Representing Situational Awareness Data Using the C2SIM Standard

Elizabeth Hosang CAE Canada.
350 Legget Drive
Ottawa, Canada, K2K 2W7
Elizabeth.Hosang@cae.com

Keywords:

C2SIM, C-BML, MSDL, Tactical Situational Awareness

ABSTRACT: *Simulation systems are used in exercises involving military planning systems. In a real scenario, a commander requires situational awareness data to react effectively. This requires the constant input of dynamic data collected by Intelligence, Surveillance and Reconnaissance (ISR) systems and sensors. Sensor data is generally less complete than the data in C2 planning systems: for example, the accuracy of location information is limited by the sensor capability. This incompleteness causes problems fitting the observed data into Command and Control (C2) data formats, such as the Coalition Battle Management Language (C-BML) and Military Scenario Definition Language (MSDL). The new Command and Control Systems - Simulation Systems Interoperation (C2SIM) standard is being developed to replace C-BML and MSDL, and is close to completion. This new standard includes a number of Observation entities, which are associated with the ReportContent entity. The attributes of these objects have not yet been added to the standard, but for the purposes of this paper, it is assumed that the Observation entities can be used to report ISR data into a simulated scenario. Several typical scenarios are considered. A sensor reports the perceived track of a hostile or unknown ship. A sensor intercepts a conversation between two parties of interest and creates an electronic recording, which is then annotated by an analyst. While the Observation entities can be used to report structured data, there is no support for unstructured data such as an analyst's observation, nor for reference to a media file, such as the raw audio or video recording. While the Observation entities open the possibility of introducing simulated sensor data into a scenario, an Analysis Extension would better allow commanders to participate in training with dynamic data.*

1. Introduction

In a modern military deployment, commanders use command and control information systems to issue orders to the organizations under their control, and to request data and receive reports. Because of the wide variety of applications that may be used, especially across a multi-national coalition, standards have been developed to define a common set of messages that can be used to exchange information between the systems. To support these standards, a number of exercises have been held to validate the standards and their use. These exercises have focused on planning and issuing deliberate orders. However, commanders require up-to-date tactical situational awareness data to respond effectively to the dynamics of the scenario. This data may be unstructured when compared to planning data, or may include values that are not part of the system's data model. Reporting this data using existing standards can result in a loss of information, because the data model in the standards is not rich enough to represent all aspects of the data. With the creation of a new communications standard, there is an opportunity to include support for tactical situational awareness data in the standards that support simulations for exercise and training.

2. Background

Simulation systems are frequently being used in exercises involving military planning systems. The Military Scenario Definition Language (MSDL) [1] was developed to initialize simulation systems. The Coalition Battle Management Language (C-BML) [2] standard was developed to communicate Command and Control (C2) data between planning systems and simulation systems during exercises. The two standards were developed to support unambiguous communication of a commander's intent. These exercises may be used for training as well as the development and evaluation of potential courses of action.

In a real scenario, a commander requires situational awareness to determine the dynamic response of actors to the deliberate orders that have previously been issued. This requires the constant input of data collected by Intelligence, Surveillance and Reconnaissance (ISR) systems and sensors. The issuing of orders and evaluation of reports showing the effects of these orders form the battle rhythm under which commanders are expected to operate. However, sensor data has attributes that cannot be properly represented by the complex elements defined in the C-BML standard.

The use of the C-BML standard has been validated through a number of exercises. However, a lack of compatibility between C-BML and MSDL has led to the development of a new standard — the Command and Control Systems - Simulation Systems Interoperation (C2SIM) Standard. The new standard was developed based on the lessons learned from the two existing standards. The new standard includes elements that accommodate observed data, and is extendable, which affords an opportunity to incorporate elements that would capture perceived tactical situational awareness data. This would allow this data to be exchanged between systems using the same interfaces and network architectures that are used to exchange Command and Control data.

3. Tactical Situation Awareness Data

The following paragraphs describe typical scenarios for reporting tactical situational awareness data. These scenarios demonstrate some of the problems with attempting to report incomplete, unstructured, dynamic data using the C-BML data model.

3.1 Planning Data versus Tactical Situational Awareness Data

Planning operations can be performed with the information about the scenario that is available at the time the plan is formed. However, once an operation has begun, commanders require up-to-date information to respond to the dynamics of changing events. Systems like the Global Command and Control System - Maritime (GCCS-M) provide tools for analysts to examine raw tactical (sensor) data, or observations, and produce current Situational Awareness (SA) [3] in the form of tracks. The track data structures may consist of data fused from multiple sources.

