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On the Introduction of Effects Based Assessment into NATO's Processes, Organization and Tools

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Abstract

In 2006 the NATO Military Committee (MC) provided guidance to the two NATO Strategic Commands on key aspects of Effects Based Approach to Operations (EBAO). Whilst Allied Command Transformation (ACT) had already started work on EBAO in its experimental program in 2003, this guidance proved a starting point for EBAO thinking and development throughout ACT and Allied Command Operations (ACO). EBAO introduced 'effects' as a means to focus on outcome, results or end-state of an operation. To ensure this, the need for continuous analysis of the operational environment to provide improved situational understanding, and the necessity of feedback to the commander to allow the choice and synchronization of actions based on their contribution to the achievement of effects, was identified. Earlier feedback mechanisms allowed for a direct, causal relationship between actions and its effects, however, experiments simulating current operational theatres demonstrated that the derivation of appropriate measures for the assessment of effects proved to be a difficult and elaborate. NATO has not emphasized assessment: campaign assessment is practiced in current NATO operations in Kosovo, Active Endeavour and ISAF, but these assessment practices are lacking the foundation of doctrine, tactics, techniques and procedures, and are short of proper investment in analysis capability – manpower, resources and tools.

The problem is compounded by the realization that current assessment analysis capability cannot adequately deal with complexity in an operational environment. Within that environment which encompasses political, military, social, economic, infrastructure and information domains, and integrates the actions of diplomatic, civil and economic players, the growing understanding is that causality is complex and networked, that the rules from yesterday do not always work today, and that predictability is reduced. Over the last decade, considerable academic progress has been made to understand system complexity, particularly complex adaptive systems which demonstrate learning behaviour essential for survival and characteristic for conflict situations. Although these efforts have focused on understanding adaptive mechanisms, insights on what complexity and adaptation brings to effects based assessment practices must be sought. NATO's overall ability to deliver on current and future operations can only benefit from the development of a flexible and pragmatic effects-based assessment methodology.

This paper focuses on the need for further development of methods for effects based assessment, based on recent work done within NATO and the nations. It stresses the need for proper design, derivation, selection, and assessment of measures, in order to be robust and appropriate for all respective action and effect chains of the tasks and activities that have significance for commander and staffs. Furthermore, the need for appropriate and practical data collection processes, modelling and simulation, tools, methods, techniques and training is discussed.

Keywords: Effects-Based Approach to Operations, EBAO, Effects-Based Assessment, Campaign Assessment, Complex Adaptive Systems, Complexity.

Introduction

Multinational Experiment (MNE) 4 conducted in March 2006 consisted of two, separate experiments involving two HQ constructs: a Coalition Task Force (CTF) HQ staffed from a coalition of 8 nations, and a NATO Response Force (NRF) Deployable Joint Task Force (DJTF) HQ. Whilst the former used a distributed network for the HQ with most of the nations at their home locations, the NATO construct was a collocated HQ within the Ataturk Wargaming, Simulation and Cultural Centre (WSCC) in Istanbul, Turkey. The aim of MNE 4 was to explore concepts and supporting tools for the effects based approach to operations (EBAO) involving stability operations within an Afghanistan scenario. The central theme for MNE 4 was the hypothesis that a set of actions that are explicitly linked to an end-state via effects can be coherently harmonized with actions of other governmental organizations in a manner that facilitates adaptive feedback within the course of the execution by effective campaign assessment [1].

Whilst this approach assumes that a holistic understanding of the operational environment as a prerequisite for the development of a plan and its execution, it is the assessment part of the MNE 4 CONOPS that has given rise to extensive discussion, as it explicitly addressed the need for a causal relationship between actions and effects. Whilst the conduct of the experiment demonstrated the necessity for assessment in providing feedback to the commander for improved situational understanding and in allowing the choice and synchronization of actions based on their contribution to the achievement of effects, the premise of causality could neither be confirmed nor contradicted. During the experiment the derivation of appropriate measures of effectiveness and measures of performance proved to be a difficult and elaborate process mainly due to the immaturity of the effects-based assessment concept and the lack of clarity of understanding of the use and definition of metrics; in addition to the lack of expertise and training [2].

NATO has not emphasized assessment: campaign assessment is practiced in current NATO operations in Kosovo, Active Endeavour and ISAF, but these assessment practices are lacking the foundation of extensive doctrine, tactics, techniques and procedures, and are short of proper investment in analysis capability – manpower, resources and tools. This is notwithstanding the publication of the a best practice guide by one of the NATO Operational Commands [3], which provides an overview of current practices in operational assessment in current NATO operations.

The aim of this paper is to elaborate on the need for assessment in support to military operations conducted in an environment ever-increasing in complexity. The advent of EBAO may provide a necessary jolt to the need and the use of assessment practices, but a particular challenge lies in developing the ability to measure effects and actions in that complex environment. Relevant in that context is the development of NATO EBAO policy and doctrine, in addition to preliminary handbooks and guidelines for the military planner and the operational analyst to be able to perform that vital function of assessment. The paper aims to provide a foundation on which to build measurement practices of complex systems. The study of complex systems is not new and a number of scientific methods exist in how to deal with complexity; non-linear systems have been modelled and analyzed using tools and methods that are available to analysts in the defence assessment trade.

Need for Assessment: Complexity

Any operational commander has posed the question of how his or her plan and its execution are holding up against the operational realities and environment. Feedback needs to be provided to ensure that the commander knows whether the objectives and the end-state of the operation are being reached. This progress towards the end-state has necessitated both an assessment of the accomplished actions and an assessment of whether the objectives will be or have been reached. The assessment of actions determines whether or not planned activities were actually implemented as planned; the assessment of effects, objectives or end-state determines whether or not the planned results actually have been achieved as planned..

The discipline of Operational Analysis (OA) has been closely related to the assessment of effectiveness and performance since the Second World War when OA was defined as "scientific methods of analysis to give useful assistance to effective executive action" [4] and as "a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control" [5]. The direct relation between action and effect in the studies of tactical questions allowed for a structured problem and the use of mathematical methods – using physical relationships – to clarify the relationships between the key parameters in the problem posed. The mathematical model has been the foundation of most of the Operational Analysis work conducted. The emphasis of OA work, however, changed in the post-war years towards justification of acquisition decisions, mostly in the material domain, and with that step the direct involvement of OA in supporting operational staff with rational problem structuring and unbiased reasoning diminished [6]. This process was further strengthened by the defence questions that were posed in the Cold War era.

