Data Farming Decision Support for Operation Planning

Dr. Johan Schubert
Department of Decision Support Systems
Swedish Defence Research Agency
SE-164 90 Stockholm
SWEDEN

johan.schubert@foi.se

LTC Stephan Seichter
Directorate IV Scientific Support and Interoperability
Bundeswehr Office for Defence Planning
DE-82024 Taufkirchen
GERMANY

stephanseichter@bundeswehr.org

Mr. Alexander Zimmermann
Dr. Daniel Huber
Fraunhofer IAIS
Schloss Birlinghoven
DE-53757 Sankt Augustin
GERMANY

alexander.zimmermann@iais.fraunhofer.de
daniel.huber@iais.fraunhofer.de

Mr. Daniel Kallfass
Airbus Defence and Space GmbH
Claude-Dornier-Straße
DE-88090 Immenstaad
GERMANY

daniel.kallfass@airbus.com

Dr. Guro K. Svendsen
Norwegian Defence Research Establishment
P.O. Box 25
NO-2027 Kjeller
NORWAY

guro.svendsen@ffi.no

ABSTRACT

Data farming is a modelling, simulation and data-analysis methodology that provides the possibility of examining vast solution spaces. In this paper, we describe how to provide support to decision makers in operation planning using data farming in an actionable support mode. We develop a Data Farming Tool for Operation Planning (DFTOP) to streamline this support to reduce the effort needed to prepare analyses and to facilitate the collaboration between decision makers and analysts. With DFTOP, the possibilities of quantitative simulation-based analysis are made readily available to decision makers and planners at the operational level. DFTOP supports evaluation of operation plans by data farming a broad set of Courses of Action (COA). The support is aligned with the planning process of the NATO Comprehensive Operations Planning Directive (COPD), providing support for the planning group. Based on initial validation efforts and user acceptance tests, it has been concluded that DFTOP meets the needs of the military planner and successfully brings data farming into the actionable decision-support domain. This tool aids in making decisions based on considerably broader decision grounds in selecting the best COA to achieve the goal with well-managed risk, adding operational value by increasing the quality of the decisions. The overall conclusion and recommendation to military leaders is that data farming is feasible for NATO and nations and should be used as a methodology for actionable decision support in operation planning.

1.0 INTRODUCTION

Over the last decade, the evolving and maturing methods and technologies in the context of Modelling and Simulation (M&S) have successfully been applied for analysis in operational studies, as well as for procurement support in the defence domain. Thus, M&S methods and tools have been established and accepted in these fields of application. One area where there is great potential for use is within direct support of military commanders and staff for concrete operation planning.

To apply M&S for decision support in direct support of military commanders and staff, it is important to align the support with the existing processes. The crisis response planning process of NATO is described in the Comprehensive Operations Planning Directive (COPD, Version 2.0, NATO 2013), for different command levels in several phases. In assessing the COPD at the Joint Head Quarter (JHQ) level to identify the best-suited phases for application of data farming for decision support, the process steps in Phase 3b to develop, analyse, compare and refine Courses of Action (COA) will clearly benefit from the characteristics of the data farming method.

Data farming is a process that has been developed to support decision makers by answering questions that have not yet been addressed. It provides an unprecedented possibility of mapping the possible consequences of decisions. Data farming allows for the examination of uncertain events with numerous possible outcomes and provides the capability of executing enough experiments so that both overall and unexpected results may be captured and examined for insights. With this approach, analysis of many different situations can be aggregated, enabling ready-to-use decision support. Simulation-based decision support complements operational experience with an objective, reproducible and transparent analysis. This opens up new possibilities by examining thousands of alternative COA revealing factors of importance concerning operational outcomes. This allows the staff to prepare the grounds for the decision making of the Commander based on quantitative data.

To address these aspects, a decision-support tool has been developed within the NATO task group *Developing Actionable Data Farming Decision Support for NATO* (MSG-124) [1]. The tool is based on data farming, adapted to the COPD with focus on analysis and visualisation, and a prototype is implemented to demonstrate its functionality. The tool supports the JOPG in conducting operation planning along the COPD guidelines. The software tool is named *Data Farming Decision Support Tool for Operation Planning* (DFTOP). DFTOP is an integrated multirole tool that provides tailored views applicable to different roles of the JOPG, i.e., operational analysts, planners and decision makers.

To provide decision support for a commander's specific questions in operation planning, we perform a sequence of process steps, implemented as workflows in DFTOP. From a top-level perspective, we begin with traditional data farming [2]. We then go beyond the traditional approach with the analysis and visualisation part automated and tailored to directly support the decision-making process.

We divide the decision-support process into three sub-processes:

- the *Analyst View* process, which automates the traditional statistical analysis usually performed in data farming,
- the *Commander's Overall Operational Questions* process, which is focused on the big picture of how to win in military combat, and
- the *Commander's Specific Operational Questions* process, which focuses on more specific questions of when we will win in different specific situations.

The purpose of the Analyst View is to set up the decision-support tool to be ready to answer the Commander's Overall Operational questions. There are several pre-prepared analysis questions that aim at giving the Commander a decision brief, pointing out the crucial elements of the operation and recommending a COA. In developing the decision brief, the JOPG may analyse the Commander's Specific Questions, aiming at providing answers to all possible specific and detailed questions.

To demonstrate our concept, we use a scenario played out on a map of *Bogaland*. This is a large-scale symmetric scenario in which the country Bogaland is attacked by a neighbouring country. The JHQ's task is to develop operation plans to defend Bogaland by the means of Bogaland's forces and combined operations including NATO forces. The scenario represents a realistic situation for potential planning tasks for a JHQ. It describes potential offensive COA of a fictitious aggressor state and the general outline and available forces for the defence by NATO. It also considers the joint aspects of planning by including air and land forces.

The approaches to simulation support of the Military planning process may be divided into statistical or case-based [3]. In data farming, the statistical approach is used. The objective is to find statistically significant answers to a set of questions, e.g., regarding the most likely outcome. A related approach to this is described in [4], with simulation-based decision-support techniques for evaluation of operational plans. Using a decision-support tool, thousands of alternative plans can be evaluated against possible courses of events. The objective is to help operational analysts understand the consequences of numerous alternative plans through simulation and evaluation. In [5], the objective is directed to support the Commander in the JOPG in process steps that involve situational awareness and analysis of the mission area. An approach called *Exploratory Modelling and Simulation* (EMA) takes uncertainties into account by simulating many plausible models generating plausible futures. In [6], the authors describe a multi-criteria simulation-based approach for operation planning. With this method, a decision maker can analyse alternative scenarios, where the concern is the best use of available resources in military operations. With this methodology, it is possible to determine which combination of parameter ranges leads to overall Blue success. Some of the methods applied in [6] are used as a basis for work in MSG-124.

