2019 NATO MODELLING AND SIMULATION GROUP SYMPOSIUM

Development of an Air Operation eXtension with the (Future) C2SIM Standard

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Overview

- **COMELEC**
- **The C2SIM Context**
  - MSDL/C-BML -> C2SIM
  - C2SIM point of views
  - Ontologies
    - Core
    - SMX
    - LOX
    - **Air Operation Extension**
    - Land Operation Extension with UAVs
    - Possible other extensions
    - Reasoning Capabilities
  - Schema Generation
- **Lessons Learned**
- **Conclusion**

Project: COMELEC

COMELEC

(Commission Electronique)

is

a) the abbreviation for

a German-French C2SIM

working group;

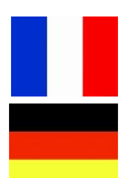
b) the short term for the

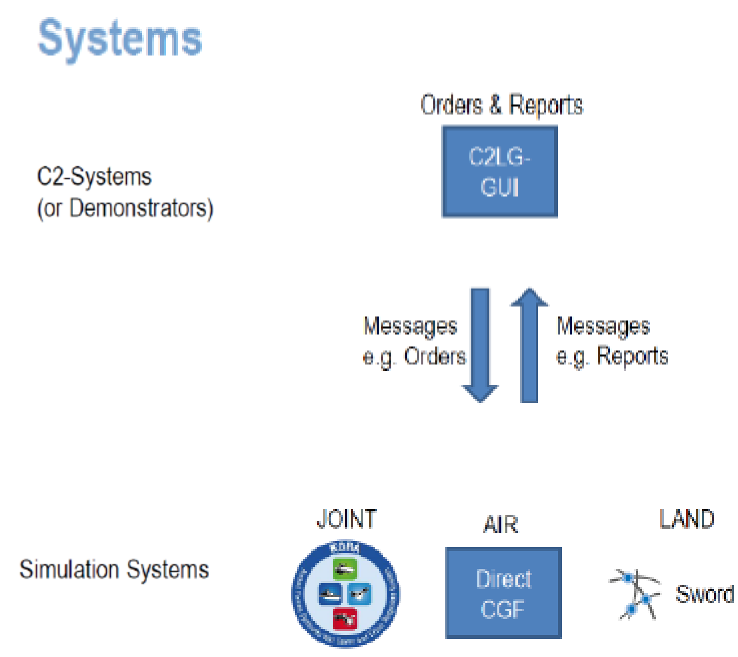
current project of that group.

Members are

DGA, Airbus, DigiNext

iABG, Fraunhofer FKIE





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Preliminary remarks

- This is work in progress. However, we already can present experience with the forthcoming C2SIM standard we judged as important.
- We presented this extension at the MSG-171 (24-25. October in Vienna, Austria).
- We plan to present an updated version of our work at the next SIW (10-14 February, Orlando, Florida).

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C2SIM Context

SISO C2SIM PDG is developing a C2SIM standard.

The SISO C2-Simulation interoperation has always been supported by NATO activities, currently by NATO MSG-145 “Operationalization of Standardized C2-Simulation Interoperability”.

Existing standards are

- the MSDL standard (SISO-STD-007-2008) for initialization and
- the C-BML standard (SISO-STD-011-2014) for the exchange of military communication (reports, requests, orders) during simulation runs.

C2SIM as new standard

Currently, SISO PDG develops a new C2SIM standard since

- the cooperation of MSDL and C-BML turned out to be difficult
- goal is an integrated solution
- the new standard is supposed to be extensible to different domains
  - military land operations
  - **military air operations**
  - military maritime operations
- C2SIM represented as ontology
- each extension modelled as separate layer
- Merging those ontologies that are needed for own application
- Automated schema generation out of ontology layer selection

C2SIM – Systems‘ point of views

C2SIM combines C2 and Simulation systems with their point- of-views.

- Simulation view:
  - military entities and their situation
  - realistical order of events and actions
  - these actions refer back to doctrins of simulated entities/units.
- C2 systems view :
  - commanding simulated units
  - command of control process and its realistical order of events

- C2SIM is to enable education of military leaders
  - Cost effective and resource conserving
  - Practice maneuvers that are difficult to be played in reality

⇒ **Interoperability** is essential!

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Simulation View on C2SIM

Simulation view: **units and their situation**

- MSDL also has focused on detailed descriptions of these

This is an Entity that is normally thought of as having constituent entities, i.e. a Unit.