However, with the fall of the Berlin Wall, the emphasis of military operational questions have returned to the roots laid down by Carl von Clausewitz of the existence of material and non-material factors in war mixing moral and physical forces where "psychological forces exert a decisive influence on the elements involved" [7]. This fundamental idea that military action alone cannot defeat an enemy and that a combined and coordinated application of all instruments of power in the political, civil, economic and military domains is necessary, found its first explicit statement with von Clausewitz, but has been applied throughout history [8]. However, current operations in Afghanistan and Iraq have emphasized the necessity of treating the operational environment in a more holistic manner, taking into account many actors, factors and situations that make the understanding of that operational environment a complex matter. The realization that defence problems seem to be inherently complex, in terms that can be best described as ever-changing interdependent variables whose identity, importance and interrelationships are continually changing [9], necessitates defence analysts to study complex systems.

From the consideration of non-linear physical systems in the early 20th century and the development of mathematical biology more recently, a significant area of interdisciplinary science has arisen that examines the underlying principles and theories behind so-called "complex systems." The aim of complex systems sciences is to understand how parts of a system give rise to the collective behaviours of the system, and how the system interacts with its environment. Examples of complex systems include: social systems comprised of individual people; the brain formed out of neurons and their connections; and the weather, comprised of air flows and pressure and temperature differences. Problem that are difficult to solve are often hard to understand because causes and effects are not obviously related [10]. The study of complex systems has been widely disseminated by the Santa Fe Institute (SFI) through contributions in biology with titles such as: *Hidden Order* [11] and *At Home in the Universe* [12]; in management *Rewiring the Corporate Brain* [13] and *Leading at the Edge of Chaos* [14]; in economy *Competing Technologies, Increasing Returns and Lock-In by Historical Events* [15]; and in mathematics *Adventures of a Mathematician* [16], to name but a few. The application to defence problems has been championed by the CCRP itself with books including: *Coping with Bounds* [17] and *Complexity, Global Politics and National Security* [18], but also in articles [6], [19].

Complex Systems

At this moment it may seem beneficial to describe what is meant with 'complex' and to contrast that with 'complicated' [20]. Complicated systems may be extremely difficult to understand, but there are several properties that distinguish them from "complex" systems, notably:

- The system is governed by simple cause-effect relationships making it clear which causes and influences contribute to the final outcome.
- The system's motion in an environment is repeatable given the same initial conditions, and the motion can be predicted to some certainty.
- The effects on the system's motion by changes in the environment or initial conditions are generally small and easily understood.

In contrast, a "complex" system has the following properties [19]:

- Causality is complex and networked, such that there are many contributing causes and influences to any one outcome and that one action may lead to a multiplicity of consequences and effects.
- Predictability is reduced: for a given option it is not possible to accurately predict all its consequences, and for a desired set of outcomes it is not possible to determine precisely which actions will produce it. Additionally the number of plausible options is vast, making it impossible to oversee and optimise and find a best solution, although it still may be possible to determine the boundaries of the solution space.
- System behaviour is coherent but the system is not fixed: there are recurring patterns and trends, but they vary and the rules seem to keep changing.

A note must be made to distinguish complex systems from random systems. A complex system, roughly speaking, is one with many parts, whose behaviours are both highly variable and strongly dependent on the behaviour of the other parts. It therefore excludes both systems whose parts just cannot do very much, and those whose parts are independent of each other.

Complex Adaptive Systems

The ability to self-organize is an additional important phenomenon for complex systems that is representative for systems in which organisms, in particular humans are involved. The ability to adapt, i.e. the changing of behaviour of the system in such a manner that it attempts to increase its 'fitness'. This latter term has been introduced by the study of complex evolutionary (biological) systems, but in general it defines how a system copes with success and failure. The complex systems that are adaptive, self-organizing, express learning behaviour, and allow competing and conflict are called complex adaptive systems (CAS). John Holland [11] developed seven basics of complex adaptive systems: aggregation, tagging, non-linearity, flows, diversity, internal models and building blocks. It falls beyond the scope of this paper to discuss these in detail and relate them to a military context, a task which was accomplished more than satisfactorily in [21]. In short CAS have – in addition to the properties of complex systems – the following additional properties [19]:

- There is a concept of success or failure: fitness;
- There is a source of variation in internal details of the system: change;
- There is a selection process in which the system retains or discards variations that increase or decrease its fitness: evolution;
- There is a feedback mechanism within the system to evaluate the impact of variations: evaluation;
- There is a retention mechanism to hold information on what variations increase or decrease the system's fitness: learning behaviour.

The analytical community has well understood this new reality. One of the first initiatives was in the domain of Command and Control (C2). The NATO Code of Best Practices (COBP) for C2 Assessment has stated it as follows [22]:

"The focus of military research and analysis has predominantly been on the physical domain. C2 issues differ in fundamental ways from physics dominated problems. C2 deals with distributed team of humans operating under stress and in a variety of other operating conditions. C2 problems are thus dominated by their information, behavioural, and cognitive aspects, that have been less well researched and understood. This focus creates a multidimensional, complex analytic space"

As the COBP apparently focuses on the C2 aspects of the non-material domain, the misunderstanding may arise that there are no other aspects of the non-material domain that need to be addressed, researched and understood in supporting the operational commander in his assessment of the operational environment. Equally, the need exists to represent the behaviour of individual combatants as well as larger organizations. The analysis and modelling of human and organizational behaviour within a military context [23] as well as the psychological effects [24] on warfare are now being equally pursued. The non-material domain is characterized by psychological factors as moral, strength and stamina: "It represents the mind and attributes that generally influence the will in the form of perception, awareness, understanding, belief and values. Consequently, effects in the non-material domain aim at changing behaviour" [25].