In Section 2, we present the alignment of DFTOP to NATO's COPD planning process. In Section 3, we introduce the conceptual idea of DFTOP, and in Section 4, we discuss a proof-of-concept experiment that we performed. In Section 5, we discuss the development of the DFTOP support tool. Finally, the study's conclusions are presented in Section 6.

2.0 ALIGNMENT OF DFTOP TO THE COPD PLANNING PROCESS

The data farming decision support is aligned with NATO's COPD; it is briefly described in this section to show how it is supported by data farming and DFTOP. The COPD is applicable to all operation planning activities at the NATO strategic and operational levels of command and can be adapted to the component/tactical level to enhance collaborative planning activity. With regard to the Operation Planning, the military strategic levels seek to translate political-strategic guidance into military-strategic directions for the operational commander.

At the operational level, planning seeks to transform a strategic direction into a scheduled series of integrated military actions, carried out by joint forces to achieve operational objectives efficiently and with acceptable risks. The process begins with a review of the situation based on the strategic analysis of the situation and the mission to develop a clear appreciation of *what* must be accomplished, under *which* conditions and within *which* limitations. Based on this appreciation, it then focuses on determining *how* operations should be arranged within an overall operational design. The operational design provides the basis for subsequent development of the operational concept as well as the detailed plan.

Phase 3, *Operational Estimate*, is the focal phase for the JOPG of a JHQ to identify what has to be done under which conditions and limitations for mission success, and subsequently, to determine *how* it should be done. In Sub-phase 3a, *Mission Analysis*, the Commander and his staff determine *what* must be done for mission success by analysing the crisis situation in depth, determining precisely the operational problem that must be solved and appreciating the specific operational conditions that must be established. In Sub-phase 3b, *COA Development*, it is determined *how* to best carry out operations that will accomplish the mission effectively and efficiently.

Applying data farming in support of decision making improves the quality of the decision making by providing a robust, reproducible, and quantitative basis. Data farming is able to provide case-driven COA analysis (based on individual scenarios comprising the opposing and own COA) by statistical analysis of thousands of scenario variants (comprising a multitude of opposing and own COA variants with varying parameters).

The DFTOP concept is able to cover and support the whole process of COA Development. There are two main parts to this. The first part covers process step Mission Analysis (3a) until process step *Develop own COA* (3b). Here, DFTOP supports gaining rough insights into important factors and initial ideas for own and opposing COA. This can be performed by providing analysis of the correlation of the important factors with the overall success defined by the commander. The second part, from Develop own COA (3b) until *Decision Briefing* (3b), provides a refined analysis based on the choices made by JOPG, e.g., answering specific questions regarding operational objectives and the consequences to own and opposing forces.

The focus of DFTOP is to translate the statistical data into actionable information in support of decision making:

- DFTOP is able to display the interdependencies between planning parameters (opposition and own COA designs, force composition and location) in relation to the achieved effects (success criteria) and related consequences (e.g., losses),
- DFTOP visualisation methods highlight the most important decision factors and their correlation,
- DFTOP visualisation of statistical results enables decision makers and their staff to capture and understand statistically derived results easily and quickly,
- DFTOP results and visualisation methods provide efficient arguments for decisions,
- DFTOP is an integrated tool, combining several functionalities for decision support such as statistical analysis, success criteria definition, and visualisation, and
- DFTOP provides reusable statistical workflows to non-statistical experts and the possibility of adapting to nearly any data farming result set to find outliers, evaluate risks and find possible and plausible outcomes.

3.0 DFTOP CONCEPT

In this section, we present the DFTOP concept and explain how it supports the COPD planning process. The functional requirements for DFTOP are defined using the results of the previous section. From these requirements, we develop methods to address the tasks supported by DFTOP.

DFTOP is intended as a tool for operational analysts supporting the JOPG Head and the commander, hereafter called the decision maker. The operational analyst prepares analysis modules, interaction possibilities and visualisation modules based on the raw simulation output. The decision maker, on the other hand, is only confronted with visualisations and limited user-interaction possibilities and is completely detached from the raw data.

As shown in Figure 1, DFTOP integrates into a data farming loop of loops by supporting the analysis and visualisation step. It takes the output data of the high-performance computation and either terminates the data-farming loop, encourages additional analysis of specific scenarios, or indicates the necessity to refine the Design of Experiment (DOE).

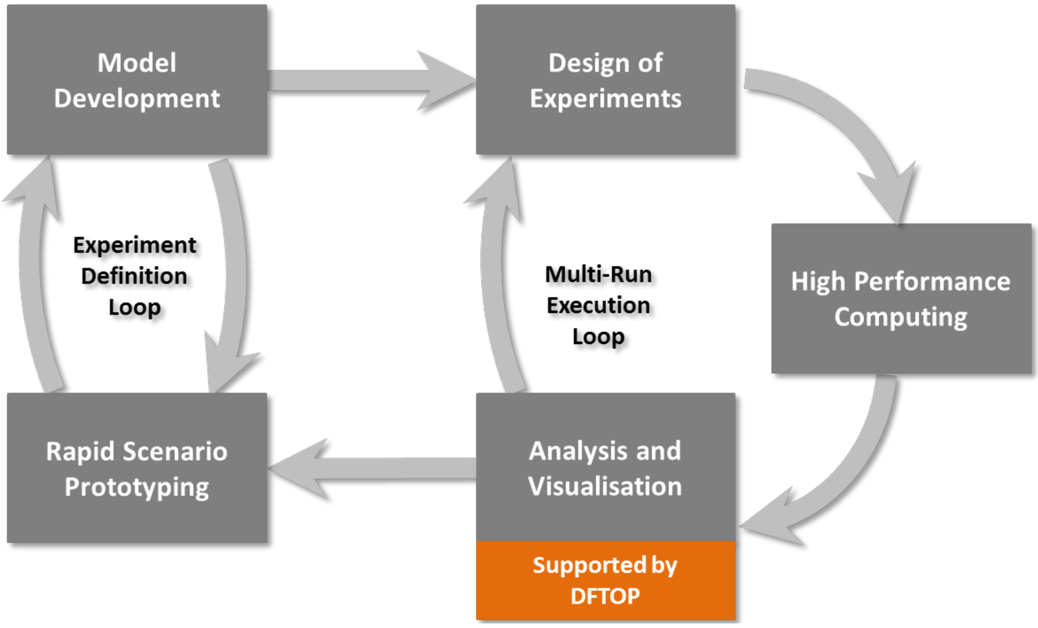

Figure 1: Integration of DFTOP into the data farming loop.

