C2SIM Logical Data Model Development: Scope, Challenges and Future

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ABSTRACT: *The SISO Command and Control Systems to Simulation Systems Interoperability (C2SIM) Product Development Group (PDG) is developing a family of standards to facilitate the exchange of Command and Control (C2) information among C2 systems, simulation systems and robotic systems in a coalition context. In this age of increased coalition efforts and dependency, effective interoperation between coalition systems is of crucial importance. In the past SISO has facilitated the development of Coalition Battle Management Language (C-BML) and Military Scenario Description Language (MSDL). C2SIM PDG has consolidated both C-BML and MSDL PDGs to create a unified, harmonious development of Initialization and Tasking-Reporting standards.*

C2SIM product nomination has identified three sub-groups that constitute the C2SIM family of standards. C2SIM Logical Data Model (LDM) will focus on the development of a model that captures essential data elements and relationships. C2SIM Initialization and C2SIM Tasking-Reporting are the other sub-groups that capture specific C2SIM applications using the LDM, including procedures for developing compatible extensions to the LDM for new domains. The LDM contains the building blocks for effective C2SIM standardization and use. In this paper we describe the model-driven approach to develop the C2SIM LDM. We describe the process of incorporating legacy data elements and soliciting use-cases. We provide descriptions of the LDM structure, classes and relationships, and discuss mechanisms to extend the LDM for domain specific implementations. This paper will provide interim results of the C2SIM LDM standard draft in the form of screenshots and descriptions. Finally, we will discuss the future course of LDM development and challenges.

1. Introduction

The Command and Control (C2) Systems to Simulation Systems Interoperability (C2SIM) is a family of standards to exchange C2 information between C2 systems, simulation systems and robotic systems in a coalition context. A number of coalition experiments have been designed and conducted to study the need and scope of coalition interoperation [1][2][3]. These experiments have captured the scope and challenges in coalition interoperability and also demonstrated the need for languages and frameworks to facilitate C2 interoperability. C2SIM is designed to facilitate interoperability by standardizing an effective, disambiguating exchange language. A Product development group (PDG) at Simulation Interoperability Standards organization (SISO) is developing C2SIM standards by incorporating use case requirements and stakeholder needs. C2SIM Product nomination was proposed and approved in 2014 [4]. The C2SIM PDG consists of three coordinated sub-groups:

1. Logical Data Model (LDM) sub-group: The LDM sub-group is tasked with creating a model of core data elements, their definitions and relationships between the elements. In addition, the LDM sub group will provide a standardized methodology to extend the model for specialized domains.
2. Initialization sub-group: The Initialization sub-group is tasked with using the LDM core elements and extension methodology to create products that exchange initialization information between interoperating C2SIM systems.
3. Tasking-Reporting sub-group: The Tasking-Reporting sub-group will us the LDM core elements and extension methodology to create products that exchange tasking-reporting information between interoperating C2SIM systems.

In this paper, we focus on the LDM sub-group progress and development. The LDM sub-group has solicited use cases from C2SIM stakeholders, developers and future users. These use cases have been analyzed to extract C2SIM requirements and data elements. These data elements have birthed the initial C2SIM LDM. In this paper, we outline the LDM development methodology and describe future work.

2. Previous Work

C2SIM is based on past SISO standardization within the Coalition Battle Management Language (C-BML) [5] and Military Scenario Description Language (MSDL) [6] PDGs. C-BML was intended to standardize Battle Management Language (BML) to a coalition context. The history and development of BML can be found in references [7][8][9]. C-BML PDG developed a Phase 1 balloted XML schema to exchange C2 information [5] which contained a full capture of the underlying data model- Joint Consultation Command and Control Information Exchange Model (JC3IEDM) and a 'light' version of frequently used elements. MSDL PDG developed a balloted XML schema to exchange Initialization information between interoperating systems [6]. The C2SIM PDG is a merger of the C-BML PDG and MSDL PDG to have a unified, harmonious standard that supports seamless initialization and tasking-reporting coordination and interoperation. The scope and challenges in merging C-BML and MSDL have been described in references [10] and [11]. Previous work has also identified the roles and opportunities for semantic models in C2SIM [12][13]. The C2SIM Product Nomination (PN) document [4] has outlined three normative documents to be developed by the C2SIM PDG; the next section describes work done in the sub-group developing the LDM. The PN is being revised to add a fourth normative document: a Maneuver Warfare Extension, which will contain specifics pertaining to that domain and serve as an exemplar for future extensions.

