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"The Operations Intent and Effects Model: A Command and Control Methodology for Increased Automation"

Topic 1: Concepts, Theory, and Policy

Topic 2: Approaches and Organizations

Topic 4: Collaboration, Shared Awareness, and Decision Making

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Abstract

Command and Control (C2) is viewed as an increasing important part of future military technologies. While recent C2 theory has focused on desirable features of complex organizations, such as Agility, and emerging work is looking at social media approaches – the key issues for many nations and programs are how to integrate and benefit from increased automation. Rapid advanced in Robotic and Simulation technologies are very apparent and challenge the current C2 methodologies that rely upon intensive human intervention and monitoring. Future C2 will need to accommodate "mixed" forces of Humans and Robots.

The uncertainty inherent in an actual mission, and the variety of potential organizations that support the mission after it is underway, makes Command Intent (CI) a critical concept for automated C2 systems. Both humans and decision support services (including simulations) within a C2 system need to have the ability to communicate and interpret a shared CI. The Operations Intent and Effects Model (OIEM) identifies the relationships between Intent, Actions, and Effects in a C2 framework. We describe this model and show how it can represent and support operations as well as enable the design of more effective C2 systems in the future.

1. Introduction

The explosion of new Information Technology has profoundly affected modern military forces. In no area has this change been as drastic as has the impact on C2. As well as providing unique new capabilities, the new Information Technology has posed significant challenges in the area of C2 acquisition and development. Modern military forces are being forced to adopt Commercial Information Technology for C2 uses due to the slow pace of innovation in military acquisition and development. An example is the impact of "Smart Phones" on current militaries and their C2 infrastructure.

However, while the new capabilities provided (e.g., more computing power, better communications) are eagerly embraced by the warfighters, they provide a challenge in how they integrate into the C2 infrastructure. Beyond this challenges, there is the issue of how the new capabilities can be optimally used to accomplish missions. Rapid advanced in Robotic and Simulation technologies can supplement current C2 methodologies that rely upon intensive human intervention and monitoring (Borgers, et al., 2008).

While the advantages of Agility and Robustness for C2 theory have been empathized in recent work (Alberts, 2007; Alberts and Hayes 2007), there is a competing need to develop dedicated C2 technologies and specific services to accomplish specialized missions. State of the Art C2

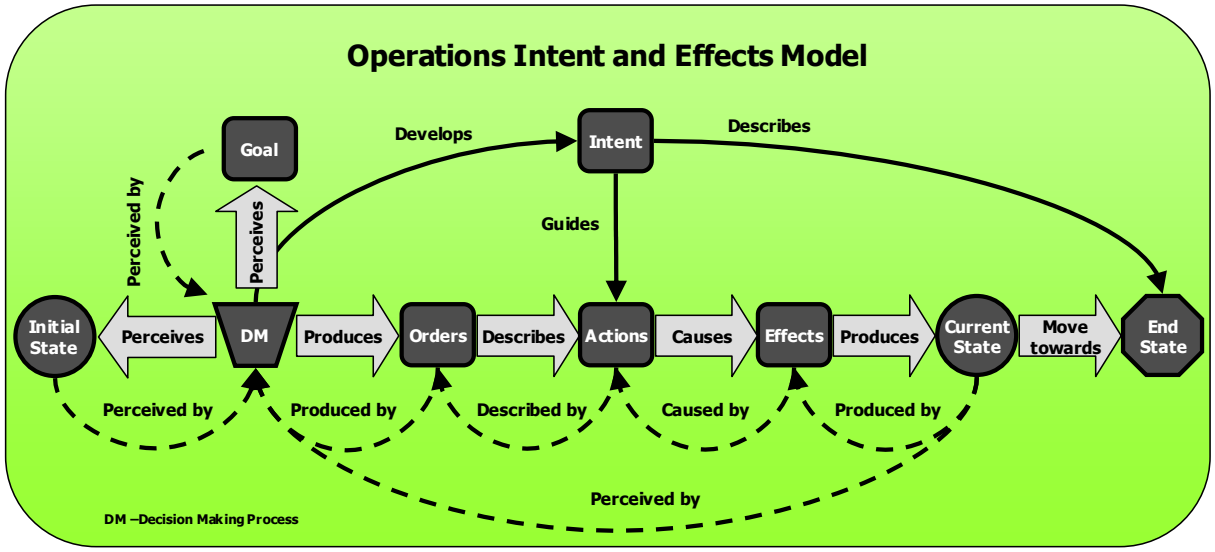

Figure 1 – Operations Intent and Effects Model

systems are geared toward "Sensemaking" – developing Situational Awareness and are starting to perform predictive analysis. There is still a very limited capacity to integrate the increasingly sophisticated robotics and simulation technologies.

