14TH ICCRTS

"C2 and Agility"

On the Formal Representation of Enemy Courses of Action

Topic 9: C2 Architectures and Technologies

Christopher J. Matheus, Brian Ulicny,
Gerald M. Powell and Mieczyslaw M. Kokar

Point of Contact:
Christopher Matheus
VIStology, Inc.
5 Mountainview Drive
Framingham, MA 01701 U.S.A.
508 788-5088
cmatheus@vistology.com

Abstract. During joint operations among multi-national forces it is imperative that the planned courses of action (COA) of coalition units be accurately and precisely communicated between battlefield operating systems, particularly when dealing with highly coordinated maneuvers. A similar need arises in being able to communicate intelligence concerning hypothesized or anticipated enemy courses of action (ECOA). In each case there is the need for a shared representational language for describing ECOAs that can be used with C4 systems. The standard exchange language for sharing such information among NATO forces today is the Joint Command, Control, and Consultation Information Exchange Data Mode (JC3IEDM). In this paper we explore the formal representational requirements for describing ECOAs and evaluate the effectiveness of JC3IEDM for this purpose.

Keywords: situation development, JC3IEDM, Enemy Course of Action, formal representation

1 Introduction

Under U.S. Army doctrine, situation development is a process that takes information about the enemy, friendly forces and their missions, weather and terrain (both geophysical and human) and outputs threat or enemy courses of action (ECOAs), ranked by likelihood and level of threat. As command and control systems become increasingly automated a growing need arises for the ability to have computer applications that can help generate, process and/or reason about ECOAs. This capability becomes particularly important as C2 systems transition to the final level of the C2 Maturity Model – i.e., that of *Agile C2* – which is "predicated upon achieving a high degree of shared understanding of a common (collective) intent" [1]; having a "shared common intent" among coalition forces implies to some degree having a shared understanding of likely enemy courses of action. Towards this end we argue for the need to have a formal representation for ECOAs – formal in the mathematical sense of a computer processable logic or language. In this paper, we will investigate what it takes to represent an ECOA and explore the use of JC3IEDM, along with its OWL implementation, for this purpose.

2 Threat or Enemy Courses of Action

In short an ECOA is a description of a sequence of actions or operations that the enemy is in the process of conducting or is planning to conduct in the near future. According to U.S Army Field Manual 34-130 ("Intelligence Preparation of the Battlefield"), each threat/enemy COA must answer the following five questions ([2] pp 2-44,2-45):

- WHAT - the type of operation, such as attack, defend, reinforce, or conduct retrograde.
- WHEN – the (earliest) time the action will begin.
- WHERE - the sectors, zones, axis of attack, avenues of approach, and objectives that make up the COA.
- HOW - the method by which the threat will employ his assets, such as dispositions, location of main effort, the scheme of maneuver, and how it will be supported.
- WHY - the objective or end state the threat intends to accomplish.

Another way to view an ECOA is as a hypothesized enemy *mission*. A *mission*, according to the U.S. Army Field Manual 6.0 ("Operations"), is defined as:

> "the task, together with the purpose, that clearly indicates the action to be taken and the reason therefore... The mission statement defines the *who, what, when, where*, and *why* of the operation."

Taken together then these definitions suggest that representing an ECOA will require the ability to sufficiently represent a hypothesized enemy mission in terms of the who (what enemy units are involved), the what (what type of operation is being planned), the where (locations of the operation), the how (specifics of the operation) and the why (the desired end state or objective).

Again according to U.S Army Field Manual 34-130 every threat/enemy COA should consist of three parts: a situation template, a description of the COA and a listing of High Value Targets (HVT). While this manual was written with a heavy emphasis on conventional maneuver-centric operations the principles continue to be employed in irregular and asymmetric operations as well, where ECOAs are often captured by a combination of graphical situation templates, textural descriptions and HVT lists or "target decks".

As an example of a narrative description of an ECOA we will use the following taken from a US Naval War College training document [3]:

> ECOA 1: REDLAND initially conducts joint operations to disrupt JTF [Joint Task Force] Blue Sword forced entry operations, and upon establishment of the JTF Blue Sword in REDLAND, the REDLAND armed forces disperse into small-unit formations in the mountains and cities and initiate insurgency operations to defeat the JTF ground forces.

We will focus on this ECOA as a running example and ask the question of how well JC3IEDM is able to handle the needs implied by the above discussion. Since JC3IEDM is not well suited for representing *graphical* artifacts such as would be required to represent situation templates we will confine our attention to ECOA textural descriptions and HVT lists.