3. Logical Data Model

The C2SIM LDM sub-group operates within the C2SIM PDG to create a logical, central data model that contains core data elements, their definitions and relationships between data elements. Data elements are consolidated into classes and class hierarchy and relationships are defined. Each data element is associated to a pre-defined data type. The LDM is designed to have minimal class complexity and to capture essential core data elements and relationships across C2SIM implementations. The LDM specification will contain an extension methodology so that implementations that have needs beyond LDM core data elements can extend the LDM and preserve interoperability across other C2SIM implementations.

3.1 LDM Design

The LDM works through a model driven framework where the model (and its extension mechanism) captures and constrains the nature, scope and use of C2SIM. Based on evaluations from past standardization efforts, the LDM is designed to be compact and robust so that implementing systems will be easy to create. The LDM is designed as classes containing data elements organized into class hierarchies and relationships. Each element will have a clear data type definition and relationship to other elements. The LDM development started with a solicitation of use cases capturing C2SIM scope and scenarios. The C2SIM PDG received the following six use cases:

1. Use Case 1 – Call for Fire: This use case requires C2SIM to support a Call for Fire scenario where a Forward Observer can properly call a call for fire.
2. Use Case 2 – Simware Implementation: This use case requires C2SIM to be able to interface with the Simware platform, which is a middleware framework for building distributed simulations.
3. Use Case 3 – Distributed Mission Planning: This use case requires C2SIM to support coalition operations of planning, rehearsing, collaboration of coalition unit operations.
4. Use Case 4 – Guideline on Scenario Development (GSD) interoperation: This use case requires C2SIM to interoperate with GSD definitions of scenarios, vignettes and other initial state definitions.
5. Use Case 5 – NIEM Interoperation: This use case requires C2SIM to interoperate with NIEM definitions.
6. Use Case 6 – Simulation- Based Joint Collective Training: This use case requires C2SIM to support training activities in coalition contexts using simulation systems.

Based on these six use cases, the LDM development group within the C2SIM PDG created two design artifacts:

1. List of requirements: Based on the use case description documents, a number of C2SIM requirements were extracted. This requirements table contains the description of the requirement, its applicability to Initialization or Tasking-Reporting (or both) and the use case proponent.
2. List of core data elements: Based on the use case description documents, a number of C2SIM data elements

needed in most or all use domains must be identified. The candidate data elements table contains the name of the class, its format and its mapping to C-BML (full and light), MSDL and MIM. Table 2 resulted from a focused effort to reduce the LDM core to classes needed by most C2SIM implementations.

Table 1 contains the list of requirements and table 2 contains the list of core data elements.

Table 1. List of Requirements extracted from use cases

Requirement	Associated Use-case	Point of Contact	LDM-Impact
C2SIM will need to capture an incident free call for fire	Call for fire	Kevin Galvin, Thales UK	Tasking-Reporting
C2SIM will need to support correction call for fire-message	Call for fire	Kevin Galvin, Thales UK	Tasking-Reporting
C2SIM will need to support actions in Call for fire scenarios(e.g. "EndOfMission, "Acknowledgements")	Call for fire	Kevin Galvin, Thales UK	Tasking-Reporting
C2SIM will need to support gateways to Simware platform with data types (Simple, Enumerated, Array, Fixed Record and Variant)	Simware	Dr. Saikou Diallo	Tasking-Reporting
Tasking-Reporting messages need to be representable in IDL	Simware	Dr. Saikou Diallo	Tasking-Reporting
Tasking-Reporting messages need to be representable in OMT	Simware	Dr. Saikou Diallo	Tasking-Reporting
C2SIM will need to include a physical IDL representation	Simware	Dr. Saikou Diallo	Tasking-Reporting
C2SIM will need to include a physical OMT representation	Simware	Dr. Saikou Diallo	Tasking-Reporting
: C2SIM will need to include guidance for supporting customizations/customized messages in IDL	Simware	Dr. Saikou Diallo	Tasking-Reporting
C2SIM will need to include guidance for supporting customizations/customized messages in OMT	Simware	Dr. Saikou Diallo	Tasking-Reporting
C2SIM will need to support exchange information between command and control (C2) systems and Simulation systems. The exchange information will include: - course of Action - orders - plans - preparatory information	Distributed Mission Planning	Dr. Mark Pullen	Tasking-Reporting
C2SIM will need to represent and exchange concept	Distributed Mission Planning	Dr. Mark Pullen	Tasking-Reporting
C2SIM will need to represent and exchange vision statement	Distributed Mission Planning	Dr. Mark Pullen	Tasking-Reporting

