MODELLING SUPPORT TO BATTLESPACE AWARENESS

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Abstract: Information operations, network-centric operations and, certainly, effect-based operations have become very popular in the last few years. Information, with its importance for battlespace awareness, occupies a special place in all three types of operations. The objective of this article is to impart a quantitative evaluation to this understanding to the extent possible. This would enable the creation of mathematical models, by means of which to investigate different information processes in the pursuit of understanding (or misleading the enemy) of the current or predicted situations.

Keywords: Effect-based operations; battlespace; understanding, quantity of intelligence information needed for understanding the information; "pulsation" of information at situation change.

The discussion in this article will be open by giving a short explanation of the nature and meaning of effect-based operations.

Effect-based operations are a sum of cause-and-effect activities that change the state of the *battlespace* in order to achieve the political goals, which are set.

The introduction of the concept of cause-and-effect activities in the definition given above is necessary because of the inaccurate translation of the word *effects* in Bulgarian. In terms of logic, the effect is always a result of the appearance of another phenomenon – a cause. Or, in other words—whenever a cause exists—the corresponding effect (result) occurs.

Cause-and-effect activities are performed through the application of a suitable combination of instruments (political/ diplomatic, economic, information, and military) to reach a desired change in the initial state of the battlespace.

It could be summarized from the given considerations that the essence of the effect-based operations is the application of a *cognitive* approach, by means of which the desired final political state is reduced to the realization of effects. Effects, on their

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part, are the result of cause-and-effect activities changing the initial state of the battlespace to the desired one.

A key concept in the problem under consideration is battlespace.

Battlespace includes the environment, factors, and conditions that have to be understood in order to apply combat power successfully, protect your own forces, or complete the mission. It includes land, air force, naval, and space components of allied (coalition) and enemy forces; infrastructure; meteorological conditions; terrain; the electromagnetic spectrum and the information environment in the operational areas and areas of interest.[1]

Let us analyze this definition. Who is the object of understanding? What is meant by the concept of understanding? What is the purpose of this understanding?

Object of Understanding – battlespace are the *environment* (terrain, infrastructure, electromagnetic spectrum, information environment), the *factors* (land forces, air force, naval and space components of allied (coalition) and enemy forces, and the *conditions* (areas of operation, areas of interest and meteorological conditions, as well as the political, economic, and social conditions, in which armed forces are used), in the interest of the completion of the mission – survival and utilization of power. As a result of the cause-and-effect activities of the participating actors (their own forces, allies, neutral, non-governmental organizations and others having an interest in the areas under scrutiny) and the actions of 'nature,' the state of battlespace constantly changes. The decision-maker should in real time (or with the necessary discretion) obtain information about the state of the elements of battlespace (state at time *t*). The change of *the state of each of the elements* (in space and/or in time) can be regarded as a particular trajectory. In such a 'trajectory,' interesting *points* and points being important for understanding the behavior of the system of *battlespace* can be investigated, especially the ones in which the behavior of the system changes entirely. The change of each one of the elements of the battlespace has to be tracked and when it reaches a specific point in its 'trajectory,' it is claimed that an event has taken place, i.e. a new situation has appeared (a change in the environment). Such elements for tactical level commanders are changes in the staff, groups and character of the actions of the enemy, the position of their own formations, their condition, problems being solved, the positions and activities of the neighbors, the climatic and hydro-meteorological conditions, the season and time of the day and night, the state of the electromagnetic spectrum, the state of the information environment and others.

Understanding can be considered from a philosophical, psychological, and logical point of view. From a philosophical perspective, it is a form of absorbing reality, which means revealing and reproducing the semantic content of the object.[2] From a psychological viewpoint, understanding is a kind of reflection characterized by ex-

tracting the correct meaning out of ambiguous information.[3] From the point of view of logic, understanding is a universal operation of thinking related to acquiring new content and its inclusion into the established system of ideas and concepts.[4]

It is evident from the three definitions above that understanding is reduced to *revealing the semantic content of the object under study* – in the case under consideration, the battlespace, and, more specifically, the activities, impacts, and interactions that take place there.

When we discuss the meaning of a certain activity, when we question its relevance, or what is the point of performing it, we are interested in the effects from the activity. An activity is considered futile/ useless when it does not lead to the effect we desire or when this effect is of no value for us. When we ask about the meaning of a certain activity, we are interested in the effects it brings or how this effect could be of use to us.[5] The meaning we attribute to a certain activity formulates our attitude towards it and forces us to begin its realization or, on the contrary, to cancel it.