The functional requirements of DFTOP are derived from the operation planning process. The functionality, processes and structures of DFTOP have to be designed to efficiently support the work of the operational analyst and the decision maker. These roles have different objectives in the planning process and need to be supported in different ways.

In general, it can be assumed that the decision maker is not a subject-matter expert in statistics or data farming. Using DFTOP, the decision maker wants to make sound decisions that are backed by simulation and statistical methods. He has a set of questions formulated into objective functions (or, more generally, into Measures of Effectiveness (MOE)) by the analyst. The sensitivity of the MOE to certain changes in the COA needs to be evaluated to analyse the risk. This is presented to the decision maker by problem-oriented visualisations. To evaluate the effect of changes in the COA, changing it must be simple. In addition, the effects of the changes must be instantly visible to support easy comparison.

The main idea in supporting the operational analyst is to offer the possibility to create and store standard workflows. Once defined, they can be reused in later projects, independent of the data analysed. The idea of reusable workflows is based on the observation that different data farming experiments are analysed with the same statistical methods. If a single statistical method is not sufficient, it is also possible to use several methods sequentially. Since the same statistical methods are used, the results have the same form and the same visualisation methods can be used. The work of the analyst can thus be simplified and streamlined by providing a limited set of analysis and visualisation methods. In addition, the results will be of consistent quality.

The question to be answered will come out of the previous COPD process step of the Mission Analysis, which is a factual interpretation of the commander’s intent and his guidance in tackling a certain operational problem. The analysis will break down these questions into different aspects and deliver answers based on hard facts in the COA Development, which will afterwards lead to a decision of the commander. DFTOP supports analysis and provides answers in a structured and comprehensive way; see Figure 2. Data farming is used to adapt questions to suitable models and simulate different outcomes to answer specific questions. In addition, it widens the point of view and presents different options and possibilities.

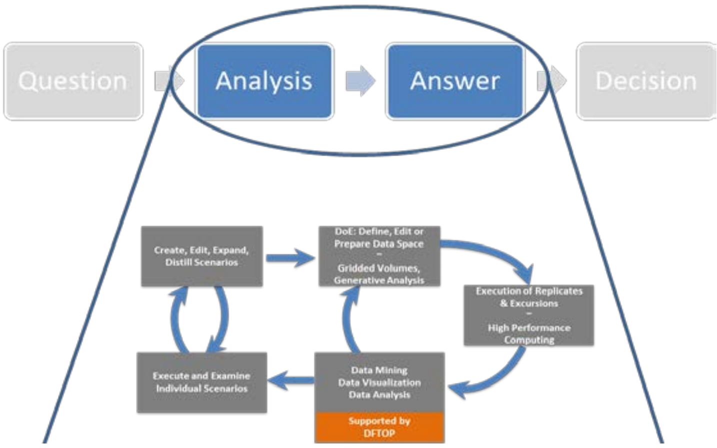

Figure 2: DFTOP integration into the decision support process.

There are three ways of interacting with DFTOP: data can be analysed, the results of the analysis can be visualised, and the analysis can be influenced by the user. These ways of interacting are encapsulated into workflow modules, each of which provides a specific functionality and has fixed in- and output channels. In addition, each workflow module can be parameterised to adapt its algorithm to the input, or to define a specific output format. The introduced workflows are defined as specific ways of analysing and visualising data using a chain of connected workflow modules. An example is shown in Figure 3.

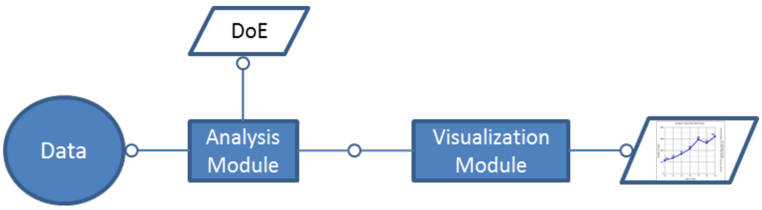

Figure 3: Simple workflow concept.

In Figure 3, the data are used as input to the analysis module. This module is parameterised by the DOE. After analysing the data, the result is handed over to the visualisation module. The final output of the module is a visualisation that provides input to the decision-support process. An additional way of influencing the analysis is depicted in Figure 4. The interaction/visualisation module is a two-way-interaction module. This allows the user to display results of the analysis and interact with the results by filtering and scaling, etc. This interaction creates a subset of the data. If more extensive adaptions are necessary, the whole workflow has to be rerun with adjusted parameters.

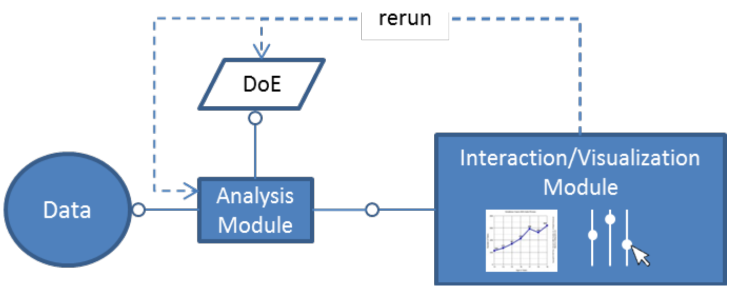

Figure 4: Workflow concept with interaction module.

More elaborate workflows are possible, as long as the standardised input and output channels of the included modules match. Workflows can be defined once and adapted to any data source using the parameterisation. Thus, it is possible to reuse workflows in another planning cycle without much effort.

Since the process of COA Development is a cooperative process of different analysis steps, there are also different target audiences that are using DFTOP: data technician, data analyst and decision maker.

The data technician is responsible for preparing data for DFTOP. DFTOP is aligned with the realms of the data farming methodology, thus the parameters and MOE have to be structured accordingly. This structuring is a required pre-processing step before the data can be used in further analysis. Furthermore, the data technician is responsible for setting up the technical structure of the workflows in DFTOP. In agreement with the data analyst in charge, he incorporates new workflow modules and connects the in- and output channels.

The data analyst is responsible for correlating the initial questions with the analysis and visualisation methods. Therefore, he may use existing workflows or create additional ones. The data analyst is also responsible for the correctness of the analysis results and the adaption of the workflows to the specific COA Development questions. This is done by parameterising all necessary workflow modules accordingly. In addition, he will decide which visualisation is best depending on the intended target audience.