CollectiveEntities may or may not hve their subordinates explicitly represented in the exercise (i.e., it may always be aggregated, or it may have subordinates that are themselves entities). If they are represented, then the hasSubordinate property will have at least one instance.

The CollectivEntity may be an abstract actor, or it may have physical properties; if the latter, then the hasCurrentState property is present with a PhysicalState.

Static attributes

The Descriptor defines static attributes of an entity, i.e. that do not change during the course of the simulation. This information is provided at initialization time.

The friend/hostile/... relationship of this entity with others can be specfied with hasAllegianceRelationship properties, to define specific and possibly asymmetric relations with other enitities.

The isAffiliatedWith property defines organizations that this entity is affiliated with. These organizations are abstract; they are not actors.

C2 structures can be defined by using the hasSuperior property.

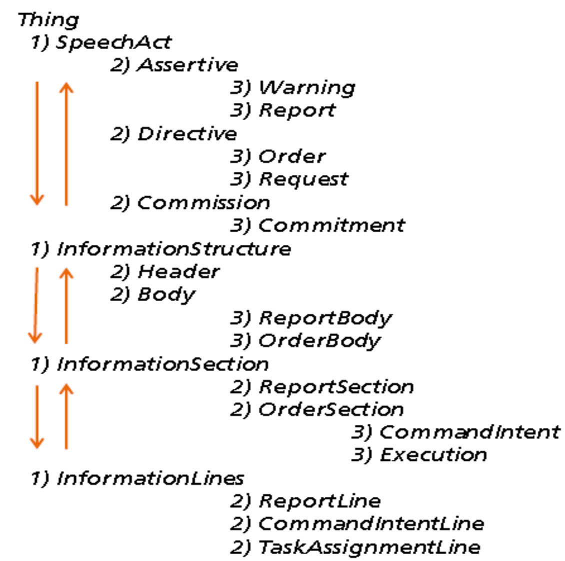
Dynamic state information for entities in the exercise.

Description of the physical state of an entity, including location, orientation, health, speed, etc.
Note that an EnvironmentalState class should be a subclass of PhysicalState.
The EnvironmentalState could be the state of, for example, a smoke plume, which would have a location and could have direction, orientation, and speed.

C2-View on C2SIM

Military and non-military communicaton (Speech act theory, Searle 1969/1979)

- Exchange messages
- Message types with specific intention
  - Orders (Directive)
  - Reports (Assertive)
  - Request (Directive)



- Intention/Purpose influences choice of words and phrases
- Expectations about reaction/ answer (acknowledgements) -> FIPA

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From C2SIM-Ontologies to Schemata – two point of views

- An ontology will serve as the C2SIM main representation.
- Ontologies represent knowledge and schemata allow the exchange of messages.
- Good ontologies represent the knowledge correctly. → Semantics
- Good schemata transmit their messages in a correct form. → Syntax
- Therefore, in the C2SIM case, schemata need to refer back to ontologies: We generate the schemata automatically out of the ontology, as is explained in Blais et al. (2019).
- Evaluation criterions:
  - can the schema generated out of the ontology (core plus air operation extension) handle the message exchange as intended?
  - And does it also work, if we extend the ontology with our Air Operation extension?

Ontology as knowledge representation

some basics

- Formal Knowledge Representation of classes (concepts of entities), individuals (instances of classes), attributes und relationes
- Semantic concepts of a domain are subdivided into classes
- Semantic concepts and their members are related to each other:
  - Hypernymy and Hyponymy (E.g.: „A Tank is a Vehicle“)
  - Meronymy vs. Metonymy (E.g.: „A Tire is part of a Vehicle“)
  - Etc. (E.g.: „Task hasTaskNameCode some TaskNameCode“)

Ontology as knowledge representation

- Classes: represent concepts that are subordinated to each other
- Subordination of classes allow inheritence
- Individuals/Instances are unique members of a class
- Instances and classes can belong to more than one subclass (e.g. a tank can be an actor entity or an equipment of a unit)
- Object Properties relate instances to each other,
- Datatype Properties: relate instances of a class to a datatype such as string, byte, integer etc.
- Restrictions: define classes with possible and/or obligatory properties
- Reasoning: In assigning restrictions on object properties and datatype properties to classes ,it becomes possible to infer memberships to different classes.