3 JC3IEDM

The Multilateral Interoperability Programme (MIP) is a long-standing, NATO-supported program intended to foster international interoperability of command and control information systems through the development of standard data models and exchange mechanisms. The data model was first released in the mid-1990s as the Generic Hub (GH) Data Model. In its current form, it is called the Joint Consultation, Command and Control Information Exchange Data Model 3.1 (hereinafter, JC3IEDM) [4]. It captures information about 271 entities, 372 relationships between entities, 753 entity attributes and over 10,000 value codes.

Several projects currently envision using JC3IEDM as the basis for automatically encoding and exchanging battlespace information, such as the German Sokrates project [5], an automatic battlespace report analysis tool, and SISO's Coalition Battlefield Management Language research program (C-BML) [6].

A high-level overview of JC3IEDM is shown in Figure 1. The entities near the bottom of the diagram that focus around OBJECT-ITEM, OBJECT-TYPE and LOCATION tend to be used to represent situational awareness, i.e., what objects there are, what qualities they have, where they are located and how they are related to one another. These elements will be useful in representing the who (enemy units), the where and some of the how pertaining to equipment capabilities. Near the top of the diagram are entities concerned with describing ACTIONs, both planned and observed; these elements are useful for

representing the what (high level actions), the how (specific detailed sub actions) and the when (as it relates to the beginning, duration and ending of ACTIONS).

