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The Representability of METT-TC Factors in JC3IEDM

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Abstract – Military commanders require relevant background information in order to exercise effective situation awareness for command and control. The so-called METT-TC factors (Mission, Enemy, Terrain & Weather, Troops, Time Available and Civil Considerations) represent the canonical, militarily significant background against which information is evaluated and decisions are made. If this background is to be encoded, shared and, ultimately, reasoned about by computers, the METT-TC background must be represented in some standard format with a shared computer-processable semantics. The JC3IEDM (Joint Command, Control, and Consultation Information Exchange Data Model) is a decades-long effort by NATO member countries at developing an interoperable representation of military situation. In this paper, we show how many aspects of METT-TC can be represented in JC3IEDM. We also point to a number of examples of aspects that are not currently or not completely representable in JC3IEDM.

Keywords: Situation awareness, data model, background knowledge, JC3IEDM, METT-TC.

1 Introduction

METT-TC factors – Mission, Enemy, Terrain & Weather, Troops, Time Available and Civil Considerations – are descriptions of militarily relevant aspects of the environment or background against which a military operation occurs. The accurate depiction of this environment is necessary for good decision-making. Furthermore, background information often informs how incoming data is to be interpreted. The military commander's view of the state of the battlespace is constructed from reports generated by both human and non-human sensors in the battlespace. In many cases (see for example the discussion in [Powell et al, 2006]), the import or credibility of what is being communicated by these reports is determined by the background information or context[1]. Therefore, unless background conditions are accurately described, accurate battlespace situation awareness is not possible.

The Multilateral Interoperability Programme[2] (MIP) is a long-standing, NATO-supported program intended to foster international interoperability of Command and Control Information Systems (C2IS) through the development of standard data models and data exchange mechanisms. Significant joint coalition effort has gone into the development of the MIP data model, which was first released in the mid

[2]http://www.mip-site.org

to late 1990's as the Generic Hub (GH) Data Model. In its current form, it is called the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) 3.1. The data model captures information about an impressive array of battlespace objects and features, their properties, and situations made up of facts about collections of objects and activities.

JC3IEDM aims at encoding all of the relevant information about an arena of operations that coalition commanders would need to share. As such, it is a very detailed and comprehensive data model. JC3IEDM allows the representation of the land, sea, and air as well as certain aspects of communications infrastructure. It represents nearly all objects of interest including organizations, persons, equipment, facilities, geographic features, weather, capabilities, and military control measure such as boundaries. On the face of it, this model offers broad coverage of METT-TC factors.

A primary concern that we wish to address in this paper is the representability of METT-TC factors in JC3IEDM. What we mean by this is: is it possible to translate particular kinds of statements about METT-TC factors into a particular knowledge representation language, here JC3IEDM, in a way that captures the intuitive semantics of the statement? A knowledge representation language is defined as a system of formal symbols to represent a collection of propositions believed by some putative agent that has or can be given a semantics. In the case of JC3IEDM, the semantics is provided informally by the documentation associated with each term and relationship. To say that a set of sentences or propositions is representable in a knowledge representation language is to say that translation into the knowledge representation preserves the intended meaning.

In the next section we briefly describe the JC3IEDM data model and in the ensuing sections we proceed to investigate the extent to which it is capable of being used to represent each of the METT-TC factors.

2 JC3IEDM

While JC3IEDM is intended foremost for the exchange of command, control and communication information between information systems, it is increasingly gaining consideration as the basis for the general data models that underlie C2 information systems. A primary reason for this trend is the desire to leverage the great wealth of experience and knowledge that has gone into its development. JC3IEDM 3.1 consists of 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. The German *Sokrates*[3] project, for example, is developing an automatic battlespace report analysis tool that uses a Protégé-encoded ontology based on C2IEDM (a precursor of JC3IEDM) to process reports and generate information to be added to both a database and to a map interface representing the common operational picture. The Battlefield Management Language research program (BML) and other project teams make a strong case for using the C2IEDM/JC3IEDM as a basis for ontologies for battlespace management.

A high-level overview of JC3IEDM is shown in Figure 1 with the main entities shaded in grey. 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 are out there, what qualities they have, where they are located and how they are related to one another. Near the top of the diagram are entities concerned with describing ACTIONs, both planned and observed; these tend to be dynamic and are used to describe capabilities, how these capabilities are to be used, how they are being used and what were the results.

An important aspect of the data model is the relationship between the two high-level object entities, OBJECT-TYPE and OBJECT-ITEM; their breakdown into first level subtypes is shown in Figure 2. OBJECT-TYPE is used for more static information associated with an entire class of objects (e.g., the fuel capacity of an Abrams Tank, its loaded weight, etc.) whereas OBJECT-ITEM is used to capture information specific to individual instances (e.g., a tank's call sign, the fact it has 5 gallons of gas, etc.). The intended use of JC3IEDM and its precursors provides an explanation of this. JC3IEDM was intended

[3] SOKRATES - Automatic Report Analysis project page. http://www.fgan.de/fkie/fkie_c41_f13_en.html

to be a stable data model, the stability of which was guaranteed by its extensibility. By basing the model on parallel hierarchies of types and instances of objects, adding a new type of equipment, for example, requires simply adding entries to the EQUIPMENT-TYPE table and then associating OBJECT-ITEMs with that OBJECT-TYPE instance; it does not require the implementation of a new schema. The OBJECT-TYPE and OBJECT-ITEM hierarchies do not fully mirror each other, particularly deeper within the structures, but they are closely related.