C2SIM will need to represent and exchange a mission definition	Distributed Mission Planning	Dr. Mark Pullen	Tasking-Reporting
C2SIM will need to represent and exchange information from Brigade commander to staff primaries	Distributed Mission Planning	Dr. Mark Pullen	Tasking-Reporting
C2SIM will need to use terminology as defined by the "Guideline on scenario development"(GSD)	Consistency between C2SIM and GSD	Dr. Robert Siegfried	Initialization
C2SIM will need to align initialization information with GSD initial state	Consistency between C2SIM and GSD	Dr. Robert Siegfried	Initialization
C2SIM will need to represent and exchange termination condition(s) for simulation systems	Consistency between C2SIM and GSD	Dr. Robert Siegfried	Initialization
C2SIM will need to align with NIEM recommendations so that a translator can be built to translate between C2SIM and NIEM	C2SIM interoperation with NIEM	Samuel Singapogu	Both
C2SIM will need to represent and exchange operation plan	Simlation-based joint collective training	Jens Inge Hyndoy	Initialization
C2SIM will need to represent situational awareness reports that can be viewed in a C2 system or Simulation system	Simlation-based joint collective training	Jens Inge Hyndoy	TaskingReporting

Table 2. List of core data classes extracted from use cases (latest draft; under review)

Note: The latest draft of the LDM description can be found on the SISO digital library (https://www.sisostds.org/digitalLibrary.aspx)

Class Name	**Definition**	**Format**	**Mapping to C-BML Full**	**Mapping to C-BML Light**	**Mapping to MSDL**	**Mapping to MIM**
Affiliation	A country…etc.	MIM Datatype	Not found	Not found	Affiliation	Affiliation
Allegiance	The reference to…etc.	patternUUID32	Not found	Not found	AllegianceHandle	Not found
AreaOfInterest	The area of…etc.	RectangleArea	Not found	Not found	AreaOfInterest	Not found
AreaSymbolModifiers	Modifiers that…etc.	AreaSymbolModifiersType	Not found	Not found	AreaSymbolModifiers	Not found
AssociatedOverlays	The overlays for…etc.	AssociatedOverlaysType	Not found	Not found	AssociatedOverlays	Not found
CommunicationNetInstances	The communication nets…etc.	CommunicationNetInstancesType	Not found	Not found	CommunicationNetInstances	Not found
CountryCode	ISO 3166 Country code	affiliationGeopoliticalCode	Not found	Not found	CountryCode	Not found