Proceeding from the deliberations made, we can reduce the understanding of battlespace to *an understanding of the sequence of situations*, which run in time and on which the decision-maker has influence in a way leading to the achievement of the desired political (military strategy, operational or tactical) results.

Using the definition given by Mica R. Endsley for situation awareness,[6] we can paraphrase understanding of the situation as *a perception of the elements of battlespace, in defined time and a special framework, becoming aware (comprehending) of their meaning and approximating (projecting) their development in near future*. Or, as Jeannot and others specify later,[7] intuitively these are answers (or the ability to answer) to the questions: *What is happening? Why is it happening? What is going to happen after that? What can I do with this?*

We can consider three types of understanding in the context of *battlespace awareness*.

The first type is understanding of the mission and tasks on senior level and, on this basis, definition of one's own role and place in their realization. Or, in other words, studying the motives of the ongoing operation (political, strategic, operational), the desired final state (political, strategic, operational) and the restrictions imposed by the senior command level, the decision-maker has to become aware of the expected results (consequences, effects) from the forthcoming actions, which are expected to be achieved by the structures under his command. In this way, a sample, a standard, or a norm of the forthcoming actions is created. This type of understanding is 'from general to particular,' but is not a deductive deliberation.

The second type is understanding intentional (purposeful) human behavior. This type of understanding behavior includes discovering links between the motives (aims, values) which guide enemies, allies, and neutrals and their actions. Understanding the behavior of the objects (actors) in this sense means to point out the goal they aim at and hope to realize performing specific activities. This type of understanding can be differentiated proceeding from the direction of the aims of the actors – active opposition, active cooperation or neutrality concerning their own goals. The result of understanding is an evaluation of the object to be understood from the established viewpoint (the views of the senior command). The interpretation that makes the understanding possible is the search for a standard of evaluation and substantiating its applicability to the case under consideration.

The third type is understanding 'nature.' All elements of the battlespace influencing mission completion (facilitating or hindering it), i.e. phenomena, which are not directed *against* or *in the interest of* the execution of the mission, but which exert influence on it, belong to this group. 'Nature' is perceived as 'indifferent,' its future behavior is unknown, but not, in any case, ill-intentioned.

To investigate such complex processes associated with not so well clarified concepts, it is necessary to study their important characteristics with the help of computer models. In this case, modeling is considered a mathematical and logical description of important aspects of a real information system, with the objective to predict its behavior in different situations. The models do not bear a complete correspondence to the real object since only parameters exerting a considerable influence on the final results are investigated.

First, to model the processes, a mathematical model of the mutual influences, interactions and actions between own forces (including allied and/or coalition) and enemy forces, the neutral participants, and the ones in between has to be created. After that, alternatives (variants) of cause-and-effect activities that lead to the achievement of the desired results are explored; these activities are not restricted only to the military field, but their influence is also sought in the political, economic, social, and information field. In the modeling process, while predicting the probable impact on the enemy, it is necessary to consider enemy's specific views on resistance linked to the existing in real-life cultural differences. During the development of different courses of action, the consequent distribution of the forces in space and time, at specific conditions of the environment, has to be performed when specific events are realized (points on the hypothetical trajectory of movement of the corresponding element of battlespace), leading to the occurrence of new situations and necessitating to make alternative decisions, i.e. at a finite number of states, which are of interest to the commander in order to execute his mission and to provide the defense of the own elements. Actually, it is the information about these states and the tracking of their

development in time that makes possible the realization of different levels of understanding of battlespace.

The process of acquiring and processing information about the enemy, the neutrals, the allies, and the environment has some specifics. The focus here is on the research of the information processes of planning and coordinating intelligence activities and using intelligence products. In order to provide intelligence information to the interested persons and organizations, it is necessary *to know what they need to make a decision*, how *tasks* to the intelligence forces available *are allocated to acquire the necessary information*, how the intelligence organizations' management is to *process these data* and to *reveal their meaning* and, finally, how to *disseminate the results* to all users. This process is known as an intelligence cycle.[8]

Different models to investigate important features of this process can be created – for example, a model for requirements definition to intelligence, a model for allocation of intelligence resources, a model for acquiring intelligence data, and a model for processing information. As result of modeling, the probabilities of the system of battlespace to be in the states under consideration have to be defined. After that, using information theory, the quantity of intelligence information obtained should be defined and its importance for understanding the situation has to be evaluated.

As a rule, intelligence resources are always limited. This is the reason why it is especially important what requirements will be set to them and what is the time frame for their completion.