ISR systems support the development of SA. ISR assets include everything from unmanned aerial vehicles to signal intelligence sensors, tracking radars, and acoustic sensors [4]. ISR data is required to support tip and cue of other sensors at critical moments. This has been identified as a strategic need for the Joint Force 2020 initiative [5]. The sensor-to-shooter sequence has data moving from sensing platforms to weapons systems [6]. However, annotations made by human analysts to the sensor data may be un-structured, or the sensor data may contain values that are not part of the existing planning data model. Making this data available to commanders during simulations would support ever evolving dynamic targeting, and allow commanders to train on the simulated battle rhythm.

3.2 Media

Human analysts prepare reports highlighting or summarizing features of captured audio, in the case of Communications Intelligence (COMINT), video, in the case of Imagery Intelligence (IMINT), or other unstructured Human Intelligence (HUMINT). These reports are made available to commanders and higher-level analysts. However, these end users may need to refer to the original media. Video imagery, in particular, may be viewed by commanders forming orders, or by their direct reports while preparing to execute these orders.

Media files are generally searchable by their metadata values. Metadata for a media file may include, but not be limited to, a unique identifier, file name, file location, media type, date and time – which may be a time point or a range, key words, and any sensor settings that are relevant to the file. For example, in the case of an audio recording, the frequency of the sensor at the time of recording may be part of the metadata. The metadata may also contain annotations made by an analyst about the content of the file, for example, the time offset at which an event of importance takes place.

3.3 Analyst Comment

COMINT and IMINT currently require human analysts to examine captured media and derive tactical information from it. This information may consist of a translation of captured audio, commentary on the meaning of a conversation that may use known code-words, or highlighting the action or location of an entity seen in a still image or video clip. This information may be presented in a text report written by the analyst and indexed to the source media by time. Text documents are not generally stored in a structured database. Instead, they may be stored in a document library, referenced by a Uniform Resource Identifier (URI).

3.4 Identifiers

A system that produces tracks may report updates to the location or other data of the tracks it maintains as a scenario proceeds. These reports are linked by the identifiers assigned to the track by the system that produced the track. A planning or other system that receives the track reports may fuse the data with sensor data from other systems, forming a single track. If any of the sensor systems produce updates to the track, the receiving system must be able to map the track identifier to the fused data structure, which may be using a new identifier assigned by the receiving system. To do this, the receiving system must retain the original track identifiers and be able to map them to its internally assigned identifier.

Additionally, some systems may assign multiple unique identifiers to a single track depending on the type of data available. Maritime vessels may have both an International Maritime Organization (IMO) number and a Maritime Mobile Service Identity (MMSI). The Automatic Identification System (AIS) is used by maritime vessels to produce position reports for the vessel. AIS messages may contain either or both of these values, and sensors that use this value to track vessels may include them in their track reports. These numbers can be used to perform correlation of data from multiple sensor systems. They should therefore be included in any report of track data.

3.5 Location History and Effective Time

Sensors that measure energy, such as acoustic or Electronic Warfare (EW) sensors, may report an entity's location as a direction relative to the sensor's location at the time of the measurement. This produces a Line Of Bearing (LOB). LOBs from sensors at different physical locations can be combined to calculate an area where the entity is probably located. This location is generally in the shape of an ellipse and is called a Direction Finding Fix (DF Fix) [7]. A sensor or automated agent that provides analysis beyond first-level analysis (data collection) may attempt to correlate a number of locations/observations with a single analysis entity. These locations become the location history for that entity. For example, a number of DF Fixes all using the same frequency may be determined to belong to the same emitter. The emitter's location history is used to form a track. While the history of where an entity has been may not be of use for fire operations, it can provide data for longer-term analysis by analysts looking at the behavior of the entity. [7]

An observation of an entity's location is only valid at the time the observation is made. A LOB or DF Fix represents the location of an emitter only for the time over which the sensors measured the emitter's activity. If the emitter is attached to a vehicle that is moving, its location may be invalid half an hour later. For this reason, a start and end time must be associated with each location in the entity's location history [7].

3.6 Track Management – Merge and Delete

Since the process of data analysis involves building an operational picture out of collected data, errors may be made. Data may be assigned to two or more tracks that are later determined to belong to the same entity. As a result, the analyst may decide to merge the tracks [3].