DateTime	Date time group…etc.	datetimeTypeFix18	StartWhen AbsoluteTimeType	StartWhen AbsoluteTimeType	DateTimeGroup	Not found
DirectionOfMovement	The direction of movement…etc.	floatCompassDegrees3_3	DirectionCode	DirectionCode	DirectionOfMovement	Not Found
Disposition	Disposition consists of the location…etc.	METOCDispositionType	AbstractFacilityType	AbstractFacilityType	Disposition	Not Found
Echelon	Modifier that…etc.	enumEchelon	Not found	Not found	Echelon	Not found
Entity	An individually…etc.	OID + name	ObjectItem	ObjectItem	Unit	Not Found
EquipmentItem	Information about…etc.	EquipmentItemType	Not found	Not found	EquipmentItem	Equipment
Facility	An object that…etc	Facility	AbstractFacility	Not found	Not found	Facility
GeoCoordinateValue	Describes the location…etc	PointLightType	AbstractLocation	PointLightType	Location	Location
Geographic Feature	…permanent or durable natural feature…etc.	GeographicFeature	GeographicFeatureType	AtWhereLightType+ RouteWhereLightType	Not found	GeographicFeature
IFF	Text modifier…etc.	textIFF5	Not found	Not found	IFF	Not found
Image	imagery product…etc.	Image	Not found	Not found	Not found	Image
RelativeLocation	A reference to…etc.	OID	LocationRef	LocationRef	Not Found	Not Found
METOCGraphic	METOC graphic…etc.	METOCGraphicType	Not found	Not found	METOCGraphic	Not found
MOOTWGraphics	Collection of …etc.	MOOTWGraphicsType	Not found	Not found	MOOTWGraphics	Not found
MOOTWSymbol Modifiers	Modifiers of a MOOTW symbol	MOOTWsymbolModifiersType	Not found	Not found	MOOTWsymbolModifiers	Not found
Materiel	An apparatus…etc.	Materiel	AbstractMaterielType	Not Found	Not Found	Materiel
MilitaryService	The service code for a military organization.	militaryOrganisationTypeServiceCode	Not found	Not found	MilitaryService	Not found
NBCEventSymbol Modifiers	Modifiers of an NBC event symbol.	NBCEventSymbolModifiers	Not found	Not found	NBCEventSymbolModifiers	Not found
Name	A word or phrase…etc.	textTypeVar100	NameText	NameText	Not found	Name
ObjectHandle	The universal…etc.	OID	OID	OID	ObjectHandle	Not found
Organization	OBJECT-TYPE that represents…etc.	ObjectItem	AbstractOrganisationType	Not found	OrganizationDetailType	Not found
GraphicSymbol	A graphic symbol for a physical entity.	GraphicSymbol	Not found	Not found	Owner + Orientation + SymbolClassChoice + SymbolClassData + SymbolIdentifier	Not found
TacticalGraphic	A specific tacticalgraphic…etc.	TacticalGraphicType	Not found	Not found	TacticalGraphic	Not found
UniqueDesignatio	The text	OID	Not found	Not found	UniqueDesignation	Not found

n	modifier…etc.					
Unit	A military organisation…etc.	C-BML UnitType	UnitType	UnitType	Units	Unit
VisibilityItems	Collection of…etc.	VisibilityItems	Visibility	Not found	VisibilityItems	Not found
version	Numeric code…etc.	integer	Not found	Not found	Not found	Not found
WhyCode	Specifies reason…etc.	actionEffectDescription Code	actionEffect Description Code	actionEffect Description Code	Not found	ActionEff ectDescrip tionCode
CommunicativeAc ts	FIPA enabling class…etc.	enumCommunicativeAc tCategoryCode	Not found	Not found	Not found	Not found

3.2 Creating classes in the LDM

Elements identified in Table 2 constitute the starting point for classes and core data elements in the LDM. These classes have a class definition, attributes with data types and relationships between classes. In order to maintain continuity with legacy C-BML and MSDL systems, classes that constitute a 'W' ('Who', 'What', 'When', Where', 'Why') group were grouped together and relationships between 'W' groups were identified. Definitions from Geography Markup Language (GML) [14] were used for classes within 'Where' and 'When' elements. GML is a grammar and markup language developed by the Open Geospatial Consortium to model geographic systems. The use of GML definitions within C2SIM core elements makes it easier for C2SIM to interoperate with other standards that use GML.

As the LDM was being developed it was recognized that C2SIM order, tasking and reporting directives can benefit from speech act theory frameworks. Foundation for Intelligent Physical Agents (FIPA) [15] is an existing standard that incorporates speech act theory foundations to markup and disambiguate speech/action directives between agents. The LDM group is working on incorporating FIPA guidelines into C2SIM directives. This includes using an ontology to associate actions and messages with their semantic context. Reference [13] contains more information on semantic C2SIM and its use of FIPA. Snapshots of current LDM classes and relationships, as visualized in Sparx Enterprise Architect 12.1, are shown below.