The OA community has realized that the analysis of non-material issues remain most challenging in a military context characterized by asymmetry, other-operations-than-war, stability and reconstruction efforts and humanitarian relief. It becomes even harder when operations include all aspect simultaneously and force the military to conduct a 'three-block war': combat operations, stability and reconstruction, and humanitarian relief within the same theatre. Additionally, many other factors in the political, economic and social domains have to be taken into account making the operational environment a true complex system.

The Need for Assessment: Effects-Based Approach to Operations

The assertion that there is a transformation of warfare, a "Revolution in Military Affairs" [26], guided mostly by new concepts such as Network Centric Warfare (NCW) and Effects-Based Approaches to Operations (EBAO), has been the subject of many conferences, articles, books, studies and experiments. On one side, EBAO has been perceived as the holy grail of military planners and strategic thinkers. On the other side there are critics of the EBAO concept that maintain that EBAO is merely "a revolution in terminology" [27]; and others criticising the concept as "largely irrelevant" [28]. Many in the defence community, however, are embracing effects-based thinking, as can be seen from more official publications such as the US 2006 Quadrennial Defense Review Report, the UK Joint Doctrine Note "Incorporating and Extending the UK Military Effects-Based Approach" [29], the German "Basic Concepts of the German Air Force Regarding EBAO" [30], amongst others. The general consensus is that EBAO thinking is not new at all and has been applied by military commanders throughout history [8]. The recent NATO Research Lecture Series on EBAO [31] held in November 2007 gained insights on how NATO nations view EBAO and the degree of commonality existing between the various national approaches.

From the military perspective, EBAO is a framework for considering all the factors that can help decision makers at all levels to cope with the complex variables involved in today's operations [9]. From the national strategic perspective, EBAO is viewed as a mechanism to achieve a comprehensive, whole-of-government approach to operations, by harmonising the actions of all arms of government to achieve a common set of effects and end-state. Again, this is not new thinking or revolutionary in any way; however, the fact that in some cases, military end-states may be dependent on the achievement of other government department's end-states, over which the military cannot exercise control, is a point of controversy for some nations.

Examination of the consequences of complexity in military operations allows us to see the potential of adopting EBAO: as a comprehensive tool enabling the military commander to better manage the complexity of the current operational environment. EBAO requires a broader and deeper understanding of the operational environment than is currently recognized or available through extant intelligence feeds. The requirement for a holistic understanding of the environment is the foundation of the EBAO concept. Analysis of this environment must be able to deal with the context, complexity, interrelationships between actors, and the causes and symptoms of crises. This analysis uses systems thinking that enables the commander to acquire situational awareness not only of those elements of the system whose behaviour are to be influenced, but also other system elements, individual components and the connections between all system elements.

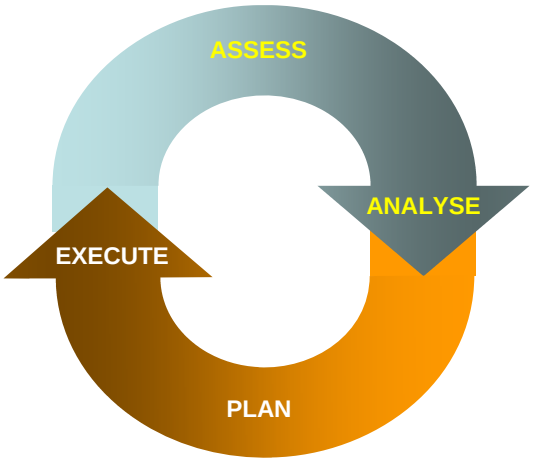

Figure 1 – EBAO Cycle

EBAO must be seen as a methodology that first attempts to understand the state of the current operational environment through systems thinking and analysis, producing a conceptual model about the current state and the expected state after planned actions have been executed. Next, after actual execution the assessment of the results of the actions will provide the ability to confirm the expected state by comparison with the new current state. This concept and use of assessment or analysis is key to an effects-based process and a continued comparison between expectations and reality will allow the military commander to execute his plan in a successful manner. In its simplest form, we can understand EBAO as a cycle of activities: analysis, planning, execution and assessment (figure 1).

It is apparent that the operational environment, by taking into account military and non-military actors, physical and non-physical factors, and short, medium and long-term effects, has not only become complicated but complex. The need for understanding what actions to take in order to reach the desired effects has been made key to the accomplishment of the commander's objective and end-state. That need for information of what the current state of the operational environment is, can only – in a complex system – be provided by constant feedback on the results of actions and the measurement of the desired effects. Whilst assessment has a role in conventional planning, it is an integral part of the effects-based planning and execution. For example, in the UK Joint Doctrinal Note [29] assessment is seen as a critical element to any decision making cycle and fundamental to the EBAO philosophy. Assessment allows the planning staff and commander to continually scrutinize assumptions, to confirm where and how the situation is changing, and to guide decision-making.

Current State of NATO EBAO

NATO's involvement with EBAO began through the transformational process that NATO Allied Command Transformation (ACT) started in 2003, and in cooperation with the US Joint Forces Command (JFCOM) took shape in a number of Multinational Experiments. In MNE 3, conducted in 2004, the concept of Effects-Based Planning (EBP) was experimented with within a NATO Response Force (NRF) HQ setting [32]. Considerable difficulties were encountered with the EBP CONOPS which was found to be mechanistic, prescriptive, and unclear. These issues were measurably improved upon in MNE 4; however, some criticism still ensued. During that experiment a number of hypotheses were tested with respect to planning, execution and assessment using a fictional scenario of an operation in Afghanistan. The experiment was deemed successful in that it provided a springboard for the development of implementation measures for EBAO within Allied Command Operations (ACO).

In parallel to the MNE 4 effort, ACT was developing the Concept for Future Alliance and Joint Operations (CAFJO), in response to political guidance received which confirmed the need for the Alliance to transform. The CAFJO: "defines a conceptual framework for the next 15 years that...shapes the future development of concepts, doctrine and capability, in order to allow the Alliance to develop a capacity to conduct an effects-based approach to operations" [33]. Although the CAFJO concept was approved at the

Bi-Strategic Command (Bi-SC) level, it was perceived as too broad and ambitious by the NATO Military Committee (MC) which instead extracted the key concepts of EBAO and presented it as guidance to the Strategic Commands and the nations in a memorandum [34]. With the results from MNE4 and MC guidance in mind, Supreme Allied Commander Europe (SACEUR) mandated the formation of a Bi-SC working group that tasked:

- ACO to create an implementation plan for EBAO within the NATO military structure, and
- ACT to develop supporting policy, concepts and doctrine on EBAO.