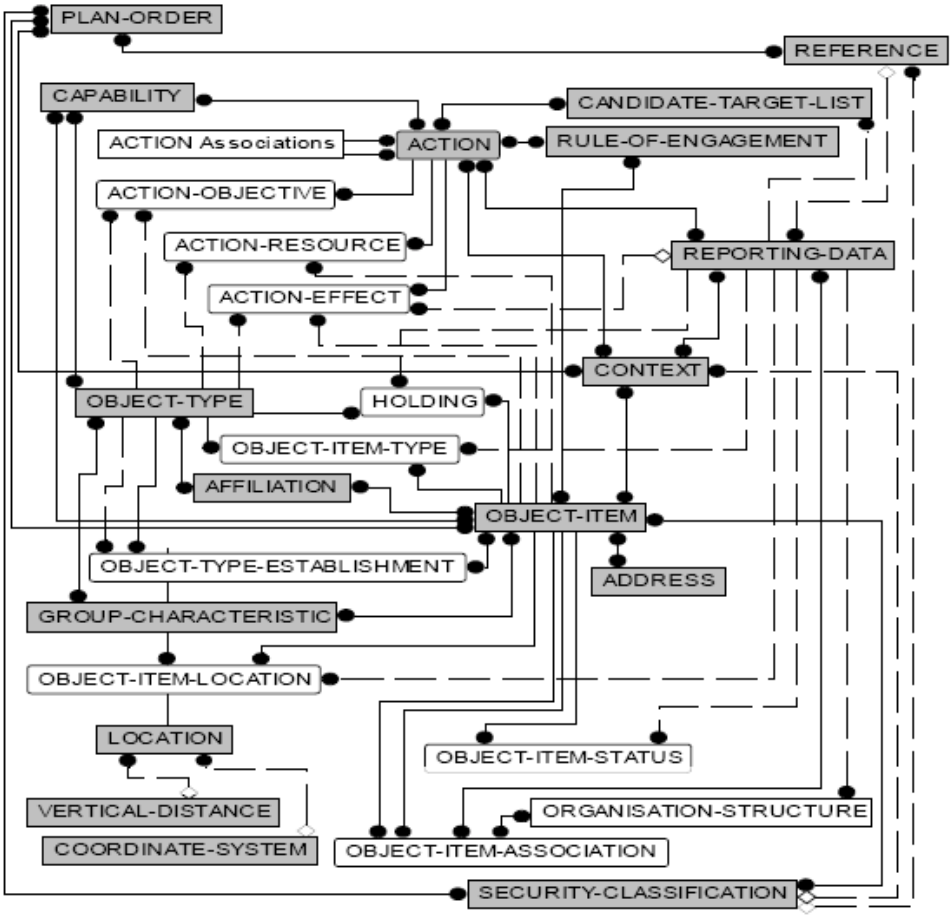

Figure 1. JC3IEDM Independent Entities represented in IDEFIX notation where a closed dot indicates that there may be many such entities in the relationship and an open dot means just one.[4]

REPORTING-DATA is also very important and represents pedigree information that is used extensively to identify when, from whom and how reliable/credible a specific piece of information is. Essentially, as we shall see, the various codes for reporting data accuracy, credibility, category and reliability function as sentential operators over the facts expressed, providing JC3IEDM with the power of modal, temporal and epistemic logics, to some extent.

[4] All data model diagrams in this paper are taken from the" JC3IEDM Main UK DMWG Edition 3.1" document available from the MIP web site: http:www.mip-site.org.

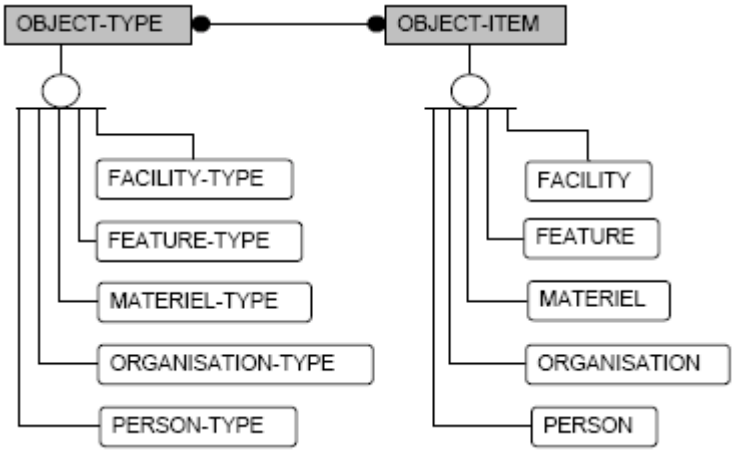

Figure 2 First level Subtyping of OBJECT-TYPE and OBJECT-ITEM.

3 Representing Mission and Time Available

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.

Mission therefore consists of one or more tasks (What) as well as any constraints applicable in achieving those tasks (Rules of Engagement). Areas of interest (Where) for the mission are identified here. The "When" is specified as the time available for acting from a given start time. (Since this is effectively the "Time Available" factor of METT-TC we group Mission and Time Available together in this section). The overall purpose of the mission (Why) must also be specified.

In JC3IEDM, a mission would be encoded as one or more ACTION-TASKs with corresponding OBJECTIVE(s), RESOURCE(s) and RULE(s)-OF-ENGAGEMENT and with allotted start and end times. For example, one could express that "Unit U's mission is to capture and defend Bridge B using a specified Rule of Engagement R in order to prevent an attack on Town C" using the following relational table entries[5]:

ACTION

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

ACTION-TASK

*-id	*-activity-code	*-category-code	is-constrained-by
[Op Alpha]	Capture	Plan	[ROE R]
[Op Bravo]	Defend	Plan	[ROE R]

(Note: * = action-task)

[5] Following the approach used in the JC3IEDM document description, sample encodings of data 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.

RULE-OF-ENGAGEMENT

*-id	*-name	*-description-text
[ROE R]	"ROE-R"	"Do not fire until you see the whites of their eyes."