Ontology as knowledge representation
Properties and Inferences

Inverse Properties:

Subordination:

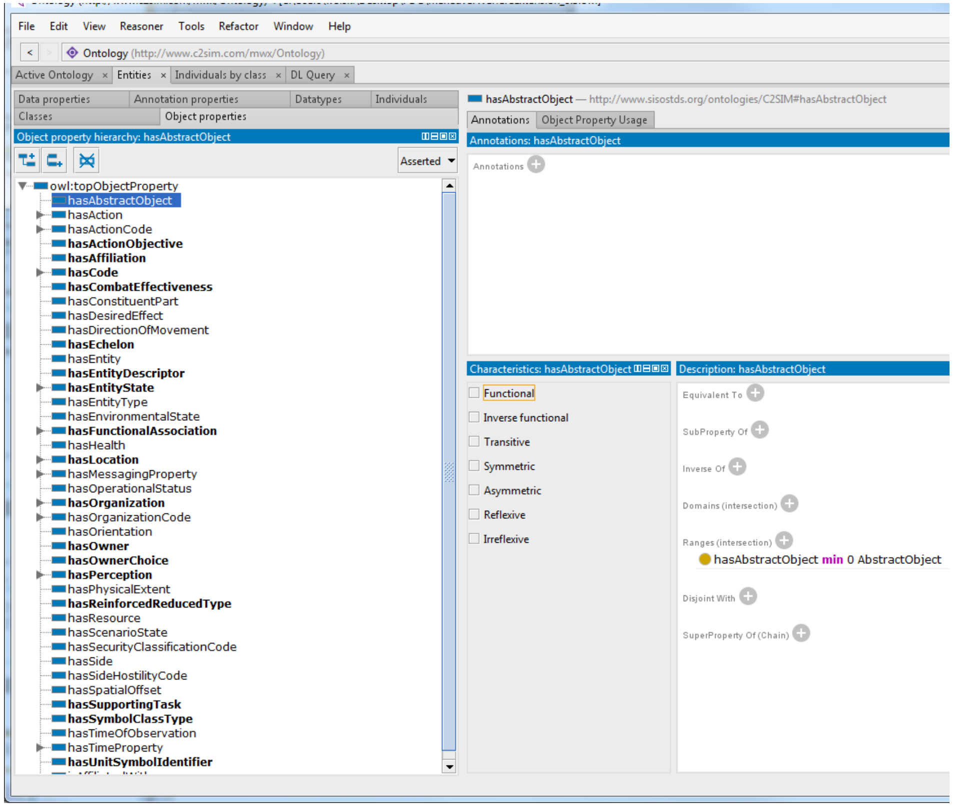
- Unit A „hasSubUnit“ Unit B
- Unit B„isSubUnitOf“ Unit A

Temporal subordination:

- Unit C „hasAssigned“ Unit D
- Unit D„isAssignedTo“ Unit C

Functional Properties:

- Unit „hasCommander“ Person



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Transitive and symmetric Properties and Inferences

Transitive Properties

- „isPartOf“
- A „isPartOf“ B
- A „isPartOf“ C => A „isPartOf“ C

Symmetric

- „hasSameAffiliationAs“
- UnitA „hasSameAffiliationAs“ UnitB => UnitB „hasSameAffiliationAs“ UnitA

Antisymmetric

- isPartOf -> hasPart

Reflexive

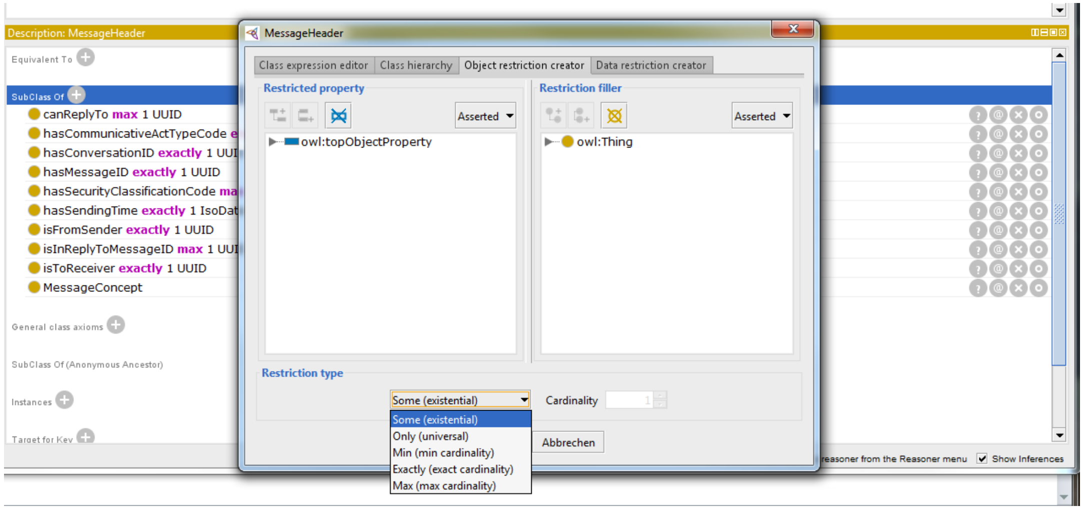
- „hasSameAffiliationAs“
- UnitA „hasSameAffiliationAs“ UnitA