As a result, the Bi-SC working group initiated the drafting of several documents; most notably the Bi-SC pre-doctrinal Handbook on EBAO [35], which is currently approved at the Chief of Staff level in both Strategic Commands, and which is intended to be used as interim measure in those exercises and operations that employ EBAO. Furthermore, a Bi-SC Discussion Note [36] was drafted with the ultimate aim to allow NATO nations to discuss the principles and assumptions of a NATO EBAO. It must be understood that the pre-doctrinal Handbook on EBAO did not require national approval, so that necessary discussion with the nations needed to be conducted through this sort of intermediates. Within NATO, although the strategic commanders have mandated the development of EBAO, and the Military Committee has recommended that the core principles of EBAO be approved, ultimately the decision on the formal acceptance of EBAO within NATO remains at the political level. The Bi-SC discussion note states the following:

"An effects-based approach to operations focuses on combining military and non-military actions to influence the overall behaviour and capabilities of other actors – national and trans-national, belligerent and benign - in an operational environment in order to create effects leading to the achievement of strategic objectives and a desired end-state"

In doing that, the Bi-SC discussion note underwrites the most basic principles of EBAO thinking, as it acknowledges the use of different instruments to create effects that alter the behaviour and capabilities of different actors in the engagement space in order to achieve our objectives and end-state. Therefore, EBAO requires a clear understanding of these different instruments and of the nature of the different systems we seek to influence, and with that recognizes that systemic understanding is a foundation for the whole of planning, management and assessment of operations. Ultimately, this has lead to the formulation of a NATO definition of EBAO [36] as:

"EBAO is the coherent and comprehensive application of various instruments of the Alliance, combined with the practical cooperation along with involved non-NATO actors, to create effects necessary to achieve planned objectives and ultimately the NATO end state."

Current State of NATO Effects Based Assessment

Initiatives of the Bi-SC EBAO working group and activities for the MNE 5 experiment are paralleled in NATO ACT taking the lead on the MNE 5 EBAO CONOPS and the elaboration of the Effects-Based Assessment principles from MNE 4. NATO took on EB Assessment as a priority for refinement: currently a NATO Effects-Based Assessment Handbook has been approved [37]. Experimentation with a draft of the Handbook occurred in June 2007 during a Limited Objective Experiment (LOE) which concluded that the Handbook allowed a more effective and efficient execution of the EB Assessment process than the MNE 4 CONOPS could have allowed [38].

The NATO process has remarkable parallels to the principles of results-based management (RBM) first developed by Peter Drucker in "The Practice of Management" [39], in which the process of 'management by objectives' is introduced. His techniques were used by private sector management, before being adopted in the 1980s by government agencies around the world. The core aim of RBM is to shift the focus of planning, management and decision-making from inputs and processes to results [56]. Similarly, EBAO attempts to change military planning and executing from courses of action to effects.

NATO's EBAO is detailed in the NATO EBAO Handbook [35], but elaboration on the NATO assessment processes can be found in the NATO Engagement Space Assessment Handbook [37]. NATO's EBAO is

based on the assumption that Effects Based Planning, Execution and Assessment work closely together and all relate to the systems analysis piece that searches for the holistic knowledge and understanding of the operational environment. NATO's term for that is 'Knowledge Development'. In order to attain assessment as described [35] it is imperative that an assessment plan, including the data collection and reporting plan for Measures of Effectiveness (MOE) and Performance (MOP) criteria defined during the planning process, is developed. Furthermore, at different levels of command, purpose-driven assessment cycles that match the required timeline and level of the operation need to be conducted. Through these cycles, the accomplishment of actions, creation of effects, and progress toward the attainment of the objective(s) and NATO end-state will be assessed. Subsequently, the assessment results are reviewed by planning and execution staff to determine if plan adaptations will be required. Throughout the process, collaboration or close cooperation with non-military actors in order to gain a better understanding of the engagement space should be considered.

Measures of Effectiveness and Performance

NATO uses two basic criteria for assessment: Measures of Performance (MOP), which are used to determine that the actions were accomplished as planned; and Measures of Effectiveness (MOE), which are used to determine that the *results* of the actions were achieved as planned. A MOP is defined as the criteria used to evaluate the execution of (own) actions. Each level (operational and subordinate levels) will normally develop MOP for the actions they will execute. Each MOP must align to one or more own-force actions; describe the element that must be observed to measure the progress of status of the action; and have a known deterministic relationship to the action. The threshold of change for system elements and/or relationships that indicates completion of the related action must be included, but is not the MOP itself. The threshold may be changed throughout the operation.

A MOE is a criterion used to evaluate how system behaviour or capabilities has been affected by actions. Essentially, a MOE is an indicator of system state, used to help answer the question "*Was the intended new system state—the desired effect—created?*" [37]. Multiple MOE may be required to fully capture the changes in system states. The MOE should be written during the development of military objective and effects. Collection methods must be a key consideration during MOE development to ensure that the desired metric can be measured. A MOE must describe a system element of interest; describe how that element is expected to change; be observable, and be as specific as possible. Additionally, a MOE should be reducible to a quantity and be objective in nature.

Each MOE must also include threshold(s) of change for a system element or relationship that indicates effect status, with one key point: The threshold value, whether used as a boundary for failure, success, or simply indication of status, is not the MOE, and may be changed during different phases of an operation without changing the MOE. In considering the drafting of MOE and MOP, the focus of the different military levels, strategic, operational and tactical must be taken into consideration, as well as the fact that MOE will be developed for Objectives. Figure 2 depicts the linkages between tactical, operational and strategic levels of NATO military operations and the political-military strategic level NATO objectives and end-state.