The decision maker will not interact directly with DFTOP. The results of DFTOP will be presented to him by a data analyst. The decision maker will have indirect influence on the analysis by rephrasing his initial questions, guidance, and important factors (i.e., parameters). This information is adopted by the data analyst to interact with DFTOP in the interaction and visualisation module or by re-running some workflows. Using DFTOP, the main objective of the decision maker is to draw operational conclusions from the results. In addition, he may adjust basic settings of the analysis if necessary.

In operations, many different aspects of the operational environment have to be taken into account. Normally, the decision maker will base his decision on more than one criterion. For example, one should not only minimise the number of own losses but also areas kept under control. These criteria can be formulated into MOE, each with different importance. In an overall objective function used for decision making, they therefore receive different weights.

This leads to a multi-criteria objective function, which is set up by different MOE derived from the commander's intent and the prior mission-analysis phase. The setup of this objective function is summarised in a single workflow by selecting desired MOE and subsequent computing of the corresponding weights and calculation of the *overall success* value for each simulation run. This overall success is the only MOE created in DFTOP itself and treated as such in all other workflows. The overall success is automatically calculated based on priorities, but may also be manually adjusted in a pure interaction workflow module implemented in DFTOP.

The main results from the COA Development are presented to the commander in a decision brief. To support this brief, a special workflow incorporates the most important analysis results into one visualisation interface. The workflow is used to summarise essential information into a single overview interface. This workflow demonstrates the possibility to merge a whole set of analysis modules into a single visualisation, which we call the *Dashboard*; see Figure 5.

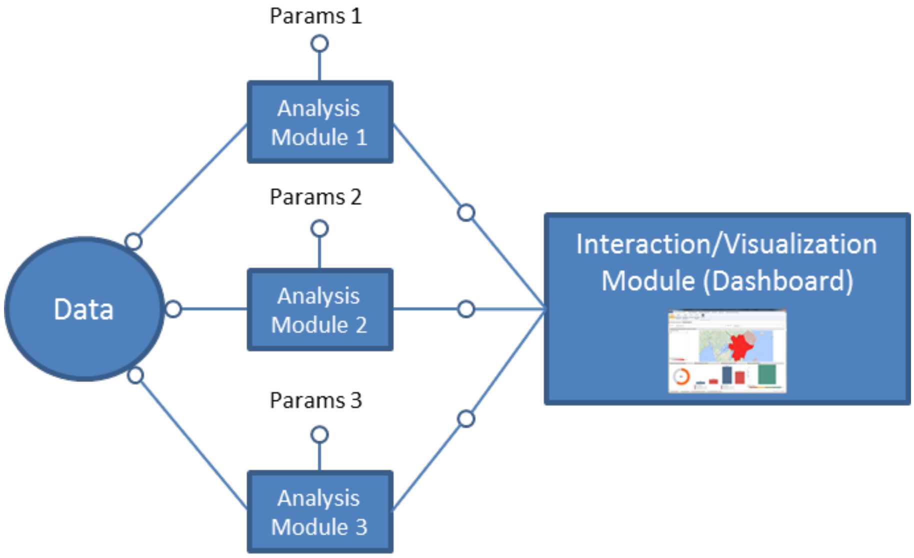

Figure 5: Dashboard principle.

4.0 PROOF-OF-CONCEPT DATA FARMING EXPERIMENT

To demonstrate the benefit of data farming for actionable decision support in operation planning, a large symmetrical warfare scenario is used [7]. The scenario depicts a large-scale conventional military operation with operations in three different phases: airstrike, entry and land-attack phases. The airstrike and entry phases consist mainly of air-to-air and air-to-ground engagements. A subsequent land-attack phase consists of brigade-level engagements supported by airborne units. In the scenario, Bogaland is threatened by occupation from its northern neighbour Northland; see Figure 6. It is important for Northland to deny the involvement of NATO allied forces in Bogaland (BFOR) in this conflict. Bogaland defence plans are based on the support of coalition forces. Therefore, the operational objective of Bogaland's armed forces in the first phase of a Northland attack is to delay Northland's advance to gain time for BFOR deployment.

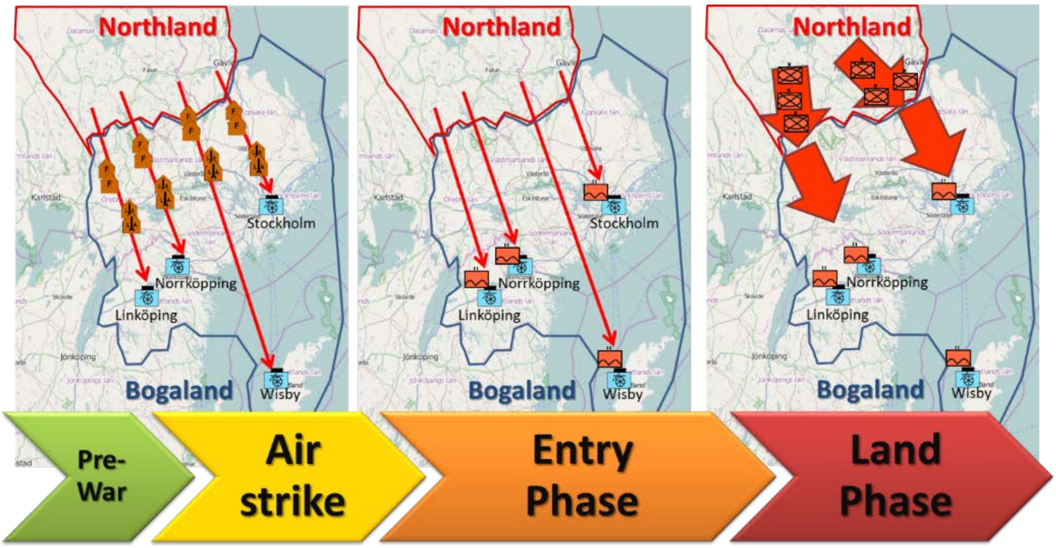

Figure 6: Bogaland scenario overview.

The main question to be answered is, *How can Bogaland best use what we have to defend the territory (including resources of NATO allied forces)?*

The goal is to provide decision support for building a robust COA that enables Bogaland to resist attacks from Northland. The commander's priorities are to maintain control of important infrastructure and areas of Bogaland. Important aspects are to delay the beginning of the land-attack phase and set good conditions for subsequent phases. It is investigated which unit types, quantities, equipment, and tactics, techniques, and procedures (TTPs) are most robust against Northland's most likely and most dangerous COA.

The next two sections outline the data farming experiment that was conducted to answer the main study question on how to defend Bogaland, by setting up the DOE and defining all MOE.