Alternately, an analyst may determine that a track is meaningless, or improperly formed, and may need to delete the track.

Through analysis, the analyst may determine that while a track is valid, some of the observations that were assigned to it are incorrect, and need to delete only some of the locations in the track history.

3.7 Improvised Equipment

Activities organized by non-governmental agencies may result in improvised weapons and equipment. One such example is adding a large weapon to the bed of a pick-up truck, such as was seen during the Arab Spring [8]. This particular vehicle may not appear in a standard library of vehicles compiled prior to deployment of the coalition forces. Analysts need to be able to identify the key features of this vehicle for commanders to be fully informed when they prepare orders for their forces to deal with the driver and gunman in the vehicle.

4. C2SIM Standard Evolution

SISO developed and maintains two standards for simulation interoperability: C-BML and MSDL. These standards have been used as part of NATO Modelling and Simulation Group (MSG) exercises to validate the ability to exchange data between multiple C2 systems used for planning and simulation systems [9] [10].

C-BML is meant to exchange plans, orders, requests, and reports across C2 planning systems, live, virtual, and constructive modelling and simulation and robotic systems in a way that is clear and unambiguous [2]. This intent is evident in scenarios used to validate the standard. MSG-048 focused on issuing orders from planning systems to simulation systems and reports being sent from the simulators back to the planning systems [11]. MSG-085 consisted of demonstrations focused on system initialization, logistics reports, and joint coalition planning [12].

An outcome of these exercises was the determination that the two standards are different enough to pose challenges when used together [10] [13]. As a result, the Command and Control Systems – Simulation System Interoperability (C2SIM) Product Development Group (PDG) is finalizing a new simulation standard to replace C-BML and MSDL.

The new standard consists of two basic models:

- Core – basic elements: actors, resources, messages, time, location, etc. [14]
- Standard Military Extension (SMX) – with the Core model, provides a "core set of data elements common to most C2 and simulation systems" [15].

The standard allows the definition of extensions that add new classes. It comes with one such extension, the Land Operations

Extension (LOX), which acts as an example for other extensions. The LOX model provides continuity with military land operations aspects of MSDL and C-BML that are not in the C2SIM core [16].

The C2SIM data model is defined in Web Ontology Language (OWL)[14][15][17]. An XML version is available for import into UML tools [16][18], although after the import it requires some editing to distinguish between subclass and aggregate relationships. The following diagrams are screen captures from both the Protégé Tool, which supports OWL notation (https://protege.stanford.edu/) and Enterprise Architect (EA), a UML tool (https://sparxsystems.com/).

The hierarchy of the Core model is shown in the figure below.

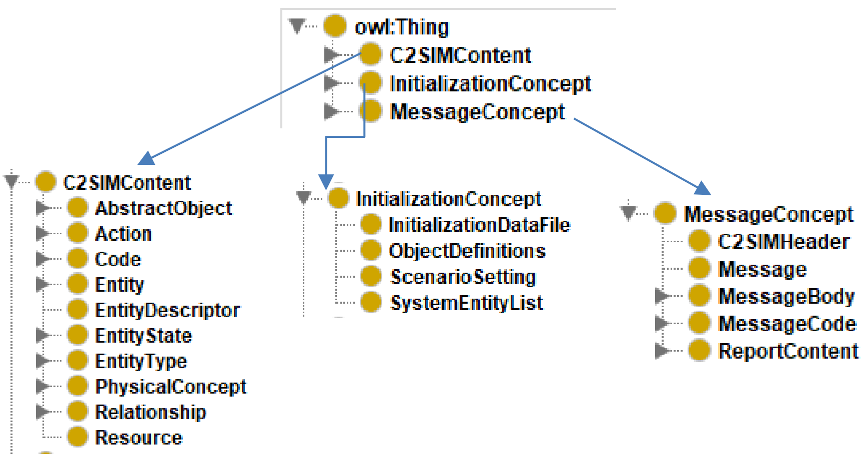

Figure 4-1 C2SIM Standard Hierarchy

Under MessageBody, which appears under MessageConcept, the Core model defines two DomainMessageBody subclasses: OrderBody and ReportBody[1]. The DomainMessageBody is associated with the ReportContent class. Entities from the C2SIMContent class are associated with the ReportContent to fill out the report.

The SMX extension defines the ObservationReportContent as a subclass of ReportContent class, and the Observation class as a subclass of C2SIMContent. The Observation is defined as "an observation of the state of something in the world; generally an actor, but possibly anything that is an entity. Subclasses define specific observations that can be made." [15] The Report and ReportContent classes and the associated Observation classes are shown in the figure below.