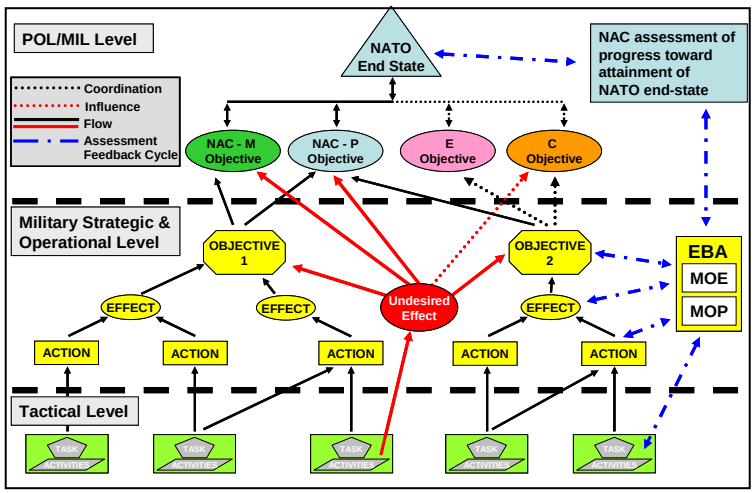

Figure 2**:** NATO EBAO Linkage Illustration

There will be multiple related assessment cycles during execution of the plan, varied both in command level and assessment cycle time. In all cases, the assessment cycle time must depend on the tempo of operations and the required time scale of the effect (Figure 3).

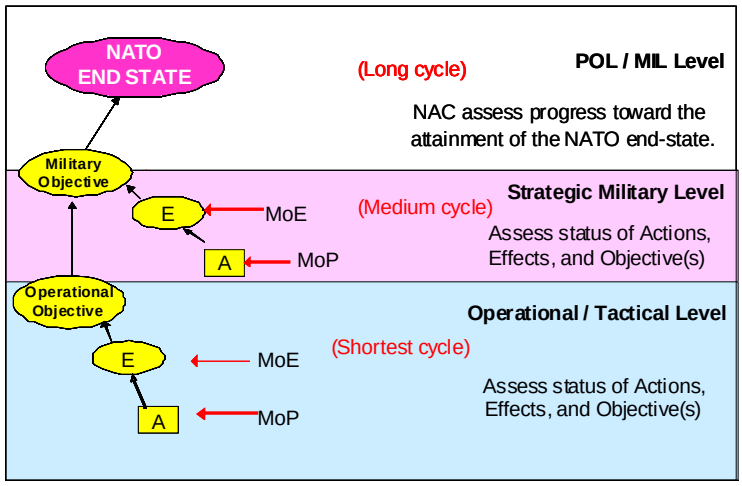

Figure 3**:** Assessment Cycles in EBAO

The first observation to be made is that in the construct of effects, a hierarchy of effects is assumed, with some effects (so called sub-effects) supporting other effects. It will be erroneous to assume that when the sub-effects are assessed as achieved based on their MOEs, that then the higher level of effect has been achieved. Equally, it cannot be assumed that MOEs from sub-effects can be aggregated indiscriminately to form a MOE of the supported effect. The assumption of causality of effects, or for that matter between effects and actions can never be assumed, but may be part of the model. To ascertain causality the model must be tested, validated and verified.

Whilst the hierarchy of effects and actions and their supporting measures will help define their relative importance in the overall plan, it is also necessary to consider the use of multiple measures to describe a single effect or action. It will be necessary to combine these measures in order to produce a single assessment result, and the most common way to do this is to apply a weighting to each measure. The weighting of each individual measure may change as an operation progresses, and this should be defined during the planning process.

A sound assessment design, i.e. the selection of appropriate metrics which truly measure the accomplishment of the end state, objectives, effects and actions, is key to this whole process. Enough attention should also be given to the collection of data, the identification of data sources and the analysis of the data. Assessment of actions through MOP provides feedback to both the planning and execution staff and creates opportunities to steer actions and adapt to changes. Assessment of effects through MOE provides feedback to the planning staff, allowing for steering of the plan.. A more challenging aspect is when planning and execution staffs have to assess how actions and effects relate. Central to this is the fact that the plan is designed around a 'model' of the operational environment provided by the systemic analysis staff. In essence, the plan design describes the *change* that will occur in the operational environment after the successful accomplishment of planned actions. The purpose of EBA is to determine the difference between the original model with its expectation and the observed reality, and to determine the reasons why the plan did, or did not succeed.

The NATO handbook further details how data collection must be planned, conducted and managed, after which a discussion of the need for a proper data analysis is conducted. While the handbook provides guidelines for checking consistency and quality of data, procedures for the absence of data, how to normalize and scale quantitative data, how to handle qualitative data, how to identify significant trends or changes, and how to visualize the data through the use of charts, graphs, spider diagrams, slide bars or traffic lights, the handbook does not provide explicit principles of drafting good measures.

Challenges in Effects Based Assessment

There are some major challenges to be overcome in the effects based assessment area. Most of the challenges lie in the area of assessment design, less in the area of data collection. If design is done properly, data analysis and reporting will normally flow naturally. The NATO handbook provides the mechanism of effects based assessment; however, it is based on the assumption that it is fairly easy to select measures of effectiveness. This may not be the case. Furthermore, although the NATO handbook provides a cautionary note on causality, it does not take away the idea that there is a high correlation between actions and effects. We discuss these two challenges in turn.

MOE Selection

Initial MOE selection occurs at the plan creation by the effects based planning staff in conjunction with their effects based assessment counterparts. The overarching goal when choosing the MOE, other than to achieve all the detailed criteria mentioned in the previous section, is to define achievements in terms of measurable and relevant quantities.

As we have previously elaborated, these achievements or 'effects' are selected based on some conceptual model of the operational environment. The good commander with a sound 'operational art' will easily create a conceptual model from the available information. In EBAO theory, operational art is formalised and the choice of effects are required to be chosen based on a comprehensive systemic analysis that specifically identifies critical nodes, critical relationships, and positive and negative feedback loops; the pertinent question is therefore: to what extent can this be achieved in reality?