The research presented in this paper addresses the problem of developing and integrating new technologies into C2 technologies and processes. A new methodology is presented that is oriented towards the development and integration of new technologies. The OIEM was developed to both portray a generic C2 process (applicable to operations conducted by Military, Civil, and Non Governmental Organizations) as well as represent those elements necessary for developing both Intent and Situational Awareness, key to using C2 to accomplish missions.

In this paper the OIEM is presented and described in detail. More detail on related C2 models (such as the Observe, Orient, Decide and Act (OODA) Loop (Boyd, 1987)) can be found in (Gustavsson, 2011), as well as the application of this model. The OIEM model is a general and high-level description of C2 information constituents, their relations and causality in the view of an organizational planning context. The paper concludes with a discussion about the applicability of the model.

2. Operations Intent and Effects Model (OIEM)

Figure 1 presents the OIEM, a model of Operations as it relates to general C2 and decision-making processes. The world is represented and bounded by an *Initial-State, Current-State and End-State*.

The model is based on Curts & Cambell's (2006) Generic Command and Control Process Boyd's, (1987) OODA Loop, and Brehmer's Dynamic OODA Loop together with military decision making models such as United States (US) Military Decision Making Process (MDMP) (US Army 2005) and Swedish Armed Forces (SwAF) Integrated Dynamic Command and Control

(IDC2) (SwAF, 2007). The OIEM has been developed and enhanced over several years concluding in (Gustavsson, 2011). In the author's first version (Gustavsson, et al., 2008b), the main characteristics of the model were introduced identifying *Intent, Initial-State, End-State, Orders, Actions, Effects, Goal* and their relation to *Decision Making*. In Gustavsson, et al., (2009) the model was enhanced to better express the causalities and relations in the model. In Gustavsson, Hieb, and Wemmergård (2009) "Commander's Intent" was replaced with "Command Intent" to better represent the collective effort in developing *Intent*, together with the insertion of plural forms of *Actions, Orders*, and *Effects* since there is not just one order, action or effect that leads towards an *End-State*. In Gustavsson, et al., (2011) the Command Intent was replaced with the general term of *Intent* to encapsulate all forms of *Intent*. For clarity, boxes were introduced for all information elements including *Mission/Goal* and *Intent*. The model presented in Figure 1 has been further enhanced to incorporate *Current-State*, and show that *Intent* "guides" the implementation of *Actions*. The purpose of the changes made is to further clarify the role of *Intent* in a C2 process and its relation to other C2 information elements.

In the OIEM C2 information elements are represented by rectangular boxes, circles and octagons. The *Decision Making (DM)* box describes the process using and generating information that is reviewed and conveyed in the organization. Block arrows present the relations and causality from the perspective of the *Initial-State* and illustrate the main flow in Traditional C2 planning, i.e., forward chaining. Dashed arrows represent the perspective from the *End-State* information object and illustrate Effects-Based planning, i.e., backward chaining. The solid arrows emphasise the Intent relations between *Decision Making* and *Intent*, *Intent* and *Actions*, and between *Intent* and *End-State.*

The general flow in the model is that the *DM* process perceives the *Goal* and the *Initial-State*, often provided by a higher Command Authority. The *DM* process then develops an Intent that can be either explicit or implicit. The *Orders* normally contain the explicitly stated Intent. In Traditional C2 planning, the *Orders* are developed by assessing the possible *Actions* that will lead towards the desired *End-State*. In Effects-Based Approaches the *Orders* are developed by assessing the *End-State* and the possible *Effects* that will lead towards the *End-State*. The content of the *Orders* produced then either focuses on the *Actions* to be performed (as in a Traditional Planning Process) or on the *Effects* to be accomplished (as in an Effects-Based Planning Process). Regardless of which planning paradigm is used in the in the *DM* process, the *Actions* produce *Effects* that are monitored and change the *Initial-State* into a *Current-State*. The *Current-State* is then analysed with respect to the *End-State*. If the *End-State* is not reached, an assessment is made (deliberate or hasty), and eventual new orders are produced.