[1] The LOX extension adds PlanBody as a subclass of DomainMessageBody.

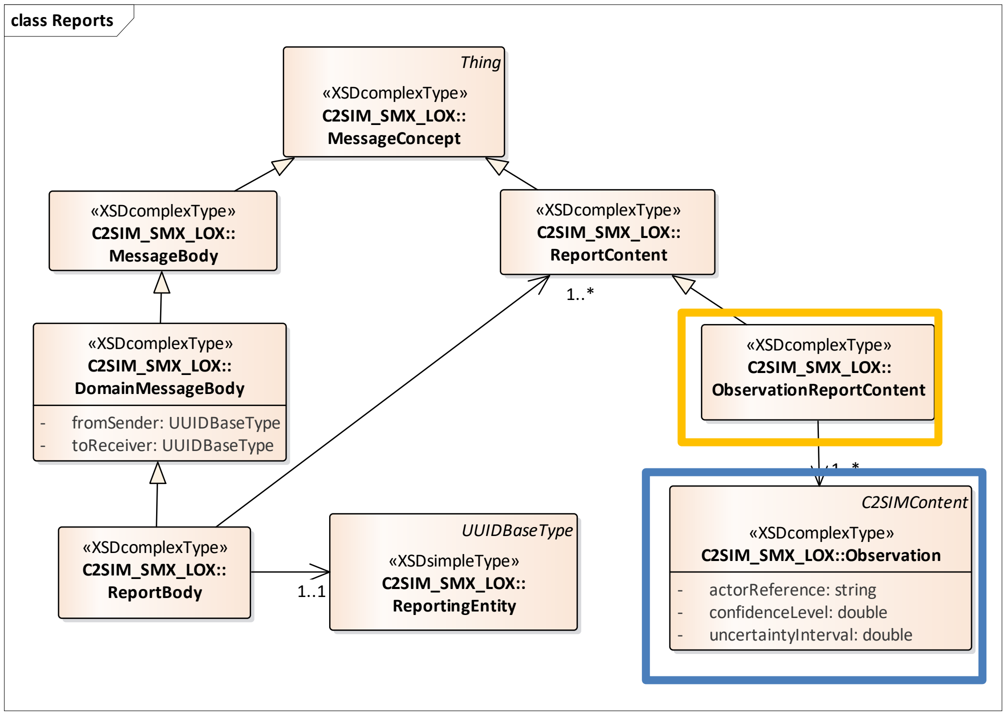

Figure 4-2 Report Class Hierarchy

The Observation class provides subclasses for different types of observed data. The hierarchy is shown in the figure below.