Once the achievements, or effects, have been defined, MOE are determined. Military theorists have ensured good practice in choice of MOE by defining the list of criteria (see previous section); however, there is something missing – the MOE, in order to achieve all the criteria necessary with commensurate rigour to the selection of effects, need to be based off the *same* conceptual model as the effects. We must also ask at this stage: to what extent can this be achieved in reality?

The current problem is theoretical and operational in nature. Evidence from current operations reveals that MOE are chosen exclusively by judgment: thus the subjectivity present in assessment of operational progress that EBA intends to counter is actually re-introduced, albeit hidden behind apparently objective formal structures, by the use of poorly chosen and defined MOE [40].

In EBAO theory, several processes for explicitly determining effects derived from conceptual models created by systemic analysis are in existence. Whilst all EBAO theory notes that MOE must have certain specific criteria and must be based of systemic analysis, no theory exists that leads to, or explicitly states a process by which this can be accomplished.

In order to illustrate this point, we describe an example from an operation, details of which have been changed to avoid classification issues. Consider the effect and MOE in Figure 4. In this case, the intervening forces acted to reduce criminality in Province X, which would obviously lead to a major improvements in residents' lives overall, and was therefore of considerable importance to the overall success of the military mission and International mission. Consequently, it was of particular importance for the operational Commander to know the progress in achieving this particular effect, especially due to the immediacy that results would be felt by the local population.

When we examine the MOE, we see that the data used to assess this effect is related to, logically, the number of crimes in the area. Notwithstanding the issues (which will be covered later) on how to determine a crime rate that is acceptable or not acceptable for the area, and the efficacy of data collection, we can question several aspects of these measures.

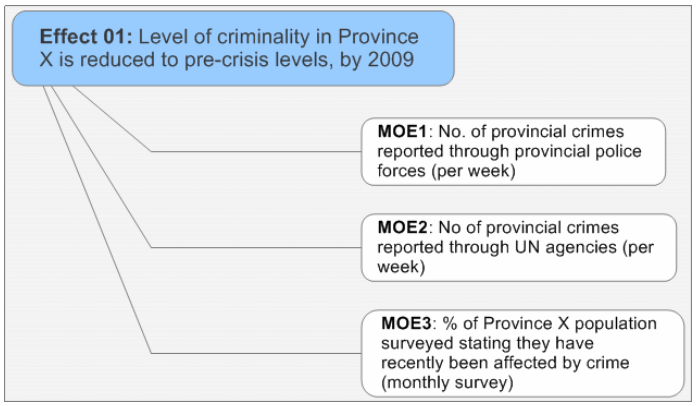

Figure 4: Criminality Effect and MOEs

In depth systemic analysis reveals that the main indicator of level of criminality is not predominately determined by the number of crimes reported, even if a high rate of reporting is present. The most important factor in determining the achievement of the effect for the 'customers' of military action – the residents of Province X, is the *perception* of crime, regardless of the actual level relative to any particular standard. Furthermore, the most important factor of an actual measure of crime rate cannot be determined by any single figure, but must be a combination of metrics, for example: the base number reported to various bodies; the type and severity of crime; the effectiveness of local police and their willingness to take action.

It is evident that the simple MOE produced in this particular operational case would by no means give a good understanding of the general level of criminality, and that to combine the results to give some overall indication of effect achievement would be misleading. In order to allow a more accurate assessment of criminality, MOE must be selected directly from a conceptual model of the operational environment, that incorporates detailed research and analysis on phenomenological and heuristic factors of criminality in general and in the specific environment.

Causality

As stated before, the planning and assessment staffs are making assumptions during the planning process. These could range from expected adversary behaviour to force availability and transportation timelines. One of the key roles of the assessment process is to periodically revisit these assumptions. The handbook therefore prescribes evaluation stating in particular that: "Part of the analytical process is comparison or

analysis of effect status and related action status" and that "without assuming causality, this effect-action analysis can give a rough estimate of assumptions". The difficulty lies in the first part of the last sentence that indicates that there are actions related to effects, while the second part wants not to immediately assume that the relation is causal.

The EBAO world has recognized this situation and seeks to explain how causal relations are established. Zoltan Jobbagy [25] treats the problem by distinguishing four rough areas representing different sort of causality depending on the interaction between cause and effect is 'linear or complex', or the coupling between cause and effect is 'loose or tight'. Linear interactions can be anticipated since the underlying sequence of causality is directly comprehensible. Complex interactions indicate branching paths, feedback loops, and jumps from one sequence to another. When causal relationships are outside the normal or assumed sequence of events as they are invisible or not immediately comprehensible, they still may be linear in the sense that they occur mostly in a well-defined segment and sequence. In contrast, complex interactions can either be linked in many different ways or may behave in unexpected ways. The coupling refers to slack or buffers in cause and effect relationships. Loose couplings can be best characterized by ambiguity and flexibility, whereas tight coupling refer to direct causality [41]. The areas that are simple or complicated (where 'linear' reigns either tight or loosely coupled) can be treated with conventional methods. In the complex area (loosely complex) "cause and effect relationships still exist but they defy most attempts at categorization or other analytical techniques" [41]. Whilst this explanation provides a framework in which we can understand causality, it still leaves us without tools or methods how to proceed further. We are left to guess now how this relation is established, when the situation is simple or complex, or when there is a tight or loose coupling.

Returning back to our assessment staff, the question becomes one of having a perception of what the real relationship is: simple or complex, loose or tightly coupled. We have to have a conceptual model of the reality against which we can compare the effects and actions. Without such reference, the staff reverts to military judgement only, which may quickly resort to making inferred references to causality. It is well accepted that in the inter-connected and complex 'real' world, determination of causal relations is particularly difficult to achieve. Generally the number of potential known and unknown factors that might or might not contribute toward the creation of an effect is large. An example may assist here.

Assume one effect: *Security in the region improves to a level consistent with pre-conflict regional standards*, with three associated MOE: Number of attacks on populace by insurgent forces; Percentage of Host Nation patrols that suffer armed attacks by insurgent forces; and Percentage of own-force patrols that suffer armed attacks by insurgent forces. Figure 5 displays the current status using a bar chart. One could conclude from the chart that attacks on population and own-force patrols have shifted to attacks on host-nation patrols.