(Note: *=rule-of-engagement

ACTION-RESOURCE

action-id	*-category	*-criticality-code
[Op Alpha]	ACTION-RESOURCE-ITEM	Yes
[Op Bravo]	ACTION-RESOURCE-ITEM	Yes

(Note: *=action-resource)

ACTION-RESOURCE-ITEM

action-id	object-item-id
[Op Alpha]	[Unit U]
[Op Bravo]	[Unit U]

ACTION-OBJECTIVE

action-id	*-category-code	*-qualifier-code	*-authorising-organisation-id
[Op Alpha]	ACTION-OBJECTIVE-ITEM	Authorised	[Division Command]
[Op Bravo]	ACTION-OBJECTIVE-ITEM	Authorised	[Division Command]

(Note: *=action-objective)

ACTION-OBJECTIVE-ITEM

action-id	*-category-code	*-primacy-code	object-item-id
[Op Alpha]	TARGET	Primacy	[Bridge B]
[Op Bravo]	TARGET	Primacy	[Bridge B]

(Note: *=action-objective-item)

ORGANISATION-ACTION-ASSOCIATION

organisation-id	action-id	* -category-code	*-intent-text
[Unit U]	[Op Alpha]	Controls	"Gain control of Bridge B".
[Unit U]	[Op Bravo]	Controls	"Prevent enemy from attacking City C"

(Note: *=organisation-action- association)

OBJECT-ITEM

object-item-id	*-category-code	*-name-text	is-geometrically-defined-through
[Unit U]	ORGANISATION	Unit U	-
[Bridge B]	FACILITY	Bridge B	[BRIDGE LOCATION]

(Note: *=object-item)

ORGANISATION

organisation-id	organisation-category-code
[Unit U]	UNIT

FACILITY

facility-id	facility-category-code	facility-primary-construction-material-code …
[Bridge B]	BRIDGE	Metal …

Here we have defined two ACTION-TASKS, one to "Capture" the bridge (Operation Alpha) and the other to "Defend" it (Operation Bravo). The ACTION-OBJECTIVE of each of these tasks is Bridge B (the

TARGET), which is a FACILITY OBJECT-ITEM having a category code of BRIDGE. Unit U is the ORGANISATION that "Controls" the two operations, the intents of which are to "Gain control of Bridge B" and Prevent enemy from attacking City C".

Planned begin and end times can be given for each ACTION-TASK in addition to specifying temporal relationships between them. 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

(* = action-task)

ACTION-TEMPORAL-ASSOCIATION

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

(Note: *=action-temporal- association)

Two actions also may be linked via an action-functional-association-category-code specifying that the first action is to be carried out in order that the second action can be carried out. Also, it is possible to group several ACTION-TASKs together via a CONTEXT entity, although it is not possible to assign an intention to the CONTEXT as a whole. Thus, while it is possible to assign an objective or purpose to the component tasks of a mission, it is not possible to assign a different mission-intent to the set of ACTION-TASKs taken together.

Since the intent of a Mission and the specifics of the rules of engagement are not codified in JC3IEDM (nor even using a category code), it would not be possible to formally reason about the overall intent of a mission or constraints on component tasks.

Finally, at the level of vocabulary, the set of codified ACTION-TASK types may not be able to represent every military task. The US Army Universal Task List includes some activities such as "raid", for example, that are not included in the JC3IEDM 3.1.

4 Representing Enemy and Troops

What understanding of the Enemy do commanders need? In FM 6.0 "Mission Command: Command and Control of Army Forces" Appendix B (Relevant Information Subject Categories – METT-TC), it is stated that a commander should consider (and therefore represent) these aspects of the enemy:

- organisation, strength, location, and tactical mobility
- doctrine,
- equipment,
- capabilities,
- vulnerabilities, and probable courses of action (COAs).

It goes on to say: that:

> [to] visualize enemy forces, commanders need detailed intelligence, such as, speed of advance, tempo, and strengths and weaknesses.

In JC3IEDM, the distinction between friendly and hostile forces is represented entirely by means of the object-item-hostility-status-code which allows for representing every item in the battlespace as friendly, hostile, suspect, or unknown (see JC3IEDM documentation for a complete list). This means that *all* the representational resources for representing friendly forces are available for representing hostile forces, and *only* the representational vocabulary for representing friendly forces is available for representing hostile

forces. One drawback of this representation is it represents hostility as being a binary property: an organization, person or facility is either hostile or friendly. It might be more appropriate, in some situations where there are multiple militias involved, to know who is hostile to whom. Some militias might be friendly to one force but hostile to one another, and so on.

The order of battle for both friendly and hostile forces, which specifies the available units and their organizational structure, can be represented using ORGANISATION-STRUCTURE and OBJECT-ITEM-ASSOCIATION. For example, consider a hostile company (Red Company) composed of two platoons (Red Platoon A and Red Platoon B) whose organization would be encoded as follows:

OBJECT-ITEM

object-item-id	object-item-category-code	object-item-name-text
[RedCom]	ORGANISATION	Red Company
[RedPlaA]	ORGANISATION	Red Platoon A
[RedPlaB]	ORGANISATION	Red Platoon B

OBJECT-ITEM-ASSOCIATION

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

(Note: *=object-item-association)

ORGANISATION-STRUCTURE

organsation-structure-root-organization
[RedCom]

ORGANISATION-STRUCTURE-DETAIL

*-root-organization	*-subject-object-id	*-object-object-id
[RedCom]	[RedCom]	[RedPlaA]
[RedCom]	[RedCom]	[RedPlaB]

(Note *=organisation-structure-detail)