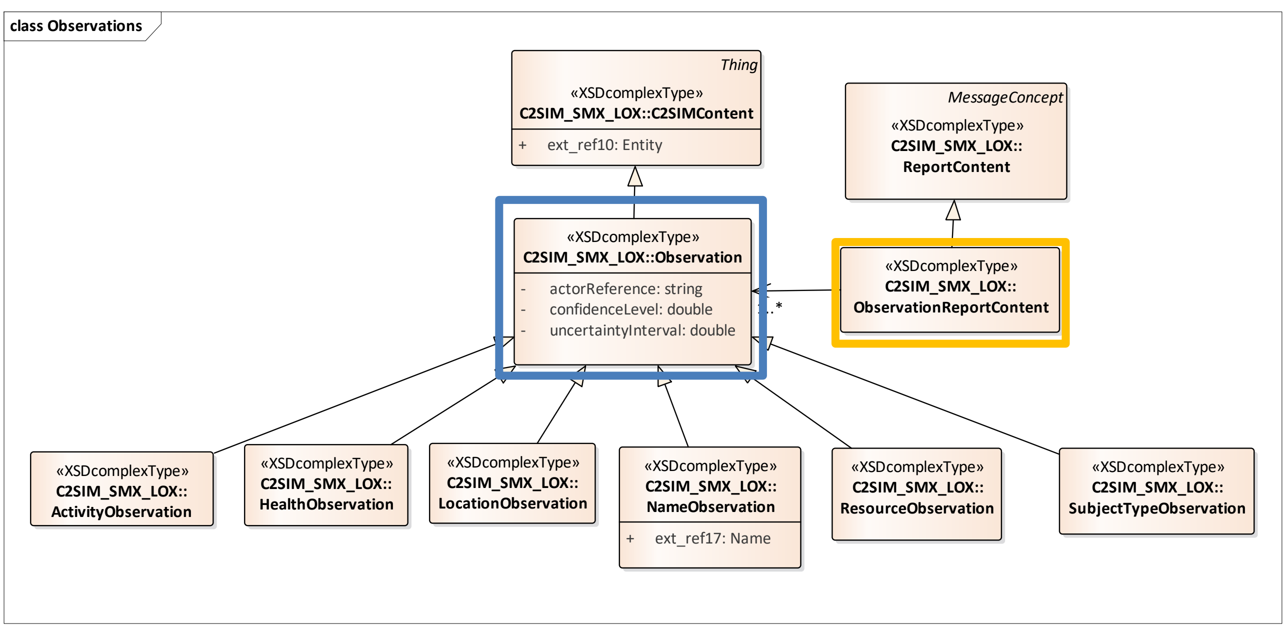

Figure 4-3 Observation Class Model

5. Modeling SA Data Using Observations

The Observation subclasses provide support for reporting some types of sensor data, but do not capture all of the data associated with sensor data. Some concepts are present, but the classes are not associated with Observations, and so cannot be used in reports. Some concepts cannot be represented by classes in the model.

One key concept that is missing in the Core, SMX and LOX models is Location as an area, e.g. fan area, ellipse, rectangle, cloud. This concept is significant for planning, as indicated by the geographic shape classes included in C-BML [2], the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) [19] and the MIP Information Model [20]. This paper assumes that area classes will be added to either the LOX model or another extension.

The possible mappings from sensor data requirements to the new data model are shown in the following sections, which present possible SA reports using the new model. The scenarios presented are representative of typical scenarios, and are not meant to be comprehensive. In order to represent all of the key data in the scenario, color coding is used. Blue classes represent the classes from the model as it was defined in November 2019. Yellow boxes represent classes that exist in the model, but that need to be associated with the blue classes in order to capture all of the relevant information. Purple boxes represent classes that are not in the current model, but could be added in an extension to the C2SIM data model.

5.1 Naval Track Report From Sensor

An ISR system working with AIS messages creates a report for a single ship that has been tracked across multiple locations. Data that needs to be included in the report is listed in the table below.

Table 1 Naval Track Data Mapping

Data	C2SIM Model Entity
Ship's name, affiliation, IMO, MMO number, callsign, etc.	Multiple NameObservations, one for each identifier.
Ship size, heading, etc	SubjectTypeObservation with associated Entity objects. ResourceObservation with associated Resource objects.
Location History	Multiple LocationObservations with associated Location objects. Location Observation requires an IntervalTime to capture the time at which the observation was valid, i.e. when ship was observed at that location.

Notes:

- The NameObservation class has a Name attribute of type String, which can be used to fill in the observed identifier. It is described as "An alphanumeric identifier that serves for humans to recognize the instance." [15] It also has a hasMarking field, which is another String. There are no restrictions on the value of this field in the current model definition. This field could potentially be used to capture the category of the identifier, e.g. Callsign, MMSI or IMO.

- Locations have errors, e.g. error ellipse, due to limitations in the capability of the sensors. These would be modeled using the Area models that are assumed to be included in another extension to the C2SIM model. They are not included in the object model diagram.

- Tracking a ship over a long period of time results in multiple locations; hence the need to be able to report a Location

History made up of multiple Location instances.

- IntervalTime is associated with Location Observations to capture start and stop time of sensor reading / monitoring of the vessel at the associated Location. IntervalTime has start, stop and duration values. Two of the three must be set.

The object diagram for the resulting message is shown in the figure below.