Figure 6 provides the associated MOP figures on what the coalition has accomplished: the number of patrols by own-forces and HN forces. The related MOP seems to correlate to the MOE picture.

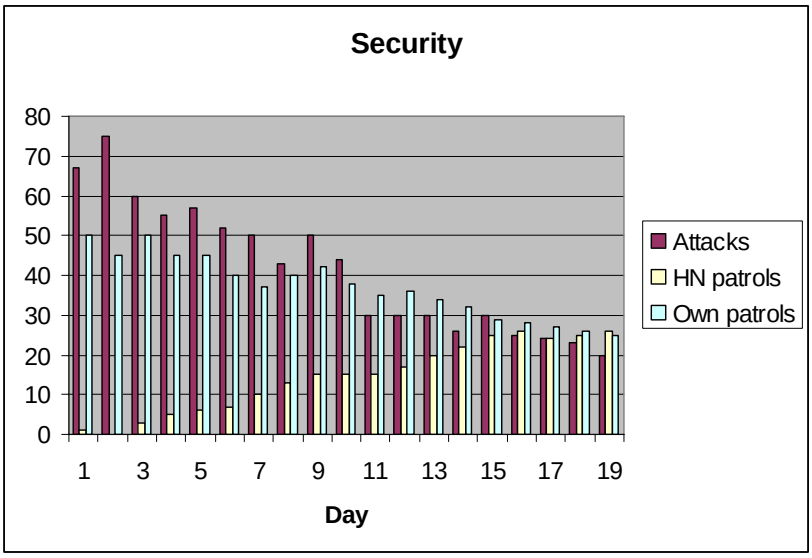

Figure 5, Bar chart with multiple MOE

However, the picture is not complete; other information may be available that indicates that bombing raids have been conducted in the first 10 days on training camps of the insurgents, weather conditions in the last 10 days have been inclement, or an armistice has been reached with one group of insurgents.

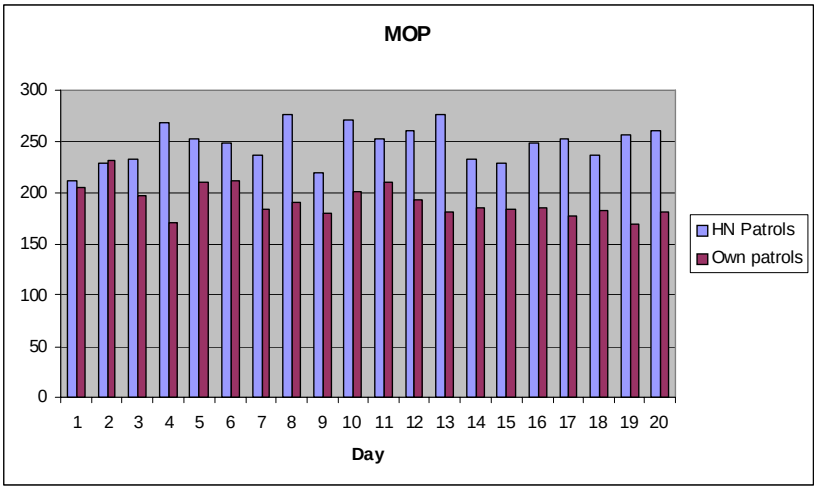

Figure 6, Bar chart with multiple MOP

A similar but usually tacit assumption is also made about the choice of MOE. The purpose of MOE is to validate the assumptions made in plan design. In choosing the MOE, an assumption is made that by meeting the criteria specified in the MOE the effect is being achieved. In some cases this may be obvious: for an effect "*reduce number of car-bomb attacks by 75% in 6 months nationwide*", the MOE "*number of car bomb attacks per week per province*" would seem to give a fairly reliably confirmation of effect achievement. However, for the effect "*eliminate political ties to all militia groups by end of year*", choosing MOE is more troubling. It is evident that deep understanding of the issues involved would be needed to accurately determine measurable quantities that are causally related to the effect.

Previous studies [42, 43] identifying the difficulty of establishing 'measurability' do not elaborate on any methods to solve the issue. The end result is that the measurement of effect achievement uses quantities that may not be relevant to the effect in any way, ultimately providing misleading results. This has led to

the situation that many in the practice of EBAO argue that the ability of the scientific and analytical world to provide answers is limited, suggesting that the answer lies with applying and inserting human judgment [9]. This assertion has greatly assisted in the further acceptance of EBAO within the military and political worlds. The early notion during the MNE 3 experiment, that EBAO was prescriptive, mechanistic, staff-led and overly engineered, has gradually faded with the realization that warfare is still an art, that the commander must lead, and that planning and execution relies heavily on the human interaction, judgment and reasoning skills. But it has also lead to the situation that any attempt of modelling or use of analytical tools is heavily discredited by referring to them as 'linear' tools, inadequate to capture complex situations particularly when human behaviour is to be represented.

Methods and Tools for Analysis and Measurement in Complex Systems

Analysis methods within the NATO Operational Analysis community are available for the wide variety of analysis needs upon which NATO embarks. During the NATO OA Workshop [44] the NATO OA community shared practices and methods currently in use. The NATO Joint Analysis Handbook [45] suggests a number of methods and tools for the analysis of operations and exercises. These are of great use to the assessment staff when supported by Operational Analysts. Patterns and trends can be analysed with visualisation techniques, such as influence diagrams, cause and effect diagrams, flow charts, organization diagrams or decision trees. When substantial amounts of numerical data is available, statistical testing allows for searching an assumed relationship in the data, with further exploration into regression analysis, cluster analysis and time series analysis to name a few. More advanced methods are suggested such as mathematical modelling, simulation, network analysis, and decision-making techniques and tools, but need the support of trained professional OA staff. Whilst for most applications of quantitative and qualitative analysis these methods are sufficient, it may be necessary to consider extending the toolset with methods and tools that can handle complex systems.