OBJECT-ITEM-HOSTILITY-STATUS

object-item-id	object-item-hostility-code
[RedCom]	Hostile

In addition to the organizational structure, information about the units' types can be can be established by defining OBJECT-TYPE instances and then associating these with the units, as such:

ORGANISATION-TYPE

*-id	*-category-code	*-description-text
[ArmCom]	GOVERNMENT-ORGANISATION-TYPE	Armour Company
[ArmPla]	GOVERNMENT-ORGANISATION-TYPE	Armour Platoon

(Note *="orgaqnisation-type)

GOVERNMENT-ORGANISATION-TYPE

government-organisation-type-id	government-organisation-type-category-code
[ArmCom]	MILITARY-ORGANISATION-TYPE
[ArmPla]	MILITARY-ORGANISATION-TYPE

MILITARY-ORGANISATION-TYPE

*-id	*-category-code	*-service-code
[ArmCom]	UNIT-TYPE	Army
[ArmPla]	UNIT-TYPE	Army

(Note: *= military-organisation)

UNIT-TYPE

*-id	*-category-code	*-arm-category-code	*-supplementary-specialisation-code	*-size-code
[ArmCom]	Combat	Armour	Armoured	Company
[ArmPla]	Combat	Armour	Armoured	Platoon

(Note: *=unit-type)

OBJECT-TYPE-ESTABLISHMENT-OBJECT-TYPE-DETAIL

established-object-type-id	*-detail-count	*-detail-object-type-id
[ArmCom]	4	[ArmPlt]

(Note: *=object-type-establishment-object-type)

OBJECT-ITEM-TYPE

object-item-id	object-type-id
[RedCom]	[ArmCom]
[RedPlaA]	[ArmPla]
[RedPlaB	[ArmPla]

Specifics about a unit's location, heading and speed can be captured in instances of OBJECT-ITEM-LOCATION and associated with specific times and information sources by their connection to instances of REPORTING-DATA. For example, the fact that Red Platoon A was reported by Recon1 to be at location L1 at one time and reported by Recon2 to be at L2 at a subsequent time could be captured by the following:

OBJECT-ITEM-LOCATION

object-item-id	location-id	*-bearing-angle	*-speed-rate	reporting-data-id
[RedPlaA]	[L1]	45	10	[RD1]
[RedPlaA]	[L2]	36	15	[RD2]

(Note: *=object-item-location)

GEOGRAPHIC-POINT

*-id	*-latitude-coordinate	*-longitude-coordinate
[L1]	35.762	42.897
[L2]	35.432	43.234

(Note: *=geographic-point)

REPORTING-DATA

*-id	*-reporting-organisation-id	*-data-reporting-datetime
[RD1]	[Recon1]	20070801121110
[RD2]	[Recon2]	20070801122310

(Note: *=reporting-data)

Capabilities of various enemy or friendly units can be captured by means of CAPABILITY entities. Rather than illustrate this with a specific example, the portion of the JC3IEDM dealing with CAPIBILITY specification is shown in Figure 3.

