a level of risk in 4 Military Risk Functions in AoR in the Day 0 situation. It reflects the white picture situation in AoR before any shocks or events are introduced, therefore, before a crisis.

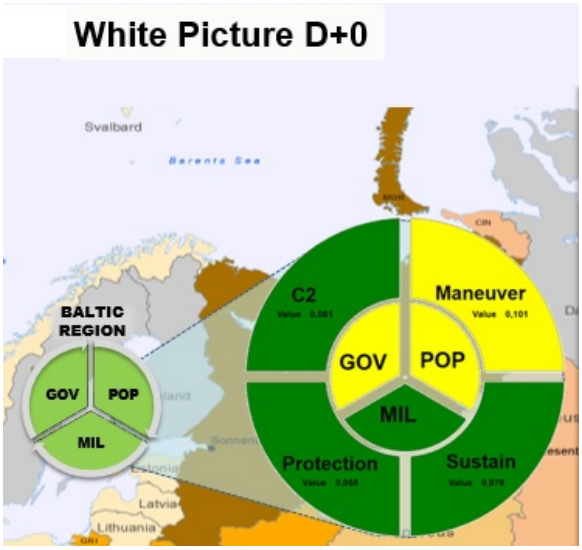

Figure 4: Strategic dashboard: Baseline D0 situation

Figure 5 depicts a situation where a strategic shock of cyber-attack and electric blackout had demonstrated their effects in Day+11 and created high risk to operation in the Sustain Military Function. Simultaneously, there was very low availability of GOV and POP Core Civilian Functions.

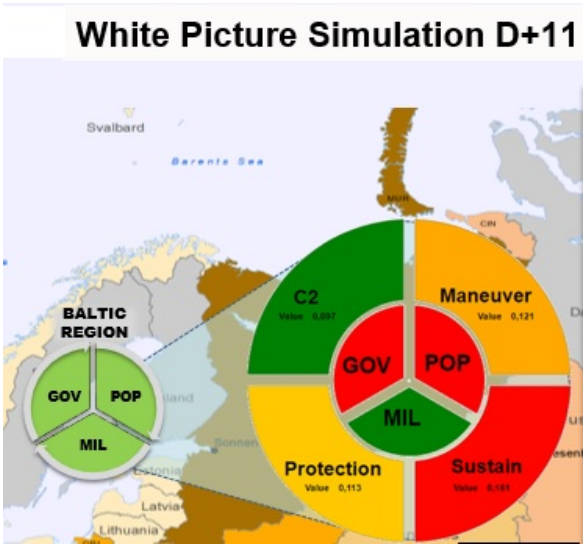

Figure 5: Strategic dashboard: D+11 situation

When further analysis is needed, the user can go into details of the Aggregated Resilience Model and to visualize the availabilities and capacities parameters of each 7 BLRs for each country in the AoR.

Figure 6 shows two main parameters of Communication BLR, namely Communication Availability and Communication Transmission Capacity, that are following Day 0 situation in country A (Run 1). There is no event or shock introduced and Communication Transmission Capacity is the overall capacity that includes the "redundant capacity". Moreover, some part of this overall capacity is "under maintenance", therefore, Communication Transmission Capacity has higher value then Communication Availability. All in all Communication Availability is the "online capacity" that is the "overall capacity" minus "redundant capacity" and the "under maintenance amount".