The following subsections describe the model into more detail.

2.1 Decision Making Process in OIEM

The *DM* should be seen as a container for the decision making process of choice conducted by commanders. In Figure 2 the *DM* is presented together with its main information objects. The *DM* in a C2 context can be illustrated with the eight steps derived from the MDMP as outlined in Army Field Manual 5-0 (U.S. Army 2005).

Step 1) Receipt of mission / Initiation

A goal is externally delivered, interpreted and adopted into the internal system or developed internally in the system.

Step 2) Mission Analysis / Orientation

The next step according to the MDMP is to search for and make use of information. In OIEM this is captured by the *Perceives* and *Perceived by* arrows. If there is a need for more information, that request is made, and is in itself, an order consisting of actions or effects to be accomplished, e.g., retrieving information in a certain area regarding some specific objects. Therefore there is no explicit arrow for request of more information in the figures. Within the model the perception, comprehension and projections of information is within the *DM* process. The *Initial-State* and *Current-State* are representation of information.

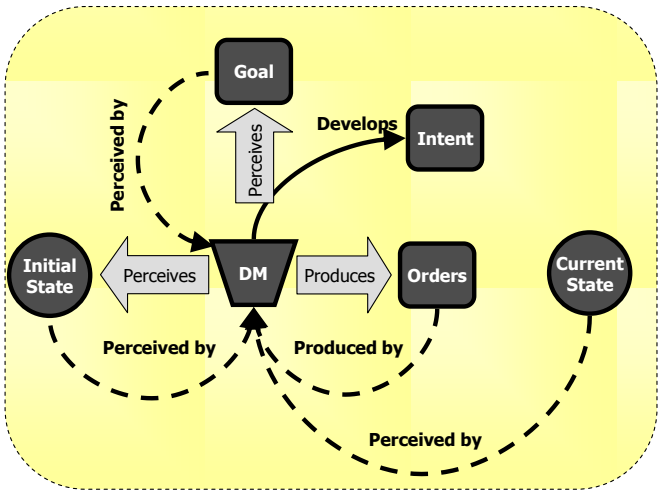

Figure 2 – *Decision Making* Process in OIEM

Steps 3-6) Course of Action Development, Analysis, Comparison and Approval / Decision

The development of a Course of Action (COA) and a Course of Effects (COE) is an internal *DM* process where strategies such as forward and backward chaining are used. In the MDMP the decision making process receives a mission goal and perceives an *Initial-State*. A concept of *Intent* and *End-State* is developed. In a forward chaining process, the decision making process receives a mission goal and perceives an Initial-State. A concept of *Intent* and *End-State* is developed. Then the question is, what actions can cause effects to change the Initial-State towards the *End-State*? The next feasible state is used as a new turn, the next after that, and so on. Eventually the *End-State* is reached and within the DM process a selection amongst alternatives is made and *Orders* can be produced.

[Depending on the C2 method used, the Analysis processes can differ. In a traditional setting, several COA/COEs are evaluated and judged against each other. The best COA/COE, according to a predefined set of criteria, is selected. For example, a criteria for Recognition

Primed Decision Making might select the first developed COA/COE that will fulfill the objectives.]

Step 7) Orders Production / Plan Development

From the process of developing COAs and/or COEs *Orders* are developed containing the information normally following a standard military five-paragraph order structure or at least the Who, What, When, Where and Why (5Ws) structure.

Step 8) Review

When the Orders are set into action, the effects will change the *Initial-State* into a *Current-State* that is perceived by the DM process. The DM process evaluates the *Current-State* towards the End-State, Intent and Goal. Depending on the outcome, the result could be that the mission is completed or that, depending on the magnitude of change, either Fragmentary Orders (FRAGOs) or new Operations Orders (OPORDs) are made.