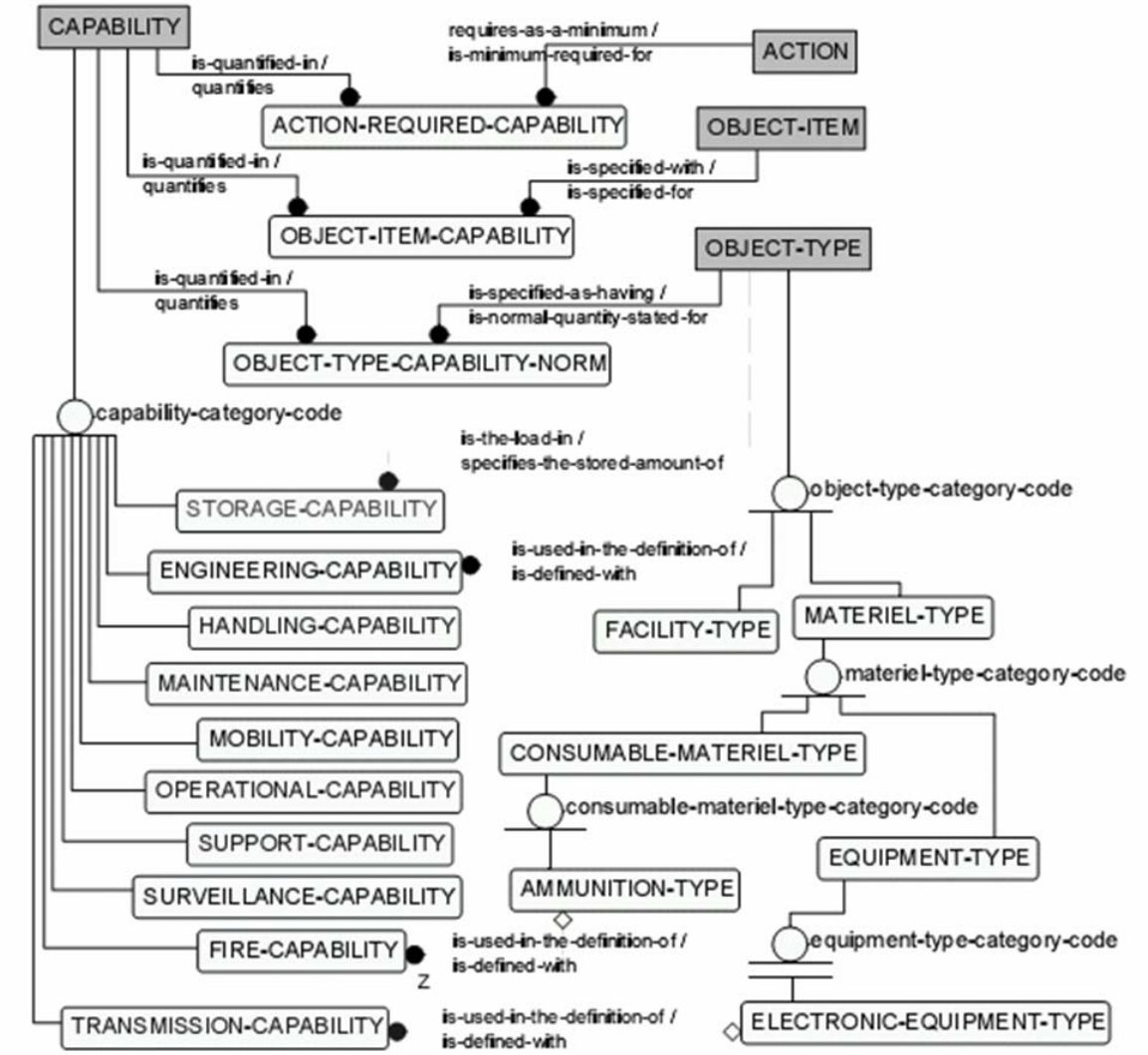

Figure 3 Specifying Capabilities of Objects.

As expected, a detailed capacity for representing the structure of forces, their hierarchical relationship, their equipment and their capabilities is a core part of the JC3IEDM model. Irregular enemy groups would be represented as GROUP-ORGANISATION with group-organisation-category-codes of Terrorist, Gang or Criminal . (See discussion of group-organisations below.)

What is not obviously representable in JC3IEDM from the list of elements of enemy information derived from FM 6-0 are: enemy doctrine, vulnerabilities and probable courses of action (COAs). Enemy courses of action cannot be represented as PLAN-ORDERs since they are essentially known, having been developed by friendly forces, whereas, for the most part, enemy courses of action are essentially inferred. ACTIONS, however, can be associated with enemy forces and reported to have predicted, assumed or planned status by means of the reporting-data-status-code. Furthermore, using ACTION-FUNCTIONAL-ASSOCIATIONS, one could say that an enemy action of a particular type is predicted (inferred, assumed) in response to or subsequent to (friendly) actions of a particular type. Enemy actions described in this way can have sub-actions, prerequisite actions, goal actions and so on. In this way, fairly complex COAs can be attributed to the enemy in as much complexity as friendly activities are detailed. Further, various levels of likelihood can be assigned to an enemy ACTION-TASK thus described by means of the reporting-data-accuracy-code, which includes values such as doubtful, improbable, possible, probable and confirmed. In a similar way, it would be possible to represent enemy *doctrine* as a (potentially complex) enemy action-

task that is reported as being assumed on the basis of some source on enemy doctrine, perhaps cited as a REFERNCE. ACTIONS would then be qualified as doubtful, improbable, possible, and probable on the basis of that doctrine. Thus, it would be possible to encode known enemy doctrine that a unit of a certain type will probably refuel 10km before attacking or that a unit will form a column before a particular kind of attack. On the other hand, there is no way to simply associate beliefs or intentions with ORGANISATIONS except, as we have seen, in association with a particular text field. There is no place, therefore to represent what motivates various groups on the battlespace within JC3IEDM.

Finally, *vulnerabilities* can be represented in JC3IEDM as being on the receiving end of predicted, inferred or reported possible (negative) actions. Thus, to represent that a certain enemy unit is vulnerable to engagement by a certain friendly unit, one would specify in JC3IEDM that the ACTION-TASK of engagement of the enemy unit (being fired upon) by the friendly unit is reported as possible within a certain period of time. These vulnerabilities can be made arbitrarily complex. Thus, for example, one could assert that it is possible that an enemy unit U will be engaged by a friendly unit V if it crosses a certain bridge B in response to an action A, i.e:

> It is reported as a prediction that it is possible that (friendly) unit V engages (hostile) unit U (5 minutes/hours) after unit U crossing bridge B in response to action A.

Furthermore, through various properties associated with ORGANISATION-STATUS, one can represent the readiness of an enemy unit to withstand or respond to such an event; for example, their availability, operational status, readiness, training, and specifics such as their CBRN dress state and number of radiation doses available.

It is possible to infer that a unit, facility, piece of equipment or the like is vulnerable based on the predicted location of another unit given a representation of the movement of the objects under consideration. That is, if it is known that unit U is moving in a certain direction at a certain speed, then it can be inferred that it is possible for unit U to attack unit V at a specific range of time in the future. This inferred, future threat can be represented explicitly within JC3IEDM.

Through the use of the these sentential operators associated with reporting-data, JC3IEDM therefore has the power of a modal and temporal logic with some aspects of epistemic logic thrown in as well. In fact, it has more sentential operators than standard modal or temporal logics. The operators "predicted" and "reported" correspond to future and past operators in temporal logic. A reporting status of "possible", of course, represents possibility; necessity is representable as the *impossibility* of the negation of an action. (There is no mechanism for expressing the negation of an action explicitly: one cannot say that a unit didn't cross a bridge, one can only say that they remain on the near side.) There are epistemic operators as well: it is certain that p, it is doubtful that p. All of these mean that complex forms of inference are supported within JC3IEDM. However, the power of these operators may mean that an implementation of reasoning with these operators may not be computationally tractable.

In any case, JC3IEDM has the ability to distinguish sets of actions that are plans, ordered actions, courses of actions (COAs), doctrine and vulnerabilities.

To summarize: a *PLAN* is a set of ACTION-TASKS, usually associated with friendly forces that are grouped under a plan id. They are neither predicted nor assumed nor inferred nor reported to occur. No assessment needs to be made of their likelihood.