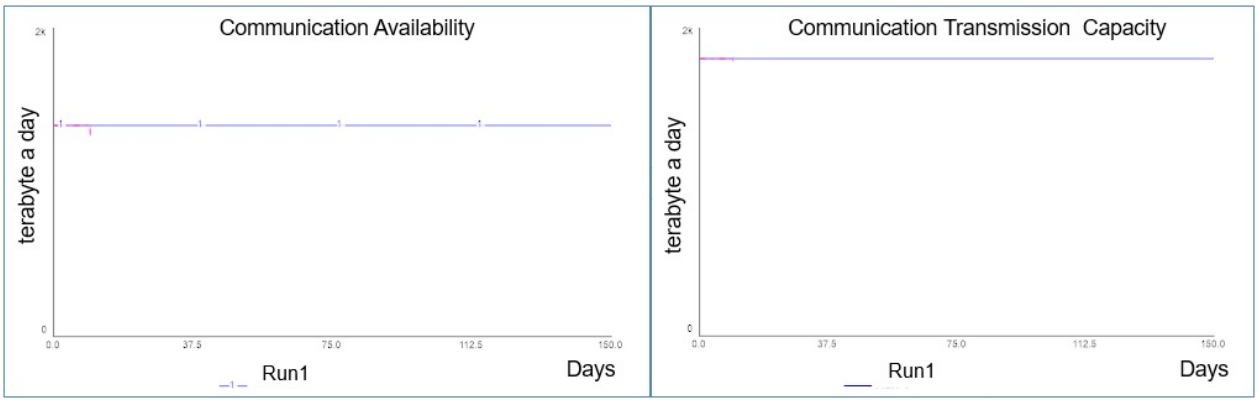

Figure 6: Strategic dashboard: Baseline D0 situation

Figure 7 demonstrates the capacity of the Aggregated Resilience Model to describe the effects of an event and a strategic shock on Communication BLR. There is a generic event decreasing Communication Transmission Capacity on day 10 (Run 2) and there is a pandemic strategic shock starting on day 35, ending on day 75, and having a decreasing effect on communication staff with a 0,50 loss fraction (Run 3).

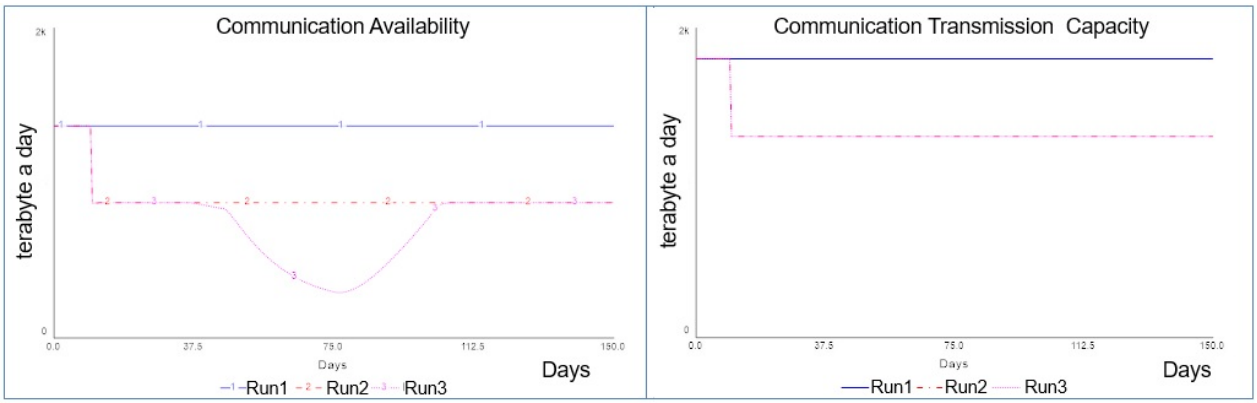

Figure 7: Strategic dashboard: Baseline D0 situation

5.0 CONCLUSION

If Aggregated Resilience Model is used in the real time and the real world data situation, then Open Source data from the particular AOR needs to be analysed, structured and manipulated to generate in automated fashion and on demand the geo-referenced information related to the Resilience 7BLRs. Then this information needs to be digested by the Aggregated Resilience Model that can foresight the risk to SACEUR's operation. Both prototypes, Resilience Data Analytics MVP and Aggregated Resilience Model, have been used in the experiment with the end-users and the critical validation efforts have been identified. Upfront, there is a need to validate the interface between the two projects to assure that the connection between the abstract level model and the real world data reflects the reality in the given constrains.

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