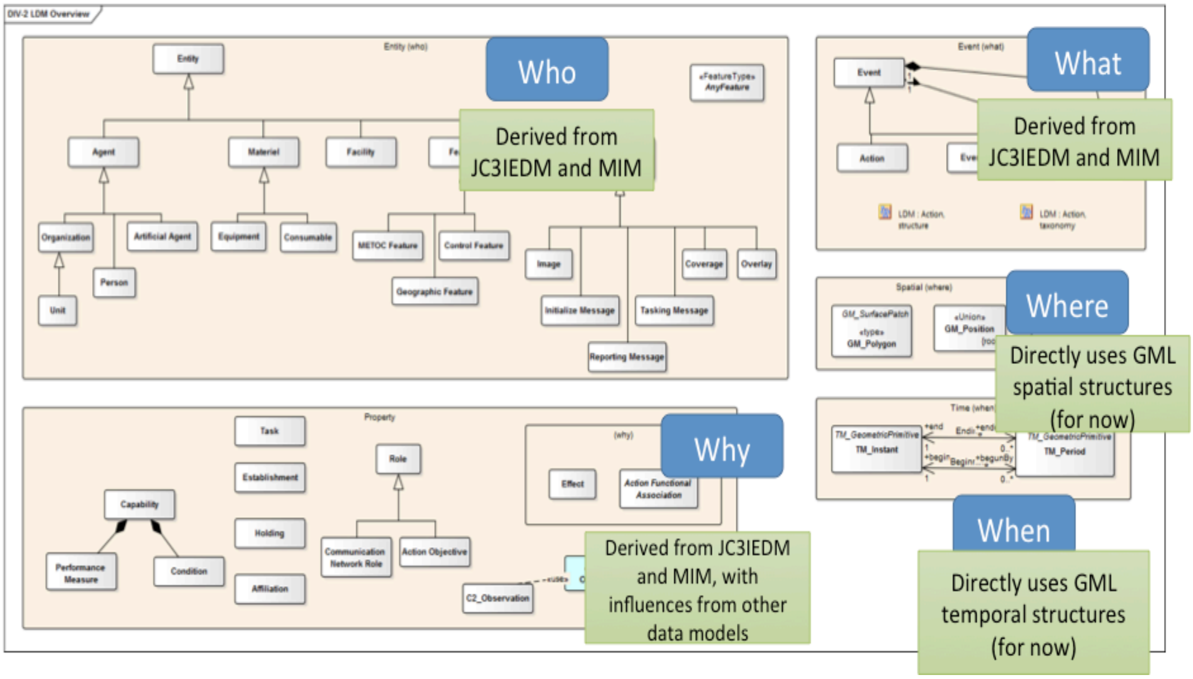

Figure 1. Snapshot of C2SIM classes organized by 'W' groups

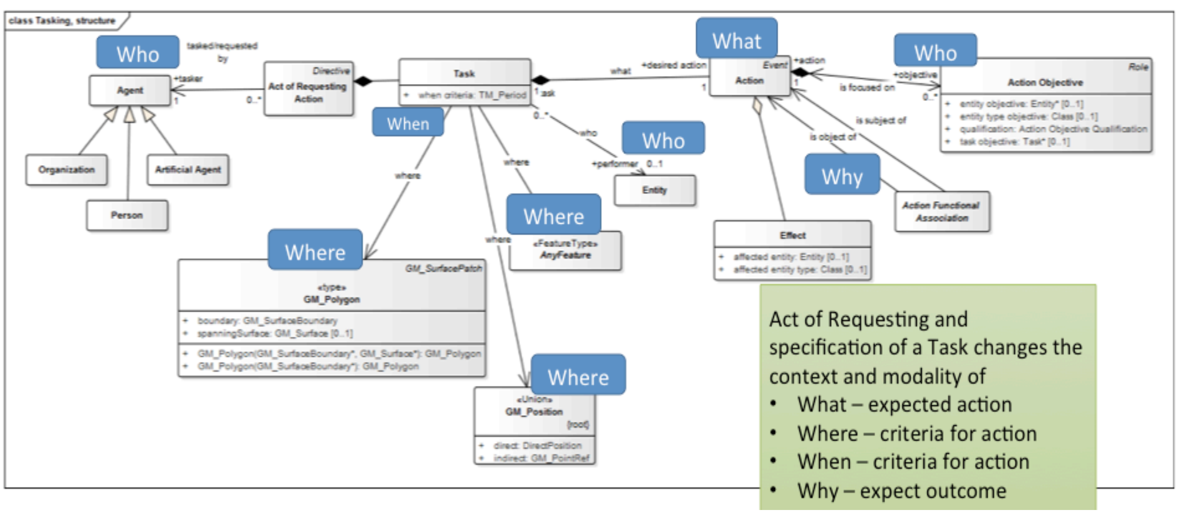

Figure 2. Tasking classes in C2SIM

3.3 C2SIM Interoperation with MIP and NIEM

Multilateral Interoperability Programme (MIP) Information Model (MIM) is a product of a NATO standardization body that provides classes, definitions, and relationships in the C2 domain. The C2SIM LDM is working on mapping C2SIM classes to MIM and using definitions from MIM (with attribution) for C2SIM classes. This will help C2SIM implementations interoperate with MIM systems. Reference [13] provides more information on C2SIM interoperation with MIM.

The USA National Information Exchange Model (NIEM) [16] is a framework of standards to facilitate interoperation between information systems. NIEM contains a core model and extension domains; one of the extension domain is for the military context. The LDM group is working to provide guidance on mapping C2SIM to NIEM so that C2SIM systems and NIEM systems can interoperate effectively. Because these mappings have not yet been developed, they have not been included in Table 2.

4. Extending the LDM

While the C2SIM LDM captures core data elements, it is expected that C2SIM implementations will need elements that are not available in the LDM. The LDM specification will define a extension methodology so that implementations can extend the model by adding new classes and elements. This standardized methodology will enable C2SIM implementations to interoperate after extensions. The extension methodology is designed to persevere continuity and consistency with C-BML and MSDL while allowing implementations to create new classes and attributes in the data model. The proposed extension methodology contains two design constructs:

1. Clear identification of standard data elements: The core contains a unique identifier with value "Standard" to identify all data elements that are in the standard core data model. All C2SIM implementations are expected to support these data elements in order to be compliant with C2SIM.