- *Ordered actions* are actions according to a plan that has been authorized; they have a (relative) start and end time.
- *Enemy courses of action* (ECOAs) are (complex) action-tasks that are associated with hostile forces and predicted to occur with various likelihoods (possible, probable, improbable, etc).
- Enemy *doctrines* are (complex) ACTION-TASKs that are assumed to occur in-response-to/after/before/in-order-that some other ACTION (-TASK or -EVENT) occurs. They may be assigned a likelihood.

- Enemy *vulnerabilities* are represented as possible ACTION-TASKs that may happen to hostile forces/equipment/facilities perhaps in-response-to/after/before/in-order-that some other action by friendly forces.

Thus, it would seem that nearly everything that a commander would want to represent about the enemy is indeed representable in JC3IEDM, albeit by making heavy use of the sentential modality operators inherent in the REPORTING-DATA structure that is mandatory for all assertions in JC3IEDM.

5 Representing Terrain and Weather

The five military aspects of terrain are:

- Observation and fields of fire
- Cover and Concealment
- Obstacles
- Key and decisive terrain
- Avenues of approach

As for weather, it must be possible to represent all aspects of current and projected weather and atmospheric conditions in a location as well as to record the effect of weather on terrain, troops and equipment.

Man-made features of the environment are represented in JC3IEDM as FACILITIES. Natural terrain elements are represented as FEATUREs. Military features are represented as CONTROL-FEATURES. Atmospheric elements are represented as METEROLOGICAL-FEATURES. A Road, for example, would be represented as a FACILITY, geometrically defined by points specifying its LOCATION.

Unfortunately, one cannot say that a FACILITY or FEATURE is the location of an ACTION, only that the ACTION has a geographically specified location that is shared with a FACILITY (or overlaps with part of a facility). One can however say that one FEATURE or FACILITY is the location of or serves as another FACILITY. For example, one can say that a church is serving as a hospital, by means of an object-item-association.

JC3IEDM represents facilities (man-made features) at only a crude level of detail. One can only say that one of a prescribed set of JC3IEDM features is present at a location; one cannot describe it further according to sub-features. These can only be represented as features that happen to be collocated. To give an example: it is possible to specify that a sniper has a location that is the location of a particular building, but it is not possible to specify that the sniper is located at the third window from the left on the north side of the sixth floor of that building (cf. CityGML[6]).

Weather features are represented in terms of METEOROLOGIC-FEATUREs, which are OBJECT-ITEMs with locations; their various subtypes include ATMOSPHERE, CLOUD-COVER, LIGHT, PERCIPITATION, VISIBILITY and WIND. Other, non-localized aspects of weather (Moon, Sun, Wind, Nautical Twilight, Relative Humidity, Chance of Precipitation, General Visibility, Clouds, Fog, and Haze) do not really have specifiable locations, but can be associated with reports from a given location.

Of the five military aspects of terrain above, it is possible to represent, key terrain, and avenues of approach (as a kind of Route, a Control Feature). Obstacles are represented as a type of CONTROL-FEATURE, as are fields of fire ("Zone of Fire" is a control-feature-category-code).

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[6] CityGML (www.citygml.org) is an XML schema based extension of GML to urban environments, including city furniture (lights, etc). It supports various increasingly detailed levels of description up to the description of building interiors.

Observation is defined as the ability to "see the friendly, enemy, and neutral personnel and systems, and key aspects of the environment" due to the terrain and weather. Observation is therefore a collection of facts of the form: it is possible/impossible for x to be observed by y at time t. This can be encoded in JC3IEDM as an OBJECT-ITEM-ASSOCIATION with category-code Observes obtaining between x and y with reporting data with reporting status as 'possible' or 'impossible'. Overall visibility is describable as a METEREOLOGIC-FEATURE VISIBILITY.

An Avenue of Approach is represented in JC3IEDM as a ROUTE with various codes for ROUTE-TYPE.

Cover is representable in terms of an object-item-association-code (x is-protected-by y). Only concealment is not representable at all in JC3IEDM; there is no representation of a concealment relationship between two objects: one can represent that something cannot observe an object, but one cannot represent that this is due to the concealment provided by a second object or feature.

6 Representing Civil Considerations

The civil considerations aspect of METT-TC is much more unbounded than the other factors. The other factors represent the military players in the battlespace and the physical and temporal background in which they are situated. There are many more elements of the civilian and/or non-explicitly military aspects of the wider world in which the battlespace exists that can influence or must be considered in military planning.

Civil considerations comprise six characteristics, expressed in the memory aid ASCOPE[7]:

- Areas, including
  - Areas defined by political boundaries, such as, districts within a city or municipalities within a region.
  - Locations of government centers.
  - Social, political, religious, or criminal enclaves.
  - Agricultural and mining regions.
  - Trade routes.
  - Possible sites for the temporary settlement of dislocated civilians or other civil functions.
- Structures, including
  - High-payoff targets such as: bridges, communications towers, power plants, and dams.
  - Cultural sites that are protected by international law or other agreements, such as, churches, mosques, national libraries, and hospitals—are cultural sites that international law or other agreements generally protect.
  - Facilities with practical military applications—such as, jails, warehouses, television and radio stations, and print plants.
  - Certain aspects of the civilian infrastructure that may influence operations, such as the location of toxic industrial materials.
- Capabilities, including:
  - The ability for local authorities—those of the host nation, aggressor nation, or some other body—to provide a populace with key functions or services, such as, public administration, public safety, emergency services, and food.
  - Capabilities include those areas in which the populace may need help after combat operations, such as, public works and utilities, public health, economics, and commerce.
  - Capabilities also refer to resources and services that can be contracted to support the military mission, such as, interpreters, laundry services, construction materials, and equipment.
- Organisations (nonmilitary), including:
  - Church groups, fraternal organisations, patriotic or service organisations, labor unions, criminal organisations, and community watch groups.