2.2 Goal in OIEM

Figure 3 presents how *Goal* relates to *DM*. Decisions are made by purposeful systems, meaning that there is an underlying goal for the system to pursue and that there is some sort of decision making process that supports the achievement of the goal (Ackoff, 1999). A goal is either internally developed (within a humans mind or within an organization), or is an externally disseminated goal. Within the author's work (Lagervik and Gustavsson, 2006) a goal is important for a purposeful system. Internal goals are the goals that an organization or individual develops. External goals are derived from mission statements or from Intent statements (and in a military setting derived from higher commanders OPLAN or OPORD). The word "goal" is chosen to represent all the types of statement that provide the purpose and rationale for the operation and guides the DM process.

Therefore, a goal can describe what the effects ought to result in, and the goal identifies the higher intent, i.e. intent from a higher commander or organisation. From a collaborative cooperative view, a goal is the overarching unifier for the teams.

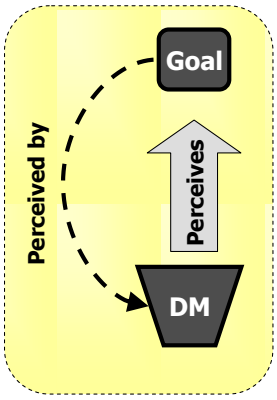

Figure 3 – *Goal* in the OIEM

2.3 Initial-State / Current-State in OIEM

A C2 process incorporates the search for more information. This information is then used as a basis for the decision making. For this work, a state is said to describe a condition or parameters' values at a certain time. A state is produced by a situation assessment process shown in Figure 4. There are many well defined models of Situational Awareness such as in Endsley (1995) or the Joint Directors of Laboratories (JDL) Model (Llinas, et. al., 2004).

The Initialization of such a process is made by the decision making process in the search for new or updated information.

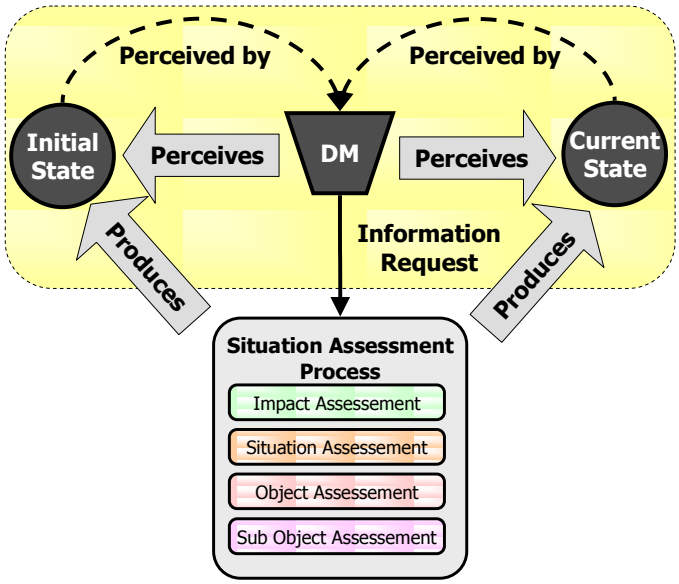

Figure 4 – *Initial-State* and Situation Assessment Process in the OIEM

An ongoing state is said to be *current*, a state that has been is said to be *previous*, and an anticipated upcoming state is said to be *future*; e.g., *current:* would be a battalion is moving into attack position; *previous*: the battalion has disembarked and marched to the designated area of operations; and *future*: the battalion will attack and seize the enemy. Depending of the purpose of what a state is describing, states may also have different sets and granularity of conditions and parameters. An object can belong to several states at the same time.

A state is not only physical; it also covers cognitive states, i.e., humans' states of mind. The cognitive state will change over time and can range a whole set of attributes, e.g., consciousness, political, intention, goals, and will. Further, a state can also be informative in describing the capability and ability (e.g., that the battalion can attack ground forces); or, state of readiness describing to which degree a person or system can conduct a certain task (e.g., that the battalion has appropriate resources to conduct the task at hand).

An *Initial-State* is the starting state that is/was used during the decision making process. It can be physical, i.e., describing objects' positions and actions; or, cognitive, i.e., describing a person's and system's state of mind; or, informative, i.e., describing objects, environment, person and systems.

Both *Initial-State* and *Current-State* contain the relevant information for that particular decision making process. In a military setting the Initial-State contains physical, cognitive, and informative information about own forces, enemy forces, other forces, civilians, other organizations, and the environment.