2. Reference to extensions: Each data element has an attribute called "referenceName" that points to a data file with the extension definition and any supporting documentation.

The C2SIM PDG will provide governance principles and documentation to create extensions. These principles and recommendations will enable C2SIM implementations to effective create, manage and submit extensions. C2SIM implementations will be required to consider elements defined in the core before creating duplicate extensions. The PDG will provide guidelines on naming convention, creation of enumerations and taxonomy definitions. In addition, there will be guidelines on submitting the extension to a C2SIM repository so that other implementations and discover and use the extension.

5. Future LDM development

C2SIM currently contains core classes and data elements. In order to gather consensus, the LDM drafting group has requested PDG members and stakeholders to provide feedback on classes and attributes to finalize the C2SIM LDM. Once the LDM is consolidated, the LDM group will provide the model, a standard document and any guidance material for balloting. The standard document will also describe the extension mechanism to extend the LDM for specialized products and implementations. The Initialization and Tasking-Reporting sub groups will use the LDM and the extension mechanism to create specialized products. Future work can also focus creating interoperation frameworks and prototypes with MIM and NIEM. A semantic model offers tools to formalize semantics, check for semantic inconsistencies and gather inferences; future C2SIM work can explore semantic technologies.

6. Conclusions

C2SIM PDG is currently focused on creating a stable, compact and robust logical data model. This data model and extension methodologies will enable implementations to use core data elements and specify extensions. Initialization and Tasking-Reporting sub-groups will use the LDM and the extension methodology to create seamlessly interoperable products. In this paper, we have described the background of C2SIM, development of the LDM and future work.

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