[7] FM 6.0 Appendix B.

    - Other organisations may come from outside the AO. Examples of these include multinational corporations, United Nations agencies, US governmental agencies, and nongovernmental organisations (NGOs), such as the International Red Cross.
- People, including:
    - Civilians
    - Those whose actions, opinions or political influence can affect the mission.
    - Their needs, capabilities and intentions.
    - Their historical, cultural, ethnic, political, economic, and humanitarian background.
- Events, including:
    - National and religious holidays, agricultural crop/livestock and market cycles, elections, civil disturbances, and celebrations.
    - Disasters from natural, manmade, or technological sources.

Civilian considerations are crucial, especially in asymmetric warfare. It has been remarked, "Cultural awareness will not necessarily always enable us to predict what the enemy and noncombatants will do, but it will help us better understand what motivates them, what is important to the host nation in which we serve, and how we can either elicit the support of the population or at least diminish their support and aid to the enemy."[8]

Simple assignments of civilian properties to physical features are straightforward in JC3IEDM. For example, one can identify a particular FACILITY with an assigned FACILITY-TYPE "Religious facility", and then associate that FACILITY with a RELIGIOUS-AFFILIATION. Thus, one could say that the Golden Mosque of Samarra is a Shi'ite mosque as follows:

FACILITY

*-id	*-name-text	*-alias
[GMS]	"Golden Mosque of Samarra"	"Askariyya Mosque"

(Note: *=object-item)

FACILITY-TYPE

*-id	*-category-code	*-name-text
[ShiaMos]	worship place[9]	Shi'a Mosque

(Note *=object-type)

OBJECT-ITEM-TYPE

object-item-id	object-type-id
[GMS]	[ShiaMos]

AFFILIATION-RELIGION

affiliation-id	affiliation-religion-code
[Shia]	Shi'a Muslim

[8] MG Benjamin C. Freakley, Infantry 94, 2 (March-April 2005), quoted in Jacob Kipp, Ph.D.; Lester Grau; Karl Prinslow; and Captain Don Smith. "The Human Terrain System: A CORDS for the 21st Century" *Military Review*, Sept-Oct 2006. The authors go on to say: ''Many of the principal challenges we face in Operations Iraqi Freedom and Enduring Freedom…stem from… initial institutional disregard for the necessity to understand the people among whom our forces operate as well as the cultural characteristics and propensities of the enemies we now fight.''

[9] Could also be religious-facility. The distinction might be between religious facilities that are primarily places for the public to gather for religious services and places that are sites of more closed religious activities, such as that of a seminary or religious school.

OBJECT-TYPE-AFFILIATION

object-type-id	affiliation-id
[ShiaMos]	[Shia]

It is similarly straightforward to assign ethnic, religious, or geopolitical affiliation to any individual object in the data model, where each of these requires selecting from one of several pre-established options, saying it is not known, or saying it is not one of the provided choices. It is not possible to add high-level religious, ethnic or geopolitical affiliations to the model, but it is possible to add lower-level subgroups, as detailed below.

JC3IEDM makes a distinction between AFFILIATION and membership in an ORGANISATION that is crucial here. ORGANISATIONs in JC3IEDM are full-fledged agents, as exemplified by MILITARY-ORGANISATION-TYPEs such as military units. JC3IEDM also allows for the representation of other PRIVATE-SECTOR-ORGANISATIONs-TYPEs such as companies, CIVIL-ORGANISATION-TYPEs such as the Red Cross and so on.

AFFILIATIONs, on the other hand, are simply a specific set of properties assignable to an object. Objects (e.g. persons, facilities or organisations) can have AFFILIATIONs, but ORGANIZATIONs can have members, leaders, subgroups and supergroups, and can participate in actions. It is possible to assign a functional affiliation to an object (e.g. a criminal or terrorist group or a grouping for the purpose of a military exercise or multinational agreement), but such functional group affiliations are distinct from organisations.[10]

Consider, for example, the representation of a tribe in JC3IEDM. A tribe would be represented as a ORGANISATION with type GROUP-ORGANIZATION-TYPE, but none of the available group-organisation-type-codes are specific to tribes, so it would be "not otherwise specified".

GROUP-ORGANISATION-TYPE

object-type-id	object-type-name-text	object-type-category-code
[ShamTri]	"Shammar Tribe"	Not otherwise specified

This ORGANISATION could then be assigned persons as members (has-as-member) or groups as parts, as well as leaders (is-under-command-of) through the mechanism of object-item-association-category-codes. Thus, it could be possible to specify a particular person, the sheik, as the leader of tribe (and, of course, a member). Through ORGANISATION-STRUCTURE-DETAILS, it would be possible to specify sub-organisations, such as clans or families.

Although religions are sometimes organisations in the ordinary sense, JC3IEDM's use of religion as an affiliation means that a religion or other group specified as an affiliation cannot be assigned leadership. Any of the specific affiliations in JC3IEDM could be elevated to the status of a full-fledge organisation if this was required in the data, however. For the sake of completeness, one would have to specify that, e.g. the Anglican Church organisation was affiliated with the Anglican Church, however.

As noted above, it is crucial to represent the "human terrain", especially in an asymmetric or low-intensity warfare situation. Once various demographic groups were constructed as above, one could specify that the local inhabitants (a group organisation) of an area (a facility) with a specified location are part of (object-item-association) a certain tribal or clan group (another group-organisation). Further, it would even be possible to say that a particular group of inhabitants, identified as being the inhabitants of one area at a past time, are now displaced and living in another area. All such associations of groups with geophysical areas requires the instantiation of a generic facility which is assigned a geometry corresponding to the area under consideration.