To assess the completion of the intent, plans, orders, tasks, actions, etc., the *Initial-State* is evaluated against the *Current-State*. From a planning perspective an intelligence product is often used that contains the previous state, the Current-State and assumed future states. This intelligence product is the *Initial-State* for the planning and decision making therefore the OIEM in Figure 4 incorporates both initial and Current-States.

2.4 Intent in OIEM

In Figure 5 *Intent* and its relation to the *DM* process, *Actions* and *End-State* is visualized. With this approach *Intent* is captured to be an output from a *DM* process regardless if it is implicitly or explicitly declared. The representation of Intent follows Klein (2008).The *End-State* in OIEM can be described through the three *Intent* facets: Goal, Antigoal, and End State. Goal describes the high-level purpose of the desired outcome, i.e., the rationale, Antigoals describe unwanted outcomes; and, the End State describes the more detailed desired outcome. The guidance to *Actions* is described mainly of the remaining four facets of Intent: Initial-State, Sequence, Key Decisions, and Constraints. The Initial-State describes the situation and assumptions when the Intent was developed, Sequence directs the order of actions, Key Decisions provides the most important decisions that are expected to occur, and Constraints provide the rules of engagement and the consequences of external events (e.g., weather and populations). We note that in current NATO and US doctrine Sequence and Key Decisions may not be specified. With this approach *Intent* is modelled in order to support a *DM*. The *Initial-State* described in the intent statement is equal to the *Initial-State* presented in the OIEM.

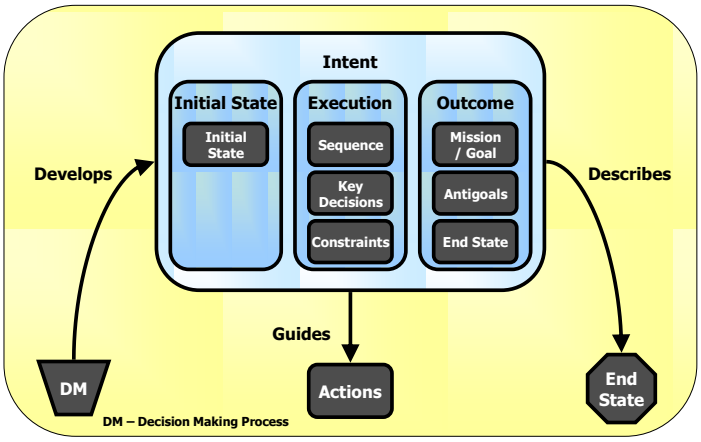

Figure 5 - *Intent* in the OIEM

2.5 Orders in OIEM

Orders are well rooted in military doctrine, and from the military decision making perspective the output is often a Warning Order (WARNO), OPLAN, OPORD, FRAGO, or an Air Tasking Order (ATO). In other Organizations (e.g., Police, Fire Departments) there are also well-specified formats for Orders. *Orders* are disseminated to subordinates to be executed. For the OIEM the wording *orders* are used to encapsulate all formal written orders along with simple direct vocalized orders. The focus for OIEM is the information specified in the OPLAN/OPORDs first three paragraphs of Situation, Mission, and Execution since these are oriented towards the actions to be performed. In Situation the *Initial-State* of Own, Friend, and Foe are described. Mission describes the *Goal*, i.e., internally or externally developed as described in Section 2.2 above. Finally Execution conveys Intent, COAs/COE, tasks to subordinates and tasks to supporting organizations. The purpose of the *Orders* is to provide coordination of actions to establish effects in the most effective area at the most effective time to move towards a desired *End-State*. That also is the core of Effects-Based Operations.

2.6 Actions in OIEM

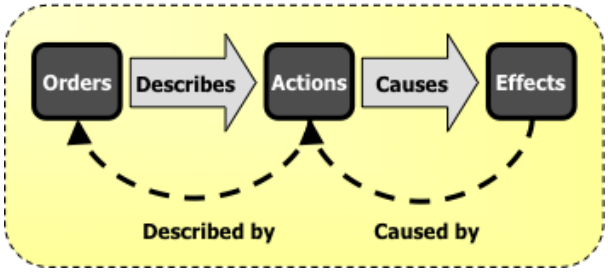

Figure 6 – *Actions* in the OIEM

An action is something that is executed by a system. The system can be technical or human controlled and can range from a single executer to a whole echelon of executers. In Figure 6 the OIEM action relations is visualized. The basic interpretation is that an action causes an effect. Several actions together can cause a specific effect and sometimes a single action causes several effects. Actions are described in an order. Here the order can be as vivid as an OPORD or OPLAN, or a verbalization of some simple direct action.