4.1. Design of Experiment

Based on the scenario, ten decision factors (i.e., factors of the Blue forces that we control) and five noise factors (i.e., factors of the Red forces outside our control) are defined. A Nearly Orthogonal Balanced (NOB) design [8] with 512 design points is used for all decision factors but one. For the noise factors, a small fully gridded design is used to allow for individual filtering of each factor. This also allows the Red factor values to be varied from a most likely COA to a most dangerous COA. The decision and noise factors are crossed to ensure that each decision-factor combination of Blue is combined with each noise factor of Red.

The crossed NOB fully gridded design is further augmented by crossing it again with a categorical *Strategy* factor. There are 20 combinations of the strategy factor. The crossing of the strategies is chosen to allow for better analysis and is implemented by running the land phase 20 times per design point of the air and entry phases. The resulting number of design points, N_{DP}, of the whole DOE is

$$N_{DP} = 512\ (decision\ factors) \cdot 16\ (noise\ factor\ design) \cdot 20\ (strategies\ design) = 163\,840. \qquad (1)$$

4.2. Measures of Effectiveness

The development of the MOE is driven by the main study question and the commander's intent. The commander's intent is described by the following prioritised list: hold Stockholm, hold as many areas as possible, delay the start of the land-attack phase, generate favourable conditions for future operations, and keep airports under control and with active Patriot systems. Furthermore, favourable conditions are assumed to be achieved by minimising Blue losses.

For a multi-criteria analysis of the overall mission success, an objective function of eight weighted MOE is defined. The weights are used to represent the priorities in the commander's intent.

5.0 DFTOP REALISATION

In this section, the DFTOP realisation is presented. The modular design of DFTOP allows for creating and modifying workflows freely. Workflows are created here to support Phase 3b COA Development of the COPD version 2 planning process. Following the process in COPD Phase 3b chronologically, some workflows are presented.

The commander's intent and the commander's planning guidance have to be incorporated into the data farming analysis and DFTOP in the form of a multi-criteria objective function. DFTOP offers a two-step process to do this. The first step involves identifying relevant MOE for the objective function with an automated suggestion for weights in the linear objective function. To help decision makers assign appropriate weights to all MOE, a preference-based algorithm has been incorporated. The decision maker may express preferences on importance between any two disjoint subsets of MOE [9, 10]. A preference-ranking method is focused on finding the order of importance of the MOE, causing preferences with high importance to have large weights. Since the objective functions quantify the overall success for Blue, they are named OverallSuccess.

Having incorporated the commander's intent into the OverallSuccess MOE, the next workflow supports the definition of COA for both sides. In DFTOP, COA are defined using filters on decision and noise factors, thus defining subsets of the data. The definition of these filters uses the same interaction modules as in the main DFTOP GUI. After defining the COA in the COA Definition GUI, they can be saved and used in all other workflows, limiting the analysis to subsets of the DF data corresponding to respective COA.

A workflow called *Factor Importance* is designed to give top-level answers to questions like: *What are the most important decision and noise factors for success?* Using this workflow is one possible way to analyse the COA influencing factors. The decision maker defines a successful outcome by setting a threshold on the OverallSuccess. The result of this workflow is qualitative and gives an indication of which factors are most important; see Figure 7. In the figure, an opposing COA is used to filter the data. Thus, the most important factors for success are shown for this COA.

Figure 7: Chart of most important factors.

A workflow called *Histograms* is designed to give a top-level overview of the distribution of OverallSuccess, e.g., when looking at a specific COA or combination of COA. The histogram can be used to get an estimate of success and of the risk in the selected COA combination. This workflow can also be used to modify COA interactively, or to get a better understanding of the data. Figure 8 shows a histogram of OverallSuccess for all simulation runs, filtered by a selection of Red strategies.

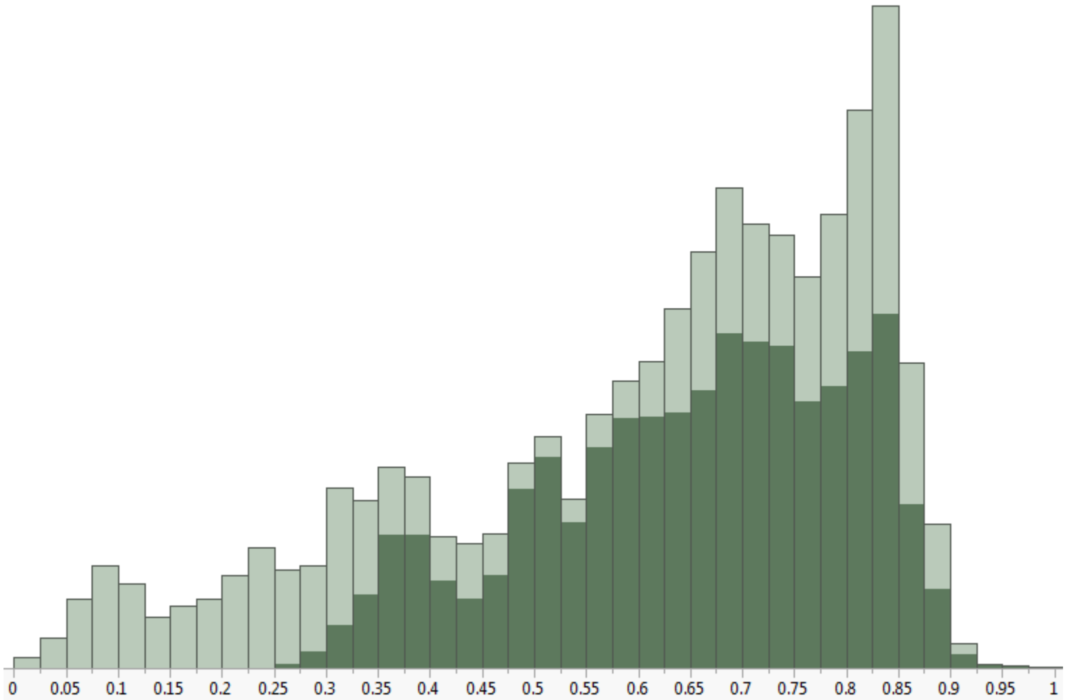

Figure 8: Histogram of OverallSuccess filtered by a selection of Red strategies.

An alternative factor analysis is the *Skewed Distribution Analysis* (SDA) approach [11]. The idea behind SDA is that, if a factor is important for the operational outcome, the value of this factor is significant in differentiating between success and failure. This implies that the distribution of values within the subset of best simulations should be highly uneven, that is, *skewed*. The *skewedness* can be measured using Shannon entropy [12]. This analysis can also be performed for several factors simultaneously, to discover correlated factors. Low entropy of a factor means a highly skewed distribution and suggests that the operational outcome is highly sensitive to the value of that factor. The minimum entropy value, zero, is achieved when only one factor value leads to success.