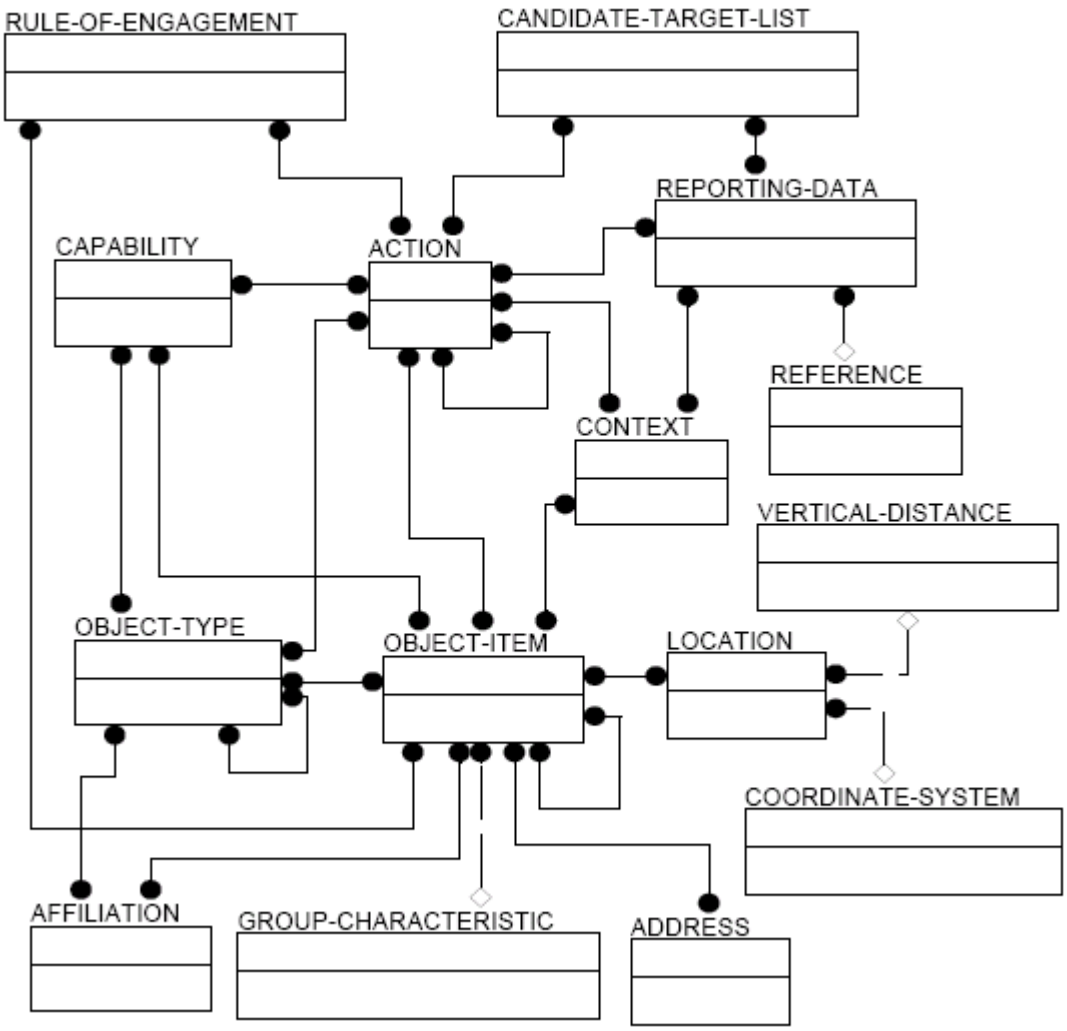

Figure 1 Basic JC3IEDM Elements

3.1 ACTIONS: Representing the What

In an earlier ICCRTS publication [7] we described how JC3IEDM could be used to represent friendly missions. A similar approach can be used to represent enemy missions as ACTION-TASKS. Following the approach used in the JC3IEDM document description, sample encodings of data below are represented as partial Entity tables, data

values in square brackets represent internal ids, quoted strings are free text and all other values are codes taken from the model.

JC3IEDM treats ACTIONs as first-class entities alongside physical objects, locations, times, reports, and so on. ACTIONs are further subclassified as ACTION-EVENTS and ACTION-TASKs, the distinction being that ACTION-TASKs are known to be planned. Taking ACTIONs as primitive members of the ontology places the JC3IEDM approach within the tradition initiated by philosopher Donald Davidson [8] who argued that events are particulars that constitute a fundamental ontological category over which quantification is necessary for a first-order model-theoretic semantics of natural language.

Here we capture the ECOA's three operations: disrupting (Disrupt code in JC3IEDM) the JTF, disbursing or distributing (Distribute code in JC3IEDM) and initiating insurgency. This last operation is not available as a type of action code in JC3IEDM so we have used Ambush as a less than satisfactory stand in.

ACTION

action-id	action-category-code	action-name-text
[Op Alpha]	ACTION-TASK	"Enemy Op Alpha"
[Op Bravo]	ACTION-TASK	"Enemy Op Bravo"
[Op Charlie]	ACTION-TASK	"Enemy Op Charlie"

ACTION-TASK

*-id	*-activity-code	*-category-code
[Op Alpha]	Disrupt	Plan
[Op Bravo]	Distribute	Plan
[Op Bravo]	Ambush	Plan

(Note: * = action-task)

In JC3IEDM, an ACTION has several possible entities that optionally further characterize it beyond its type. An ACTION has an agent (*who*) specified through an ORGANISATION-ACTION-ASSOCIATION. An ACTION may also have an associate

set of RESOURCEs which may represent additional units or equipment; in the case of our sample ECOA from above no such resources are specified.

ORGANISATION-ACTION-ASSOCIATION

organisation-id	action-id	* -category-code	*-intent-text
[REDLAND]	[Op Alpha]	Controls	"Disrupt JTF".
[REDLAND]	[Op Bravo]	Controls	"Disperse"
[REDLAND]	[Op Charlie]	Controls	"Initiate Insurgency"

In addition to identifying the organization it is also possible to describe its structure, specifically by defining it's make up. While this kind of information is not provided in the sample REDLAND ECOA one could imagine something of the following being appropriate for this operation:

OBJECT-ITEM

object-item-id	object-item-category-code	object-item-name-text
[REDLAND]	ORGANIZATION	RedLand Company
[RedPlaA]	ORGANIZATION	Red Platoon A
[RedPlaB]	ORGANIZATION	Red Platoon B

OBJECT-ITEM-ASSOCIATION

*-subject-item-id	*-object-item-id	*-category-code	*-subcategory-code
[REDLAND]	[RedPlaA]	Command and control	Has full command of
[REDLAND]	[RedPlaB]	Command and control	Has full command of

(Note: *=object-item-association)

ORGANISATION-STRUCTURE

organsation-structure-root-organization
[REDLANDCOMMAND]

ORGANISATION-STRUCTURE-DETAIL

*-root-organization	*-subject-object-id	*-object-object-id
[REDLANDCOMMAND]	[REDLAND]	[RedPlaA]
[REDLANDCOMMAND]	[REDLAND]	[RedPlaB]

(Note *=organisation-structure-detail)

3.2 ACTION-LOCATION: Representing the Where

An ACTION-LOCATION specifies *where* the ACTION takes place. The entities defining the location are not provided here but could easily be defined using a GEOMETRIC-VOLUME, SURFACE or POINT.