It is required to create a model that is able to answer these questions (in this case, a model for requirements definition to intelligence). To this end, battlespace is represented as a system, which might end up in one state or another (as a result of different impacts) with a varying probability, i.e. a system characterized by uncertainty. The degree of uncertainty depends on the number of possible states $(H_1, H_2, \ldots, H_n)$, forming a complete group of mutually exclusive events,[9] i.e. $\sum_{i=1}^{n} P(H_i) = 1$.

In order to simplify our reasoning, let us consider two states of one of the elements of battlespace – the 'enemy forces:'

- H_1 – the enemy will impact on an element of own forces;
- H_2 – the enemy will not impact upon own forces.

The probability for the system to be in one of the specified states $P(H_i)$ can be defined using the existing database (the accumulated experience) through calculation of an inner intuition (using fuzzy sets). The specified probabilities can take the values from 0 to 1.

Using the classical theory of probabilities, we can define the degree of uncertainty through the entropy of the system applying the following formulae [10]:

$$H = -\sum_{i=1}^{n} P(H_i).\log_2 P(H_i) \tag{1}$$

After receiving intelligence information about specific actions of the enemy side (this is a cyclical probability process as a rule), the probabilities of the state of the system change. This undoubtedly leads to reducing the level of uncertainty in the system, or, in other words, to measuring the "knowledge-ability" about the state of the system. One of the ways to calculate this change is by using the following theorem of hypotheses [11]:

$$P(H_i / A) = \frac{P(H_i).P(A/H_i)}{\sum_{i=1}^{n} P(H_i).P(A/H_i)} \tag{2}$$

where $P(A/H_i)$ is the probability to gather intelligence information about a certain event with the hypothesis H_1 or H_2 for the example under consideration.

For values of $P(H_1) = 0.7$ and $P(H_2) = 0.3$, $P(A/H_1) = 0.8$, and $P(A/H_2) = 0.2$ the "clarification" of the state of the system in the course of a sequence of intelligence cycles is shown in Figure 1.

This dependence changes its appearance for other values of the specified parameters. Regardless of this fact, it is possible to study how the duration of intelligence impacts the reduction of uncertainty (validation) of the system. The conclusion that could be made is that not in all cases the decision made faster is preferable, owing to the fact that it is made in a more undetermined situation, which would increase the risk of making an incorrect decision, i.e. it enhances the risk of executing the mission.

Interesting are also the questions "How the simultaneous utilization of different types of intelligence devices impacts the removal of system uncertainty? What sort of impact do the times necessary for the enemy to perform an interconnected sequence of actions have upon revealing of characteristic events? Can it be compensated by the simultaneous work of several intelligence bodies with extending the time for these events? If it is possible, for what level of control is such compensation acceptable? etc.

Solving the problem in general, recommendations can be given as to how the questions (requirements) to intelligence should be formulated, so as to provide a maximum quantity of information within a reasonable use of intelligence resources.

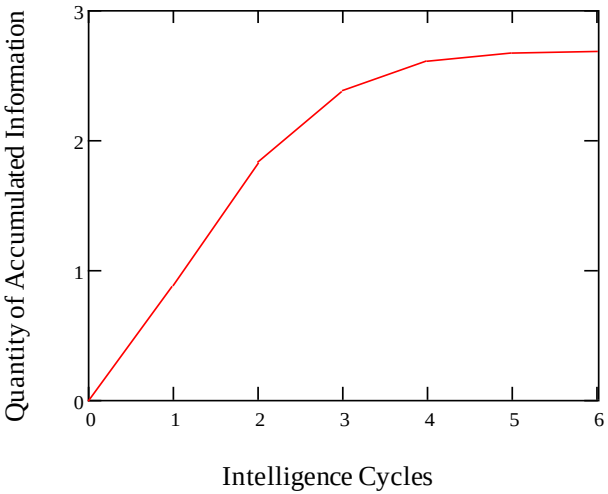

Figure 1: Knowledge about the System State as a Function of Intelligence Cycles.

What would happen if the enemy uses the methods of military deception and introduces a number of misleading signs in his actions? What effect would the information noise have when accumulating the required information? To this end, we can reformulate the task of delivering information with distortion as a task for defining the quantity of accumulated information with the use of military deception by the enemy [12] for the conditions of the example under consideration:

$$Inf = [-P(H_1).\log_2 P(H_1) - P(H_2).\log_2 P(H_2)] - [-\mu.\log_2 \mu - (1-\mu).\log_2(1-\mu)]$$

Where μ is the probability to accept false actions for actual ones.