Standard Operating Procedures provide a set of actions that are applicable for a specific organization, echelon or individual, i.e., actor. How well an actor can perform an action is captured by its capability.

2.7 Effects in OIEM

The Effects-Based Operations approach can be seen as a method to model the causes between actions and effects, physical and behavioural as well as direct and indirect effects. This is captured in the OIEM by linking *Actions* to *Effects* by the arrow denoted "causes" as shown in Figure 7. This relation defines Effect-Nodes-Action-Resources (E-N-A-R) linkages.

Actions represent both low level actions executed by individuals (e.g., fire a weapon), and high level actions (e.g., mission executed by a Corps force such as operation Desert Storm). *Effects* represent both low level effects (e.g., impact of bullet), and high level effects (e.g., Enemy force defeated). Thus, separate actions can be represented by a higher level action and separate effects can be represented by a higher level effect. Further, one or more actions causes either a single effect or a set of effects to occur. An action of shooting causes the effect that some one gets hit. At the same time a *side effect* of revealing one's own position is caused. If the person that got hit dies we have a *cascading* effect, i.e. *Effects* can be said to cause *Effects*.

2.8 End-State in OIEM

In Field Manual 5.0, (U.S. Army 2005) an End-State consists of those conditions that, when achieved, accomplish the mission. An *End-State* is described by the relationship between own forces and opponent forces, terrain, other people and organizations.

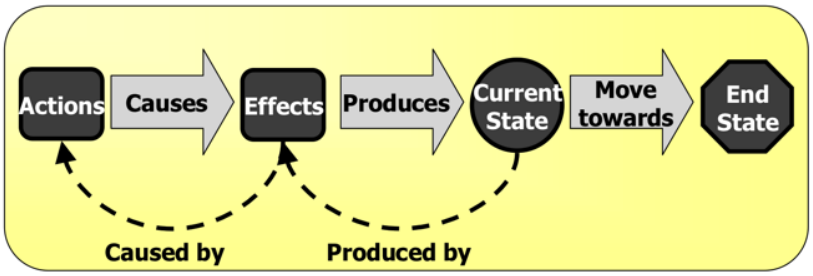

Figure 7– Effects in the OIEM

The relationship of *End-State* to *Intent* is visualized in Figure 8. An *End-State* can be represented by graphics overlays, in matrices, or described textually. An *End-State* can either be direct (e.g. destroying a bridge, when the bridge is destroyed the end-state is reached) or abstract (e.g., secure airfield). Also an *End-State* can have a varied time span (e.g., for how long shall the airfield be protected, and for how long is the end-state valid to pursue?). Further, an *End-State* can be articulated in the *Effect* that should be gained. An *End-State* in an OPORD is usually in bullet form and it normally does not exceed five sentences. The use of *End-State* enables the subordinates, supporting organizations and collaboration partners to establish effects in the most effective area at the most effective time within the scope of the Intent. The *End-State* is described by the Goal, Antigoals, and End-State as defined in Section 2.4 above. The expected result from a series of actions-cause-effects is observable changes in the Current-State. If the Current-State meets the criteria of the End-State the OIEM assumes the *Actions* produced the End-State.