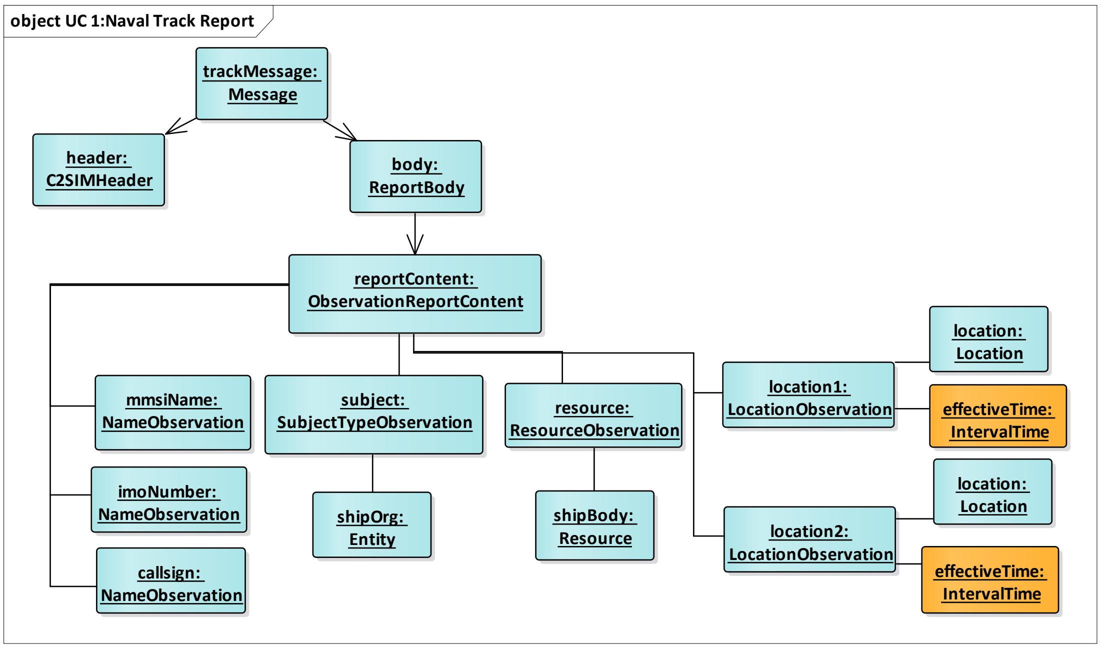

Figure 5-1 Naval Track Report Class Diagram

5.2 Intercepted Audio From Sensor

An analyst working with audio recordings from Electronic Warfare Sensors transcribes a conversation between two parties and creates a report listing the participants in the conversation, including aliases. The conversation describes planned activities of interest to the exercise commanders. The analyst creates a report and uses an analysis tool to generate a report.

This scenario also applies to other recorded sensor media such as video footage from an Unmanned Aerial Vehicle (UAV) or a recording from a Radar Warning Receiver (RWR).

Data that needs to be included in the report is listed in the table below.

Table 2 Naval Track Data Mapping

Data	C2SIM Model Entity
Names of parties involved in conversation. May be callsigns, nicknames, proper names, or aliases.	One or more NameObservations. There may be multiple names for each of the parties in the conversation.
Planned activities, or events that have already occurred.	ActivityObservation. Requires association with Event class (subclass of Action.)

Information about individuals	SubjectTypeObservation, with possible NameObservation. (Not shown in diagram.)
Meta-Information about the intercepted communication, e.g. network, frequency.	ResourceObservation associated with Network class.
Media file reference	Proposed Media class (see section 6 Possible Extension: Analysis Model)
Analyst Comments reference	ActivityObservation with associated proposed AnalystComment class.

Notes:

- ActivityObservation needs to be associated with Event, an occurrence or phenomenon. Event is a subclass of Action.
    - Currently Action only has a TaskActionCode.
    - ActivityObservation association should be with Action class, allowing any subclass, including Event class.
- ResourceObservation is associated with Resource, but Resource currently has no associations. Adding an association to Abstract Object or Entity is required.

The object diagram for the report is shown in the figure below.