At value of $\mu = 0.05$ (a very low probability of leading into deception), the result for accumulating information under conditions of deception and under conditions when such activities are not performed by the enemy is shown in Figure 2.

At probability of $\mu = 0.5$ for situations demanding an answer of type 'yes-no,' the real actions cannot be differentiated from the false ones, i.e. in this case the information system collapses.

In terms of research, experiments can also be made from a psychological point of view. In case of differences in the results from modeling of the understanding of the situation and the psychological idiosyncrasies of the commander under scrutiny, an answer can be sought whether this difference appears as a result of the application of 'common sense' or whether there are imperfections in the methods applied.

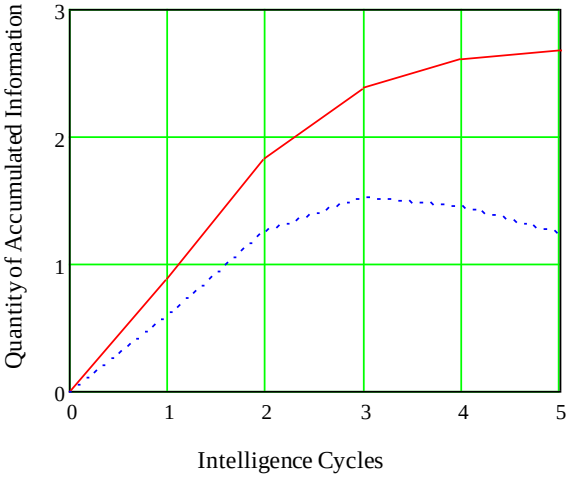

Figure 2: Examining the Effect of Deception on the Accumulated Intelligence Information.

The amount of information about the object includes information of primary, secondary, and other types.[13]

Information of primary type is the one being perceived with one's own senses or sensors without having undergone any intellectual processing.

Secondary is the information having undergone an intellectual analysis for authenticity and having received a mark for authenticity. These analysis and mark are done by comparison with similar information from other sources, evaluation of the reliability of the sources, and comparison with the available knowledge about the object.

Tertiary is the information summary. It represents the result of analysis of different information related to an individual object or its quantitative or qualitative indicator and represents identification of the individual object or establishing an indicator for it. There exist a multitude of indicators, for which a historical analysis is necessary, i.e. analysis of the change of certain information in time. It requires the availability of at least two separate sources for obtaining information about the same thing, with a difference in the time of obtaining. A historical analysis is also possible through the comparison of one-time information with the available knowledge about the object.

With each successive stage of intellectual processing, the information is increasingly transformed into knowledge – knowledge about the current state of the object. This is the natural way of transforming information into knowledge: checking, comparing with a priori information, summarizing, comparing once again with similar summaries, comparing with other summaries, comparing with the a priori knowledge and

with the a priori information until the construction of an information model of the object in consideration.

The models proposed will facilitate the search of cause-and-effect relationships and reveal regularities and laws, thus enabling their application in commanders' practices.

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Notes:

[1] See *DOD Dictionary of Military and Associated Terms*, <www.dtic.mil/doctrine/jel/doddict> (12 September 2007).

[2] Michail Bachvarov, *Philosophical Dictionary* (Sofia: Science and Art, 1977, in Bulgarian).

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[5] Liliya Gurova, "Meaning and Action," <dem-pr.hit.bg/2003_1/2003_1_05.htm> (12 September 2007) (in Bulgarian).

[6] Mica R. Endsley, "Situation Awareness," in *Handbook of Human Factors and Ergonomics*, ed. Gavriel Salvendy (Wiley, 2006); Mica R. Endsley, "Theoretical Underpinnings of Situation Awareness: A Critical Review," in Situation awareness analysis and measurement, ed. Mica R. Endsley and D. J. Garland (Mahwah, NJ: LEA, 2000); Mica R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," *Human Factors* (1995): 32–64.

[7] E. Jeannot, C. Kelly, and D. Thompson, "The Development of Situation Awareness Measures in ATM Systems," HRS/HSP-005-REP-01, (Brussels: Eurocontrol, 2003), <www.eurocontrol.int/humanfactors/gallery/content/public/docs/DELIVERABLES/HF35-HRS-HSP-005-REP-01withsig.pdf> (21 September 2007).

[8] Gurova, "Meaning and Action."

[9] E. C. Ventzel, *Probability Theory* (Moscow: Vyishaya Shkola, 2001).

[10] Ventzel, *Probability Theory*.

[11] Ventzel, *Probability Theory*.

[12] Ventzel, *Probability Theory*.

[13] Ventzel, *Probability Theory*.

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