When using this module, the first step is to study single factors. After that, the interaction of several factors should be studied. In our experience, studying multiple factors seems frequently to yield lower entropy than studying fewer. In Figure 9, we present an example of factors and factor value ranges yielding the lowest entropy in increasing order. The lowest-entropy factors to the left tend to have skewed distributions with particular value ranges of importance. On the right, we have factors that did not turn out to be decisive for the outcome of the simulations.

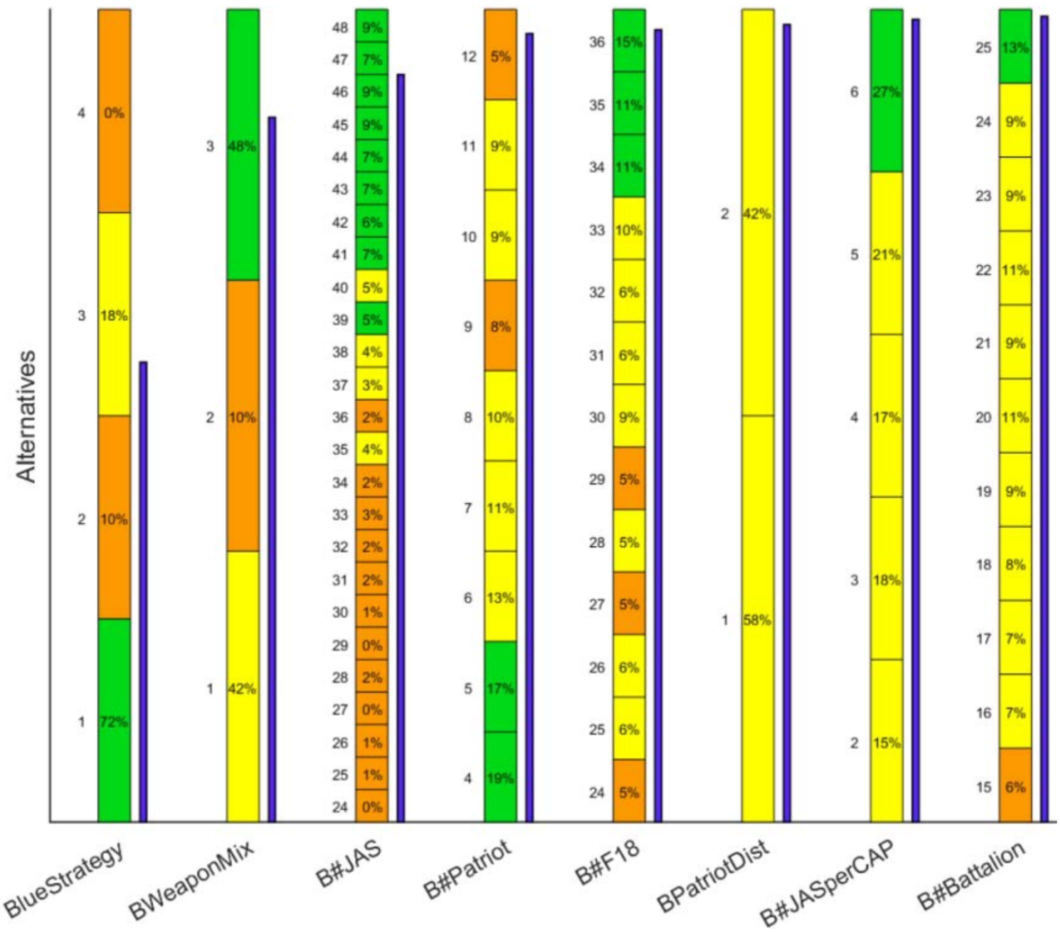

Figure 9: Skewed distribution analysis.

A *Wire Diagram* workflow provides immediate visualisation of the effect of chosen factor values on the OverallSuccess. It is designed to support development of COA and is used for an interactive analysis of interdependencies between the factors and their influence on OverallSuccess. The diagram type used is called Parallel Coordinate Plot [13], which creates parallel vertical axes for a set of factors and OverallSuccess. Each simulation run is represented by a line combining the input values of all decision factors with the resulting output value for OverallSuccess.

The Wire Diagram is set up to support COA Development, thus only decision factors are integrated and there is a possibility to filter by opposing COA. The analysis provided with the Wire Diagram is closely related to the SDA; the Wire Diagram is therefore also set up as an extra item in the SDA workflow. In Figure 10, data regarding a single specific opposing COA are plotted against all own COA. It is seen that all factor values are equally distributed, which is a consequence of the DOE. When we select the most successful simulation runs, a state diagram, as shown in Figure 11, is obtained. Typical questions that can be answered with the Wire Diagram are the following: *Which set of own COA results in a certain range of OverallSuccess?* and *What is the range of OverallSuccess for a specific COA?*

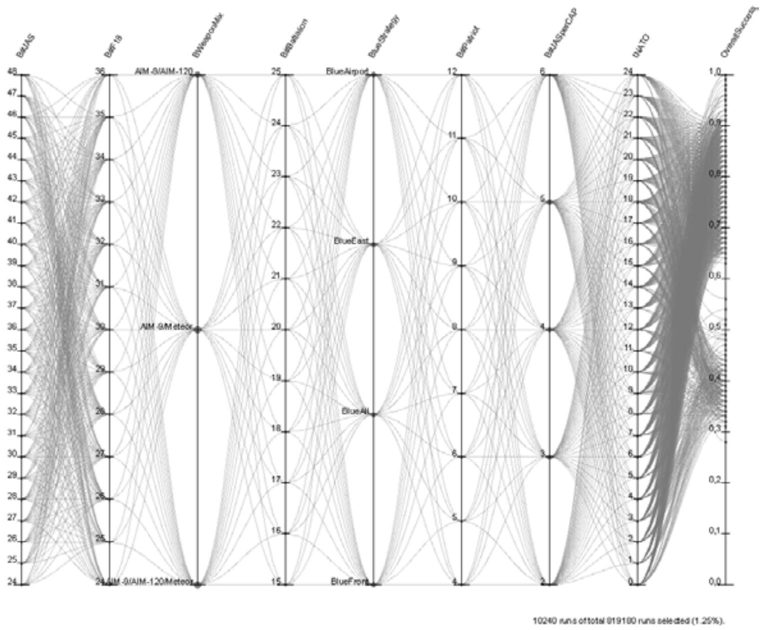

Figure 10: Wire diagram showing all own COA against one opposing COA.