[10] There is some language in the JC3IEDM documentation that indicates that object item affiliations are supposed to be exceptional

While it is possible to make quite fine-grained distinctions among types of persons and their affiliations within JC3IEDM, it is not possible to represent all the sorts of relations between groups that one might like. Thus, it is not possible to represent that two religious sects are traditionally hostile to one another, or that two tribes are rivals. This again is due to the representation of hostility as a binary feature in JC3IEDM, rather than a relation between groups. It is possible to associate groups that are affiliated with a common functional group (e.g. al-Qaeda), but it is not possible to specify disaffiliation or enmity in the same way.

Facilities can be identified as having various civilian purposes, such as mine, farm, hospital, or industrial area, and so on through a facility-type-category-code. Routes (trade routes, pilgrimage routes) can also be associated with specific groups in this way.

It is clear, then, that JC3IEDM provides a number of mechanisms to store information about human demographics and associate these with facilities and/or geophysical locations. It is also possible to broadly characterize the civilian purposes of facilities. In the temporal dimension, it is possible to associate various group-organisations with actions (tasks or events). Unfortunately, it is not quite possible to say that, for example, members of a certain group observe a certain holiday or religious feast or rite on a particular date. At best, one can specify, say, a certain tribe as controlling or initiating an action-event of the type 'national holiday', which may be close enough.

The ACTION-EVENT entity seems mostly to have been envisioned as a way of encoding singular events. There is no concept within JC3IEDM of a recurring event type (such as a religious or civil holiday). Thus, there is no way to represent such recurring event types in JC3IEDM.

Thus, while the nature of civil considerations is much more unbounded than the military-specific objects in the battlespace, JC3IEDM has a robust and flexible means of assigning a wide variety of demographic information to the areas, events, facilities, persons and groups within which military operations unfold. What it lacks is a perspicuous way to specify the relationships between groups beyond that of common affiliation or location.

7 Negation in JC3IEDM

It is not possible to report negative facts in JC3IEDM. One cannot directly encode the statement that an event of a particular type did not occur: for example, one cannot represent that the (anticipated) invasion of a city by the enemy did not take place. At most, one can report the current state of the situation at issue, if this corresponds to the negation of the issue at hand. For example, one cannot say that a bridge was not destroyed. One can report, however, that the bridge is still standing. To give another example: one cannot report that a hospital has not been evacuated; one can only report that the number of patients is some non-zero number. When no such representation of the current state is possible (as with being non-invaded), the representation of negative facts is not possible.

On the other hand, it is possible to indirectly record a negative fact in JC3IEDM as a negative response to a REQUEST. So, one could record that the response to a request (did the enemy invade such-and-such location before time t?) is 'No'. This makes reasoning within a logical representation derived from JC3IEDM more complicated than that envisioned in most automated reasoning systems.

Finally, it is possible to represent an ACTION as both possible and impossible, which involves negation.

8 Conclusion

The main goal of this paper is to show which aspects of METT-TC are and which are not easily representable in JC3IEDM. By working though numerous examples of representation of such aspects, we have become convinced that JC3IEDM is a very powerful data representation language that can express most of the concepts needed for conveying information about METT-TC factors. In particular, according to our findings, JC3IEDM can be used to represent nearly all of the METT-TC factors as outlined in FM 6-0

Appendix B. The main payoff for the effort of expressing information in JC3IEDM is that such encoded information can then be shared between coalition partners, leading to the goal of achieving semantic interoperability.

On the negative side, JC3IEDM lacks certain depths of vocabulary that other, more specific models have. For example, it does not provide as detailed a representation of as many geographic or built features as the US Army's Terrain Common Data Model (TCDM) or CityGML.

In this paper, we have also pointed to a number of other examples from the METT-TC domain that could not be directly represented in JC3IEDM with a sufficient degree of semantic information; these included:

- Mission Intent can only be represented as unstructured text.
- Concealment relations are not expressible at all.
- Civil events can only be represented as national holidays.
- The relationship of various groups of the population to one another is not easily represented. One can represent groups as having a common affiliation, but one cannot express that two groups are rivals or hostile to one another.
- The needs and intentions of groups (and, by inference, the persons that belong to them), can only be represented as unstructured text.

Military applications making use of background information are increasingly converging on the JC3IEDM data model as the basis of representing military situations. Therefore, it seems necessary to resolve the expressivity problems discussed in this paper by taking advantage of the concept of extensibility of this data model, a feature that was at the core of the original idea behind this model. However, some of the problems identified in this paper would be rather difficult to implement simply through the allowable extensions.

Finally, reasoning about the impact of background conditions on military command and control would require the translation of JC3IEDM (or a successor) into a knowledge representation formalism that supports inferencing. JC3IEDM currently exists only as a database schema. As such, it does not support inferences among statements, only queries and updates of the data stored in relational tables. One step toward automated formal reasoning about METT-TC conditions would be the translation of JC3IEDM into a more expressive and formal language that allows for extensions. As part of our efforts in this direction, we have made a translation of JC3IEDM into an OWL[11] ontology freely available for others to use (http://vistology.com/ont/2007/JC3IEDM3.1/). The translation was performed automatically using the XML document that specifies the JC3IEDM 3.1 ERwin data model definition [10].

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[11] OWL (Web Ontology Language) is a W3C standard for representing ontologies [17] An *OWL ontology* may include descriptions of *classes*, *properties* and their instances. Given such an ontology, the OWL formal semantics specifies how to derive its logical consequences, i.e. facts not literally present in the ontology, but *entailed* by the semantics. Not every fact that one might want to see entailed is entailed by the OWL semantics alone; additional entailment rules can be defined by a rules language (such as SWRL, the Semantic Web Rules Language) [18] on top of OWL.

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