Properties that are reflexive, symmetric und transitiv define equivalent classes

Ontology as knowledge representation
Value ranges of property restrictions

Supreme Commander **isComander** Unit:

allValuesfrom **Unit**



Commander isCommander Unit

someValuesFrom Unit

Action **hasTimeInstant** **exactly** 1

Location **hasCoordinate** **min** 2 (Longitute, Latitude)

Location **hasCoordinate** **max** 3 (Longitute, Latitude, Altitude)

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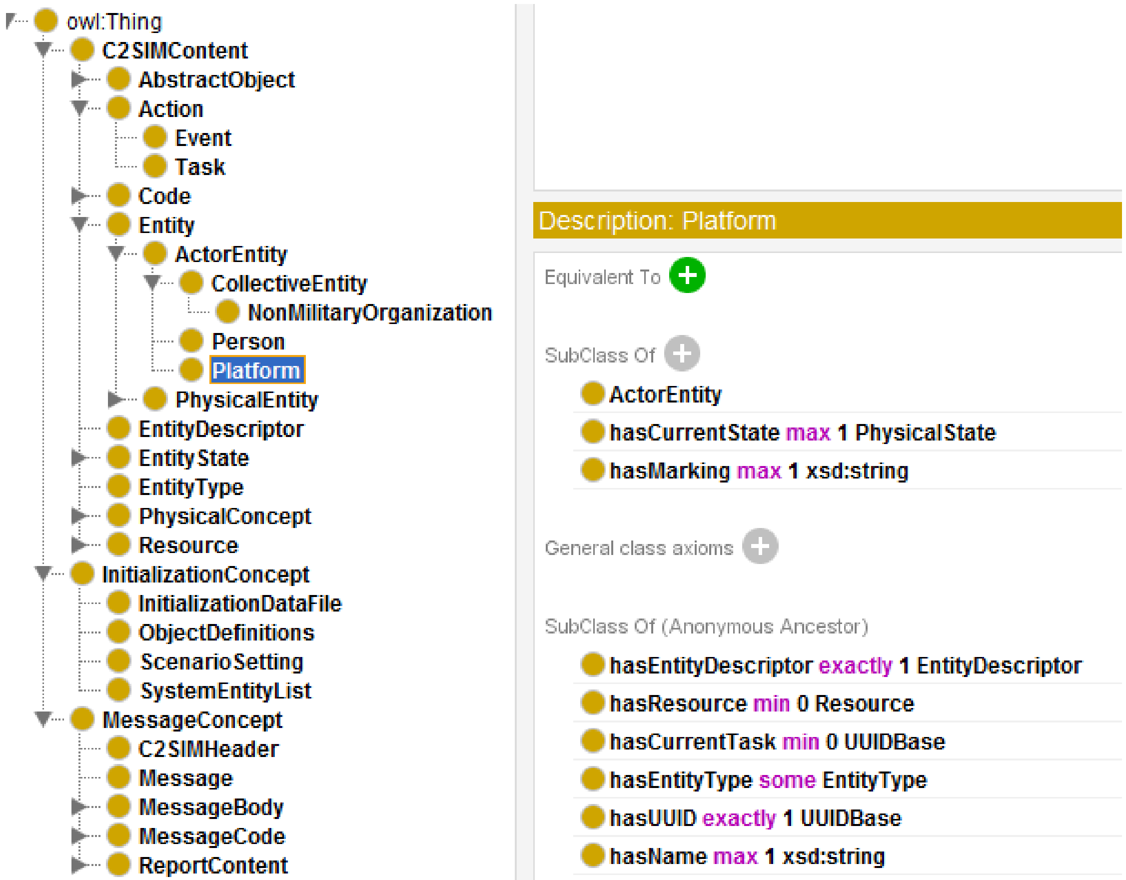
Purpose of Knowledge represenation in ontology