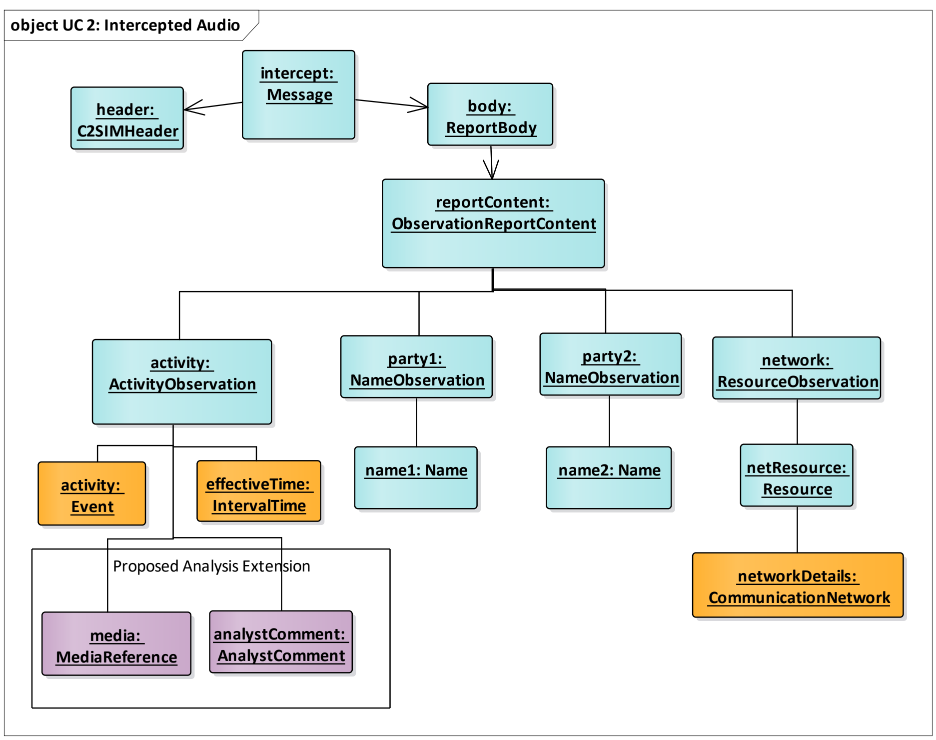

Figure 5-2 Intercepted Audio Object Diagram

6. Possible Extension: Analysis Model

As discussed in the scenarios above, additional classes are needed to capture references to media and document libraries. In addition, track operations such as merging or deleting entities need to be represented in order for automated analysis systems to participate in scenarios. A class diagram for the proposed extension is shown in the figure below.

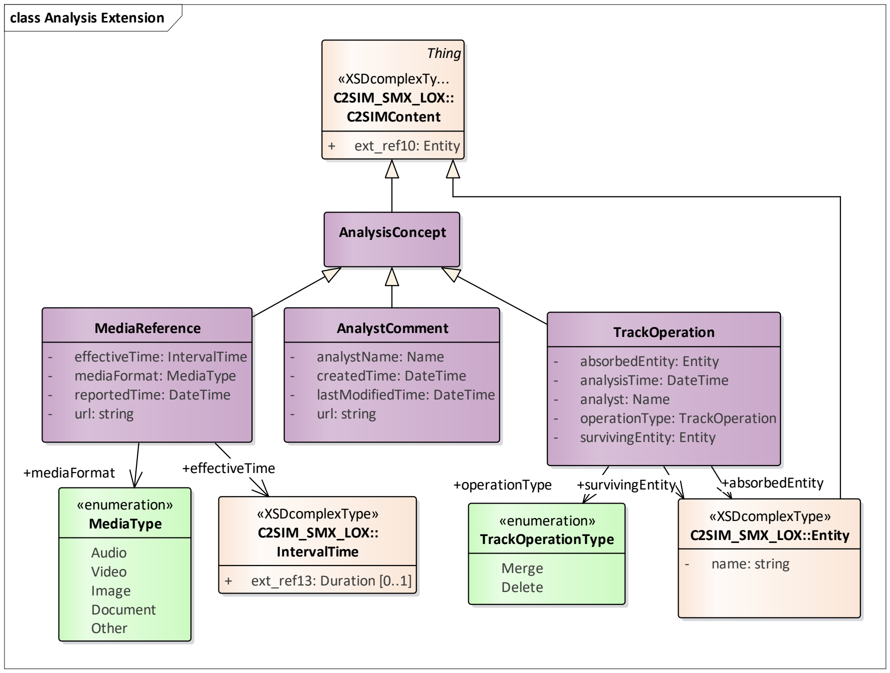

Figure 6-1 Proposed Analysis Extension

7. Conclusions

In military scenarios, once the initial orders have been issued, commanders are required to respond to dynamic situation data, often presented in the form of sensor data and HUMINT. In order for them to train, simulations need to support the reporting of incomplete and unstructured data. The new C2SIM standard provides some support for this in the form of the Observation class hierarchy. Multiple Location Observations could be included in one report, allowing a sensor system to report on a perceived target track. Multiple Name Observations could be included in a report, supporting both identifiers from other C2 protocols, and aliases for a person of interest. The current version of the C2SIM standard is not rich enough to capture all of the data available from intelligence assets, It does not allow reference to unstructured external sources such as media files or documents containing analyst comments. It also does not support operations that may be performed by automated analysis systems, such as the merging or deleting of perceived target tracks. The C2SIM standard is designed to allow the definition of extensions, so these concepts could be added to an Analysis extension. Doing so would greatly enhance the ability to simulate the dynamic nature of warfare. This would allow a commander and staff to adapt their mission to include targets that they were not aware of and prosecute as required to drive mission success.