Statistical Learning and Data Mining

Complex systems are systems with many strongly interdependent variables. Recent developments in statistics and machine learning have made it possible to infer reliable and predictive models from data through techniques of data mining [46, 47]. Data mining attempts to fit a model to the data with minimal assumptions either about what the correct model should be, or how the variables in the data are related. The advantage of data mining is that it can guide us what kind of patterns are in the data and guide then our model building. The basic aim of data mining is making predictions, but in doing so we want to know whether or not our predictions are good guesses or not. In this context we have to ensure that if we have a set of data that represents one situation, and that our model building of the situation is general enough such that it represents the next situation also: our sampling of the situations must be so that the out-of-sample error or true error is minimized. On the other hand we must ensure that our data fitting to our expected model is not such that it reproduces every feature of the current set, as it will reproduce also the quirks that are present in our current set. It that case we have over-fitted our data to the current set. Techniques that are available to us then are to divide our data into a training set and a validation set, and use the first set to fit the model and the second to evaluate its performance. Other methods exist are based on regularization: they add penalties to the model depending on how many parameters there are in the model to ensure over-fitting to the data is punished [48].

Time Series

Time series analysis, long used by statisticians, social scientists and engineers, has acquired a following from physicists involved in experimental nonlinear dynamics. For the analysis of effects and actions, it is important that time series involve the state of a system, or the rate of change of the components of a state. Simple representations try to represent the system by only the present state, assuming that *all* information needed to determine the future is contained in the present state. In those instances that our mapping of the present state to the next time step is independent of time we call our systems autonomous or homogeneous. This is not general the case for situations in the operational environment which is complex when the present state has a long memory and a prediction of the next state requires that information. Less simple

representations of time series assume that there is some periodicity, i.e. that the state of a component depends on a number of states in the past spanning over a time *t*, and that the effects of what happened before time *t* have disappeared. Of course, we do not observe the real state itself, but just its measure which is a noisy, random, non-linear function of the state. In essence we assume that the probability distribution of *observations* of the system sate do not change over time. One of the most traditional forms of time series is the moving average, another is the autoregressive process; in the latter the next state is represented as a linear combination of its previous values – providing us with a form of causality. Extensions of the linear models exist: long memory models but also nonlinear and nonparametric models. For an overall discussion on time series, see [49] and [50].

Agent-Based Models

If there is one technique that is associated with complex systems, it is agent-based modelling. In an agent-based model individual system element are represented with their individual and collective behaviour. Agents have a state that we would like to represent and they interact with other agents modifying each other's states. The agents' states can be simple or complex. For most simple agent-based models, we may be better off using models that are described by overall rules or aggregated quantities that apply equally to each agent. However, the strength of agent-based models lies in the ability to apply different rules and variety in interactions, which cannot be described by aggregated rules. The computing power we now have available enables us to represent thousands and even millions of different agents. That this implies a lot of effort to define interactions and characteristics of the agents depends on the problem at hand and what we hope to learn from it. If the population is heterogeneous, we may not learn from aggregate models so much as we can learn from agent-based models. One of the most remarkable features of agent-based models – as representatives of complex models – is that they are so simple. Agents often have a few possible states and interactions.

Complexity Measures

Models of complex systems can become large, cumbersome and hard to validate. That this is an issue becomes clear when we realize that a precise model of the complex world needs to be as large as the world itself. Information theory has introduced the notion of algorithmic or Kolmogorov complexity [51]: one can describe the data set to be represented in a model by a program that will reproduce the data. The simplest program is one that prints out the data and then stops. Programs that are shorter have had a way to compress the data. We assume that some regularity exist in the data; complex data only looks random. However, in measuring complexity of models, it may be better to separate the data from the model. The notion of logical depth that measures the number of computational steps the minimal program must execute to replicate the data [52] comes a long way, as does algorithmic statistics [53]. Stochastic complexity recognizes that we do not need an exact description of our data, just a statistical one as the world is full of noise [54]. But the most useful for describing what we want to understand from complex systems, is the Grassberger-Crutchfield-Young Statistical Complexity [55] which only considered the predictive power of the data. In essence, we are only interested in a mapping of our data into a current state on which basis we want to do an accurate prediction. A true measure of complexity is the minimal amount of information needed for optimal prediction.

Data Collection

Having discussed tools and methods, it is necessary to note that collection of relevant data for the measurement of actions and effects is not a light task. Elaboration on data collection methods is not at its place here, however, we understand that our tools and methods cannot do without proper data sets collected for many variables recorded over long stretches of time to allow us to make sense of what is happening in the operational theatre. Essential in that respect is that we have to have an idea of the kind of data and the amount of data to collect, as many data collection efforts have been ill-guided and not properly resourced. For non-physical effects (i.e., cognitive and social effects) the tried and true methods include opinion poles, surveys, human observations, and interviews. This needs to be in the tool box for assessors assessing complex systems.

Conclusions: Way Forward

Progress is being made in developing methods and tools to analyze complex defence problems. The need for better and different tools and techniques has been expressed earlier [19]. The problem is compounded by the fact that complex models could treat similar data sets differently, making validation of models extremely hard. However, new programming methods (Genetic Programming, Evolutionary Computing) may allow the generation of code representing complex problems.

Regardless of these issues, the fact remains that the very process of *creating* the model in the first place forces the designer to think about relationships in the operational environment in detail. The largest and immediate advantage to military planning and execution that EBAO brings is the formalization of systemic thinking at all stages and levels of war. Furthermore, the process of assessment should be, in fact, a continuous validation for the models created by systemic analysis and intelligence staff. The advantages and deeper understanding will come when the detailed system relationships written into a model are compared and contrasted to the results from a period of assessment.

In the same way that economists have created a variety of different laws that model to varying levels of granularity and scales economic markets, there is no reason in principle, why the laws governing insurgency patterns, terrorist recruitment and C-IED development timelines for example could not be developed. It is certain that today's operational analyst needs to become familiar with social science, psychology and criminology; it is equally certain that today's modeller needs to be entirely conversant with the techniques discussed above.

The challenge for Effects-Based Assessment is to provide the military planner and operator a quick but yet accurate analysis of the operational environment. In the search for applicable models, the measure of complexity of the tools is of great importance. And the reality of the day is that that choice may be further restricted by the availability of the data.

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