- Purpose of formal knowledge representation:
  - Database (defined vocabulary) to exchange between systems
    - no ambiguities
    - no redundancies
  - Inheritence and reasoning:
    - Economic aspect
    - Used to evaluate modelled knowledge

C2SIM Core Ontology



Defining platforms

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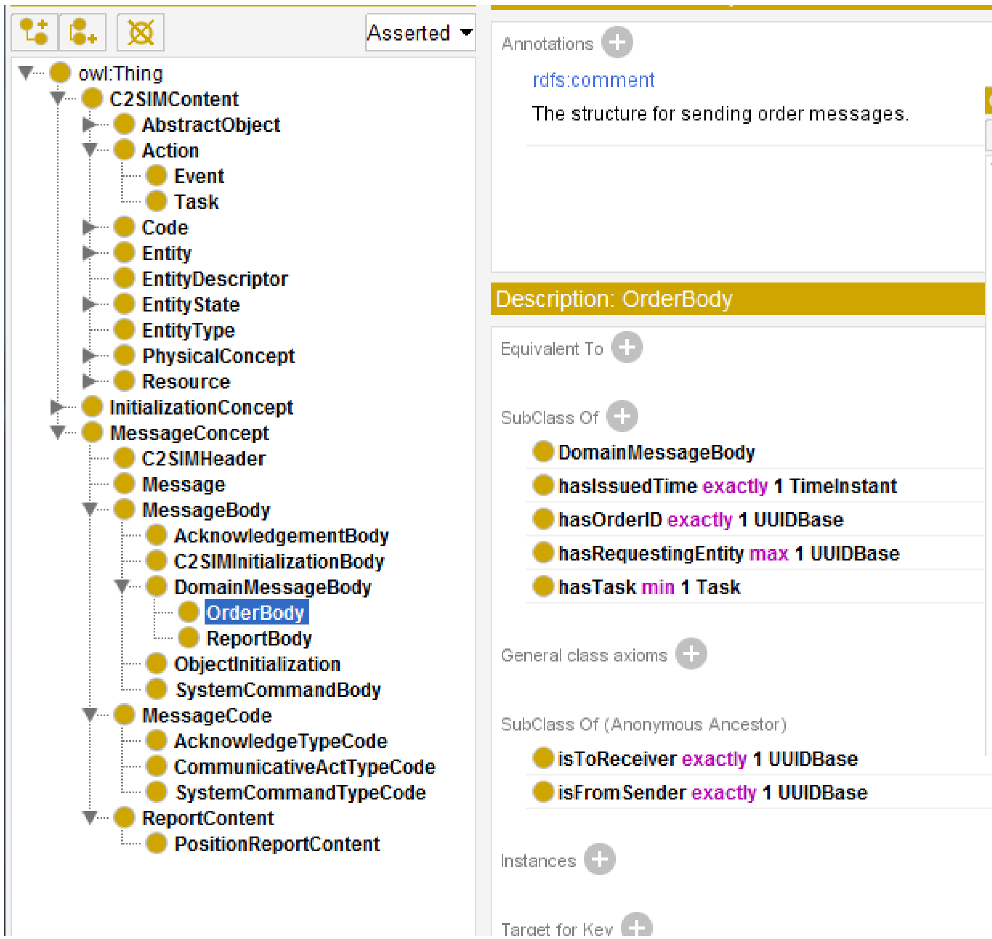
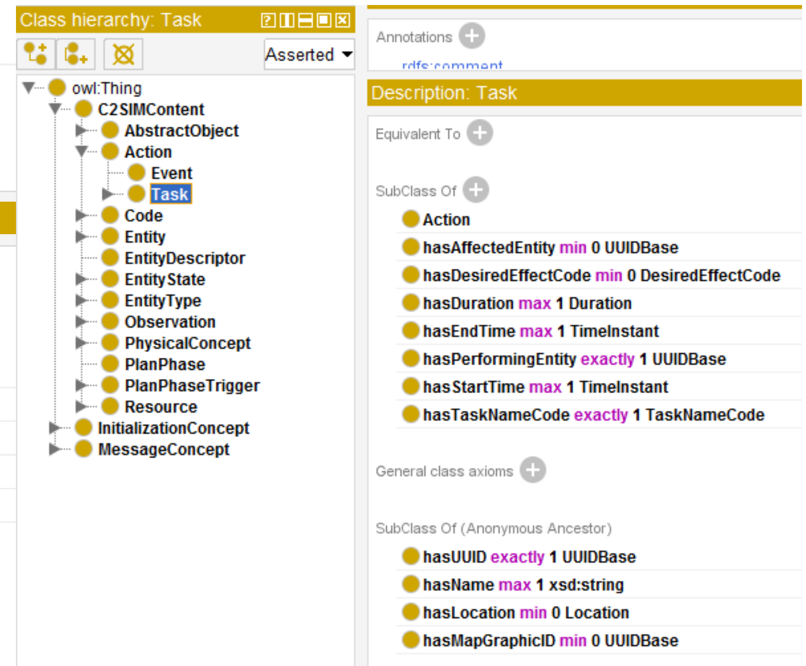
C2SIM Core Ontology