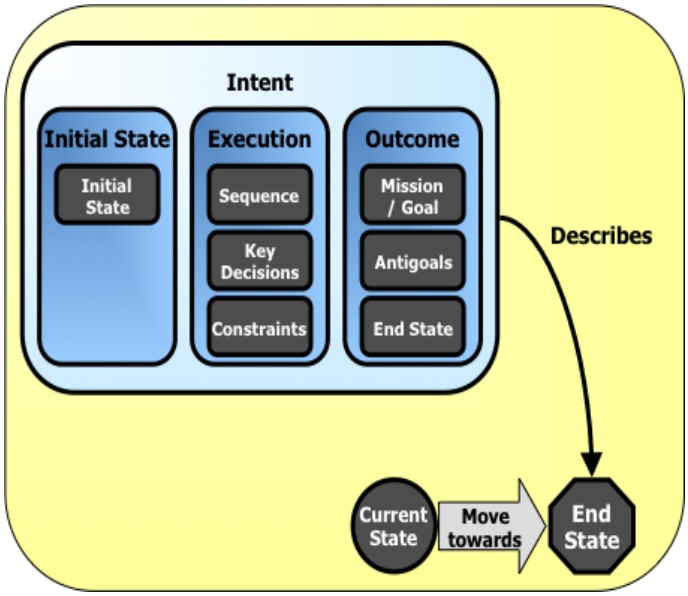

Figure 8 – End-State in the OIEM

3. Challenges

C2 is still a very human process, with fewer automated tools that support the planning and execution phases then the large number of C2 tools that provide situation awareness. In order to develop more sophisticated C2 tools, there needs to be a better integration of current and emerging technologies. An example is the current visualization technologies such as Google Earth. These have the potential to provide virtual simulations of areas where future operations will occur. Small Unmanned Aerial Vehicles will be available that can map large areas very accurately. But to integrate all of these technologies requires a guiding principle and the OIEM suggests that the concept of Intent may be the best paradigm to use.

There are various representations of Intent that can be used in reasoning systems. Many of these have been developed from the domain of Military Simulations (Carey, et. al., 2001; Gustavssson, et. al., 2008a; Schade and Hieb, 2006; Schade and Hieb 2007). However, there are only a few tools that can currently project Actions forward to determine if an End-State can be reached. While many Military Simulations can generate Actions from Orders, the specification of an End-State is currently a major technology gap. The End-State cannot be specified in such detail that it completely describes a complex world state, so the constraints in representing an End-State are critical.

There is a need to perform more assessment of different methods of developing intent as in (Farrell, 2004).

Similarly, the area of aggregation and delegation are difficult to implement in practice. While humans can delegate easily, the OIEM depicts a very simplistic C2 process. In actual operations there are many levels of goals, actions and effects. When reasoning systems can use intent, the orchestration of different goals will need to be addressed.

4. Summary

The OIEM captures Intent and Effects and the relations amongst C2 information elements along with C2 processes in a cohesive way and provides: 1) a model of Intent for C2; and, 2) a foundation for developing a new generation of tools to support C2 with new types of Information Technology.

Regardless of the C2 method, e.g., Traditional (North American Treaty Organization, 2005; U.S. Army, 2005), or Effects-Based, the OIEM illuminates the relationship between Intent and the other C2 information elements. For C2 tools the model is used to develop a formalism of Intent and related information elements. The model can be used as the basis for the implementation of Intent in Current C2 system (Gustavsson, 2011).

The OIEM captures the traditional approach to planning presented in the Generic Command and Control Process (Curts and Cambell, 2006), in that an order describes *Actions* that cause *Effects*. The *Effects* in turn change the *Current-State* into the desired *End-State*. The detection of the *Initial-State* (the state prior to the decision making and the time the *Orders* are given) means that the system where the decision making takes place must be able to perceive and comprehend the situation, and, from reasoning and projection, produce a plan that consists of an order that describes *Actions* to be executed. The observable *Effect* from the actions then changes the *i* to another state, i.e., *Current-State*.

In Effects-Based Operations (Smith, 2008) and Networked Enabled/Agility, Focus and Convergence (Alberts, 2007) the OIEM describes the relations between a desired *End-State* and the *Effects* that could cause it. With the relations from the *End-State* to *Effects* to *Actions* to the ability and capability of the force at hand, to find the first solution that might fulfil the mission. The OIEM supports the vision by Alberts and Hayes (2007) of a goal-seeking process that guides actions and effects, in that it allows templates to be constructed that describe *Effects* from various *Actions*. The model can then be used for both backward chaining as well as forward chaining. Backward chaining is supported by the search from *End-State* and *Effects* towards *Actions* and organisations that can execute the actions. Forward chaining is supported by using the Initial-State and actions that result in effects that changes state towards the desired End-State.

In a collaborative setting the OIEM provides a way to identify where there is a need to communicate plans, intentions and orders amongst staff members, joint and coalition forces and other agencies. The relationships, such as *Effects* to *Actions*, allow a commander to express the actions he selects with the understanding of how they can deliver the desired effects. This can be used at higher level command to assess the plans. The OIEM supports computational representations of intent will allow for human machine analysis (e.g., simulation).

Acknowledgements

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