ACTION-LOCATION

action-id	location-id	*-accuracy-dimension
[Op Alpha]	[Loc 1]	15.0
[Op Bravo]	[Loc 2]	10.0
[Op Bravo]	[Loc 1]	25.0

(Note: *=action-location)

3.3 ACTION-OBJECTIVE: Representing the Why

An ACTION-OBJECTIVE specifies the focus of the ACTION, the thing that is acted upon; the objective can be specific to an ITEM, a TASK or an object TYPE. For example, for the REDLAND ECOA we would have an ACTION-OBJECTIVE-ITEM as the objective of two of the sub-operations:

ACTION-OBJECTIVE-ITEM

action-id	*-category-code	*-primacy-code	object-item-id
[Op Alpha]	TARGET	Primacy	[JTF]
[Op Charlie]	TARGET	Primacy	[JTF]

(Note: *=action-objective-item)

3.4 ACTION-TEMPORAL-ASSOCIATION: Representing the When

Planned begin and end times can be given for each ACTION-TASK in addition to specifying temporal relationships between them using ACTION-TEMPORAL-ASSOCIATION. For example:

ACTION-TASK

*-id	*-planned-start-datetime	*-start-qualifier-code	*-planned-end-datatime	*-end-qualifier-code

[Op Alpha]	20070801120000	At	20070802120000	No later than
[Op Bravo]	20070802120000	Before	20070803120000	Before
[Op Bravo]	20070803120000	Before	20070804120000	Before

(* = action-task)

ACTION-TEMPORAL-ASSOCIATION

*-subject-action-id	*-category-code	*-object-action-id
[Op Bravo]	Sarts after end of	[Op Alpha]
[Op Charlie]	Starts after end of	[Op Bravo]

(Note: *=action-temporal- association)

An ACTION-FUNCTIONAL-ASSOCIATION specifies non-temporal relations among ACTIONs. One important such functional relation is the relation of sub-ACTION, encoding a mereology of events. Specifying one ACTION as a sub-ACTION of another is a way to specify *how* an ACTION is to be accomplished [9]. For example, an enemy might disrupt an election by bombing a polling place. The bombing would here be a sub-ACTION of the disrupting. In addition, the bombing might be specified as occurring *in-order-that* the disruption occurs. In this way, JC3IEDM allows one to express the means (*how*) of an ACTION as well.

JC3IEDM also provides a way to represent the fact that other artifacts may provide further information about the ACTION encoded in the database. These artifacts would include SITEMPS, Situation Matrices, and so on. In an ACTION's optional associated ACTION-REFERENCE element, one can specify, for example, that a particular SITEMP or SITMATRIX provides further details about the ACTION described. This, of course, would cause difficulties for automating inference of ECOAs, since crucial information might be represented in these artifacts in a non-formal way, as graphics or unstructured text.

Every piece of information in JC3IEDM has a mandatory associated REPORTING-DATA element that specifies when the information was reported, by whom, and specifies other elements of its pedigree: how certain the report was, how reliable the reporter, how likely the information reported is to be true, and so on. In JC3IEDM, therefore, ECOAs

would be represented as complex ACTIONs planned by hostile forces and predicted to occur with various likelihoods (*possible*, *probable*, *improbable*, etc.).

In JC3IEDM, an ECOA's status as a prediction is reflected in the REPORTING-DATA category code *predicted*. Actions, as we have said, will be represented as having an internal structure, with sub-ACTIONS bearing temporal, causal and other relations to one another. Nevertheless, because JC3IEDM is purely a relational data model, there are some ECOAs that can't be completely captured.

3.5 High Value Target Lists

High value target lists are representable in JC3IEDM using CANDIDATE-TARGET-LIST entities and their associated CANDIDATE_TARGET-DETAIL entities. In our sample ECOA the high value targets would be elements of the REDLAND force, *i.e., Red Platoon A* and *Red Platoon B.* In practice, a CANDIDATE-TARGET-LIST is generated for each friendly unit participating in an operation – since the friendly force operations are not part of the ECOA we are using as a running example we will simply provide a depiction of the CANDIDATE-TARGET-DETAIL representation that would identify each of the two Red Platoons as candidate targets with an assumed level of priority assigned to each:

CANDIDATE-TARGET_DETAIL

candidate-target-id	*-index	*-category-code	*-focus-type-code	*-priority-ordinal	object-item-id
3456	1	ITEM	Attack	1	[Red Platoon A]
3456	2	ITEM	Attack	2	[Red Platoon B]

(Note: *=candidate-target-detail)

4 Limitations

One thing that cannot be represented in JC3IEDM is quantification. The data model is one of purely first-order relations without quantification. The first part of the ECOA says that all of the REDLAND forces (in the area) will participate in the attack. Then,

however, it says that these forces will disperse into smaller units and redeploy to mountains and cities. This can be paraphrased using explicit quantification as: for every unit that is a component of the REDLANDS forces (within the specified area), there exists some mountain or city to which it will redeploy for further attacks. (It would be incorrect to specify merely that the REDLANDS forces as a whole will redeploy to a mountain or a city, since this would entail that all of the units would wind up in the same mountain or the same city.) Lacking quantification, we must simply enumerate all of the sub-units as redeploying.