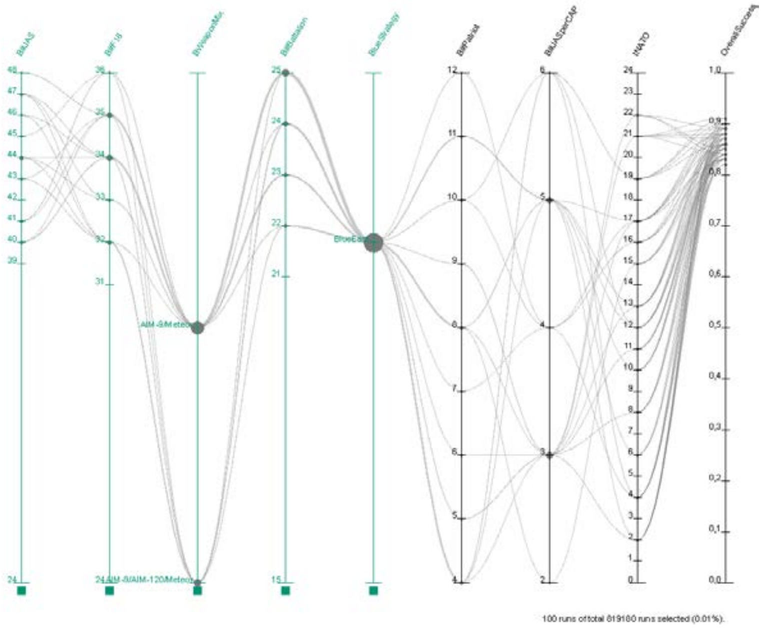

Figure 11: Wire diagram showing the most successful own COA against one opposing COA.

A *Heat Map* can be used to see how an MOE varies as a function of two factors. The ranges of the two factors span the *x*- and *y*-axes, and the MOE is mapped to a colour scale; see Figure 12. We study several combinations of factor pairs, both concerning the Red side and the Blue side. Such an analysis is performed in the Analyst View process to get an overview based on the entire data set. To answer more specific questions regarding opposing COA of interest to the decision maker, we restrict the data set to specific subsets that match those questions [14]. This is done by restricting some of the noise factors. Filtering can also be used to put restrictions on decision factors. This narrows down the scenario and makes the heat maps easier to interpret. One can also put restrictions on MOE. For instance, one can focus on simulations that have the best outcome for the Blue side by limiting the value of OverallSuccess, thereby analysing only the scenarios in which the Blue side has large success.

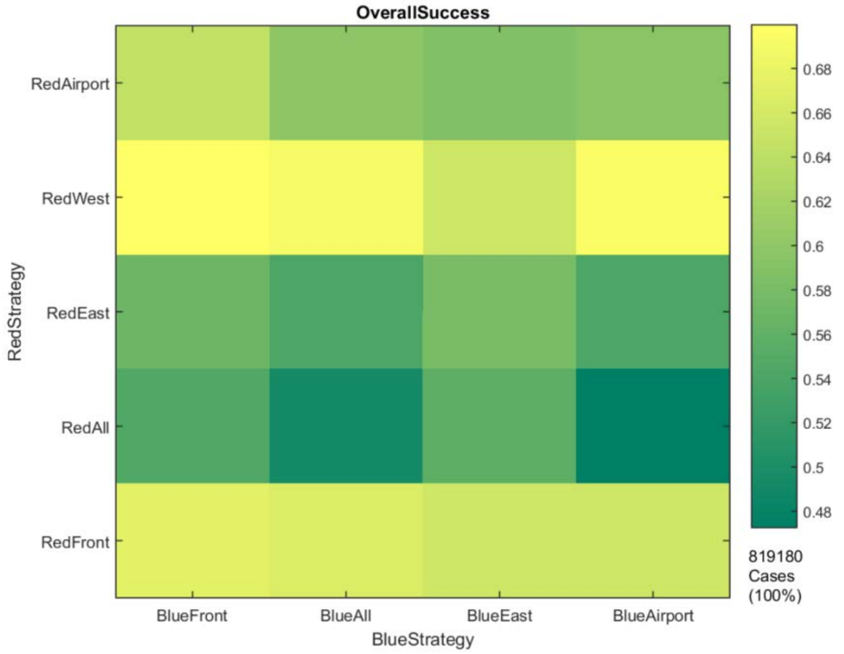

Figure 12: Heat Map of OverallSuccess.

While heat maps are used to show how an MOE varies as a function of two factors, a *Box Plot* is used to plot a condensed representation of the distribution for each factor value. The central horizontal line in a box is the median value. The upper and lower edges of each box represent the upper and lower quartiles, i.e., half of all simulation runs are inside the box. The dashed lines on each side of a box are called the *whiskers* and contain 99.3% (for normally distributed data) of the data; see Figure 13.

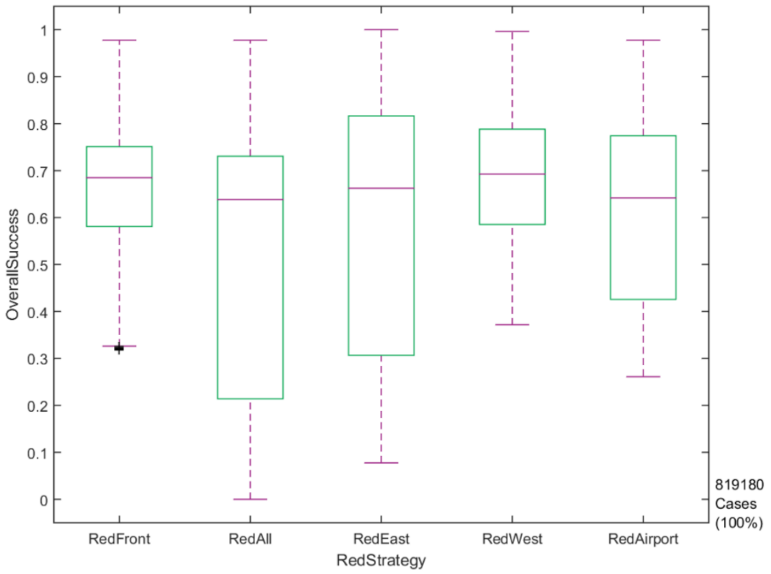

Figure 13: Box Plot of OverallSuccess.

The final workflow is the Dashboard. It is designed to support the decision brief in COPD Phase 3b. The Dashboard delivers a comprehensive overview of COA design and evaluation on three tabs:

- COA specifications (own and opposing) displayed on a map,
- OverallSuccess of a given COA combination, and a detailed look at its criteria (Figure 14),
- A geographical view of losses and remaining forces (Figure 15).