8. References

[1] SISO-STD-007-2008, Standard for Military Scenario Definition Language, 14 October 2008

[2] SISO. (2013). SISO-STD-011-2014 Standard for Coalition Battle Management Language Phase 1, Version 1.0. 31 October 2013

[3] *Global Command and Control System - Maritime (GCCS-M)*. (n.d.). Retrieved September 23, 2016, from Global Security: http://www.globalsecurity.org/military/systems/ship/systems/gccs-m.htm

[4] Accelerating the kill chain: Closing the Sensor-to-shooter Cycle. (2006 Issue 1). *Defense Update International Online Defense Magazine*, pp. http://defense-update.com/features/du-1-06/urban-c4i-7.htm

[5] Dempsey, M. E. (2014). *Joint Force 2020 White Paper.* http://www.dtic.mil/doctrine/concepts/white_papers/cjcs_wp_isr.pdf: Joint Chiefs of Staff.

[6] Chizek, J. G. (2003). *Military Transformation: Intelligence, Surveillance and Reconnaissance.* Washington: Congressional Research Service Library of Congress.

[7] Poisel, R. A. (2012). *Electronic Warfare Target Location Methods.* Norwood, MA: Artech House.

[8] Editors of the Encyclopaedia Britannica. (2015, January 14). *Arab Spring*. Retrieved September 23, 2016, from britannica.com: https://www.britannica.com/event/Arab-Spring

[9] Brook, A. (2014). UK Experiences and Lessons Identified Using C-BML in Practical Experiments. *19th International Command and Control Research and Technology Symposium (ICCRTS).* Alexandria, Virginia.

[10] Pullen, M. C. (2012). Technical and Operational Issues in Combining MSDL and C-BML Standards for C2-Simulation Interoperation in MSG-085. *NATO Modelling and Simulation Symposium.* Stockholm, Sweden.

[11] NATO RTO. (2012). *TR-MSG-048 Coalition Battle Management Language NMSG-048 Final Report.* North Atlantic Treaty Organisation Research and Technology Organisation.

[12] NATO RTO. (2015). *Standardisation for C2-Simulation Interoperation Final Report of MSG-085*. North Atlantic Treaty Organisation Research and Technology Organisation.

[13] Remmersmann, T., Schade, U., Khimeche, L., Gautreau, B., & Khayari, R. E. (2012). Lessons Recognized: How to Combine BML and MSDL. 2012 Spring Simulation Interoperability Workshop. Orlando Florida.

[14] SISO PDG. *C2SIM Core Object Model*. C2SIM_v9.23.rdf, Retrieved November 15, 2019, from https://www.sisostds.org/Default.aspx?tabid=105&EntryId=50732.

[15] SISO PDG. *C2SIM Standard Military Extension*. C2SIM_SMX_v9.23.rdf, Retrieved November 15, 2019, from https://www.sisostds.org/Default.aspx?tabid=105&EntryId=50732.

[16] SISO-STD-XXX-2018 Standard for Command and Control Systems – Simulation Systems Interoperation Version 1.0, no date, downloaded November 2019.

[17] SISO PDG. *C2SIM Land Operations Extension*. C2SIM_LOX_v9.23.rdf, Retrieved November 15, 2019, from https://www.sisostds.org/Default.aspx?tabid=105&EntryId=50732.

[18] SISO PDG. *C2SIM Land Operations Extension XML* . C2SIM_SMX_LOX.xsd, Retrieved November 15, 2019, from https://www.sisostds.org/Default.aspx?tabid=105&EntryId=50732.

[19] JC3IEDM - Annex B – IPD3 - V3.1.4-amendment1

[20] Gerz, Michael and Bau, Nico, *Introduction to the MIP Information Model*, 8 Jun 2016.

8.1 Author Biography

ELIZABETH HOSANG has over 20 years of experience in software development. Since 1999, she has been working on land Electronic Warfare systems, specializing in data correlation and fusion, and on supplying sensor data to the Canadian Forces Operational Database (ODB), the Canadian implementation of the JC3IEDM. More recently, she has been working on using C-BML and MSDL in a naval command and control context. She completed her Master of Applied Science in Electrical and Computer Engineering in 2014, focusing on computer simulation. Her thesis looked at the use of C-BML and MSDL