Disjunction is similarly inexpressible: there is no way to express that a unit will redeploy to either a mountain or a city without specifying which. JC3IEDM does allow one to say that every unit will redeploy to a mountain, but, as a provisional sub-ACTION, it will redeploy to a city (or vice versa). Note that OBJECT-TYPEs (here, "mountain" or "city") can be specified as ACTION objectives in JC3IEDM as well as individuals. JC3IEDM can represent different types of participation in an event: an organization may initiate, control, reinforce, or support an ACTION. Some actions require joint actors and some actions are distributed. For example, if Jack and Jill went up a hill, then Jack went up a hill and Jill went up a hill. But if ten ships blockaded a harbor, it doesn't follow that any one of the ships individually blockaded the harbor. Blockading a harbor (usually) necessitates joint action. JC3IEDM allows one to roll up units into an ORGANISATION via an ORGANISATION-STRUCTURE entity that would allow one to make a distinction between joint and distributed actions: joint actions are done by the hierarchically constituted group; distributed actions are done by each of several participants. Thus, one could represent that a convoy of ships blockaded the harbor and block any inference that a member of that convoy blockaded the harbor by means of this convention.

JC3IEDM also allows one to represent ACTIONS as *feints*, i.e. false attacks designed to mislead or distract. Therefore, an ACTION in the database that is marked as a feint is one that is said not to (completely) happen. It is important to check for the feint qualification on every ACTION to make accurate assessments of the situation. However,

there is no straightforward way to represent an ACTION as not occurring at all, now or in the future.

This is a serious deficiency since it is important to be able to represent that an ACTION did not take place in order to encode reports such as: Observer *O* reports that unit *U* did not destroy bridge *B*. Such a report is different from a report that observer *O* did not observe the bridge destroyed or being destroyed. The latter requires that the bridge not be destroyed while the observers are observing it; the former only requires no observations of a destroyed bridge. Either is consistent with the bridge's destruction at the time of the report.

We have developed a set of transformations to automatically translate the evolving JC3IEDM ERWIN specification into an OWL ontology comprising over 7900 elements (OWL classes, properties and their instances) [10]. A great deal of the semantics of the model remains trapped in text descriptions of the entities and relations, and we have not captured the JC3IEDM business rules for valid combinations of values in the ontology. However, it is possible to encode JC3IEDM ECOAs in a format that, at least in theory, supports formal reasoning. The parallel OBJECT-ITEM and OBJECT-TYPE hierarchy in JC3IEDM makes straightforward inferences about super- and subclasses of event participants impossible, however.

5 Conclusion

In this paper we have investigated some aspects of what is required to represent enemy or threat Courses of Action as defined by U.S. Army doctrine. In short an ECOA captures the who, what, where, when, how and why of an hypothesized enemy mission that is currently on-going or planned to happen. We then looked at JC3IEDM and considered how it would be used to represent a sample ECOA dealing with an asymmetric type of ECOA that might be encountered in hostile confrontations typical of our modern times. While JC3IEDM proved useful for capture the majority of the information inherent in the ECOA there were limitations to its use. In particular JC3IEDM 1) does not contain a sufficiently rich vocabulary of activity types when dealing with irregular warfare, 2) is

not able to deal with quantification, 3) cannot adequately represent disjunctions and 4) is unable to represent the absence of something occurring now or in the future.

A common data model such as JC3IEDM is a prerequisite to *Agile C2* in which coalition forces across all military branches must share a common understanding of both planned friendly intent and hypothesized hostile intent (*i.e.,* ECOAs). JC3IEM has been criticized for being too all encompassing (both in its detail and its extension beyond C2) as well as for being inconsistent in its coverage across military branches and specialties [11]. While we concur with these characterizations, in the area of ECOA representation we would argue for the need for a richer vocabulary to better accommodate the increased diversity of enemy activities encountered in modern warfare.

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