On the OverallSuccess tab (Figure 14), the mean value of OverallSuccess is presented, as well as the mean of the MOE of which it is composed. If feasible, the MOE are presented on a map for better understanding. On this tab, there is again the possibility to select different COA.

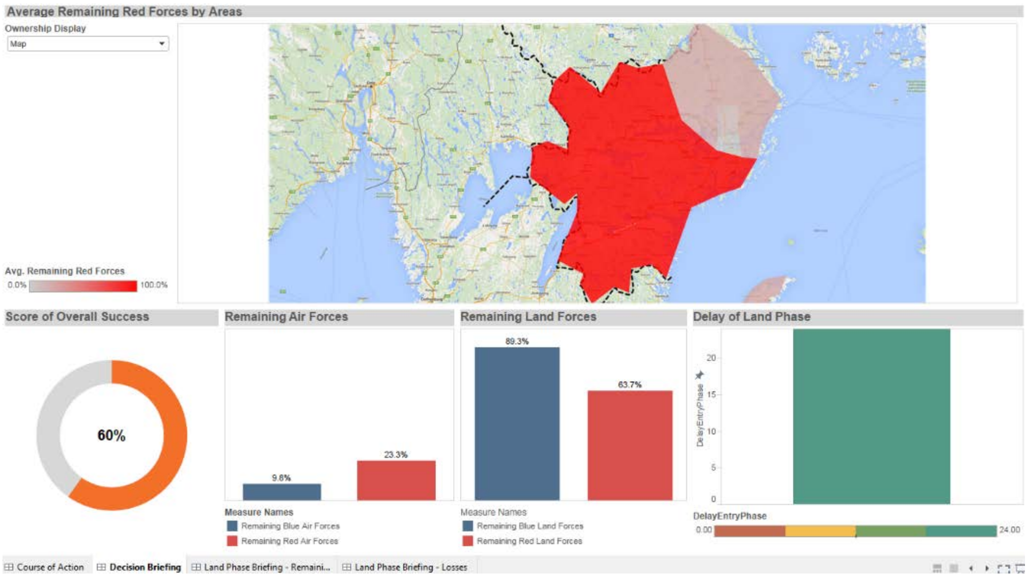

Figure 14: Dashboard (OverallSuccess).

On the last tab (Figure 15), the average number of remaining forces that are still able to operate is presented. If the area of operation is separated into sub-areas, the respective values are presented in the form of a bar chart, as well as a pie chart for each sub-area.

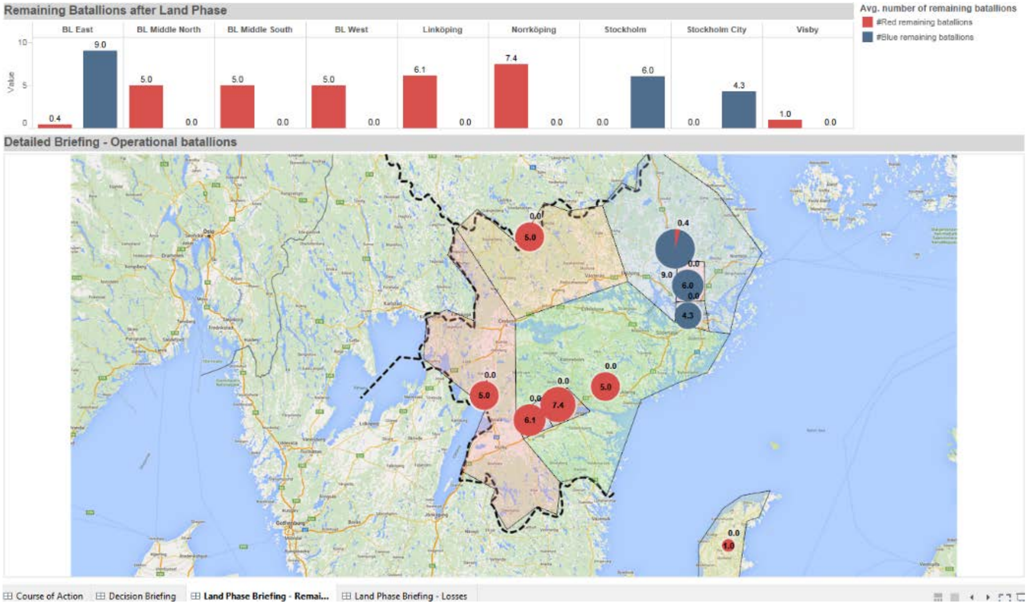

Figure 15: Dashboard (Remaining Forces).

6.0 CONCLUSIONS

DFTOP is a tool that supports the Commander when evaluating operation plans. The support is aligned with the COPD, exemplified in this study at the joint level, providing support for the JOPG in Phase 3b. This tool allows the Commander to get better insights into his operations, and make decisions based on much broader decision grounds, by analysing a broad set of COA. With DFTOP, the possibilities of quantitative simulation-based analysis are made readily available to decision makers and planners at the operational level.

DFTOP aids the JOPG in the analysis of the whole spectrum of feasible COA. This assists the JOPG in developing plans based on a robust and reproducible dataset, and making objective recommendations to the Commander. This allows for decisions based on much broader decision grounds in selecting the best COA to achieve the goal with minimum risk. In addition, every outcome can be traced back to the most important factors and their corresponding crucial values.

The tool is flexible, as open standardised interfaces ensure its interoperability with either simulation and/or analysis systems. With automated and reusable workflows, the analysis in the planning process becomes standardised, reproducible, traceable and objective, which helps the JOPG perform the planning process in a more transparent and efficient way. This adds operational value by increasing the quality of the decisions.

The DFTOP prototype was demonstrated in a relevant environment at the *Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, eXercise* (CWIX) in 2016 and will be used at CWIX 2017. The demonstration in 2016 was a milestone in establishing Technology Readiness Level 6 (TRL 6). The Bundeswehr Joint Forces Command followed the demonstration of DFTOP and found it to be promising for operation-planning decision support. After the successful demonstration of DFTOP at CWIX, it was presented to the Multinational Joint Headquarters Ulm, led by Germany. They decided to perform further testing of DFTOP. A new demonstration at CWIX in 2017 will utilise a different simulation model than that described in this report, demonstrating the flexibility of DFTOP and will test and validate the interoperability with the NATO planning tool in use: *Tool for Operational Planning Functional Area Service* (TOPFAS).

Experience from CWIX confirms that DFTOP successfully brings data farming into the *actionable* decision-support domain, translating the results of the analysis to visualisations that are directly adapted to the decision maker's needs.

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