Defining messages



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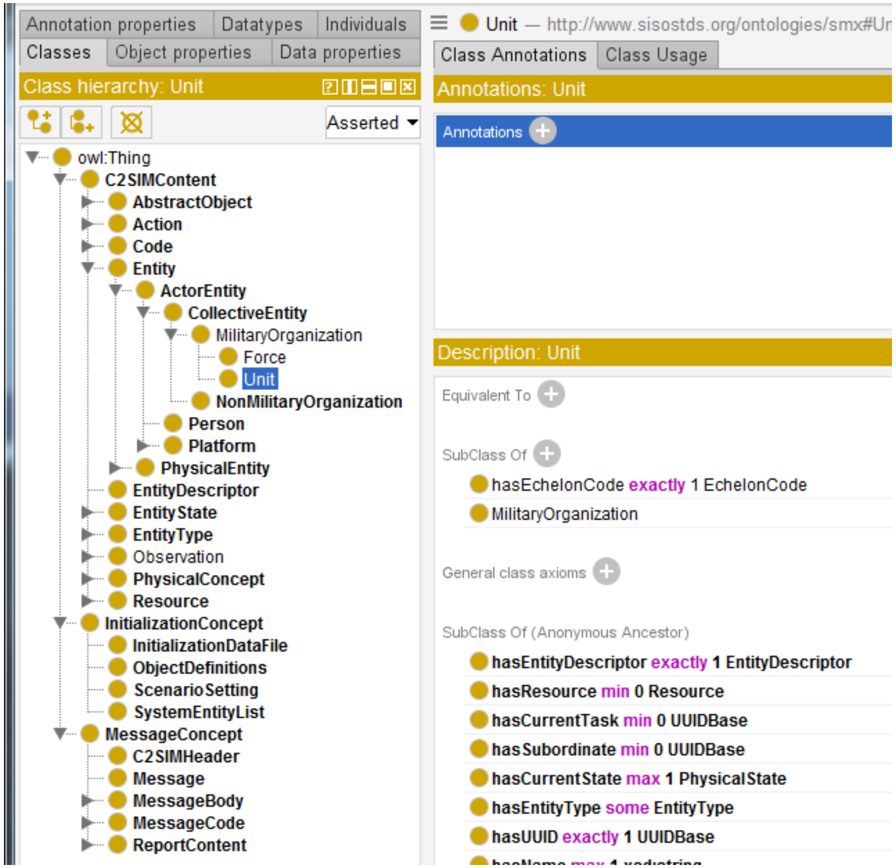
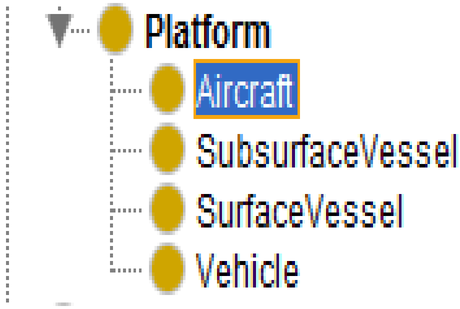
C2SIM SMX Ontology





Defining units and platforms

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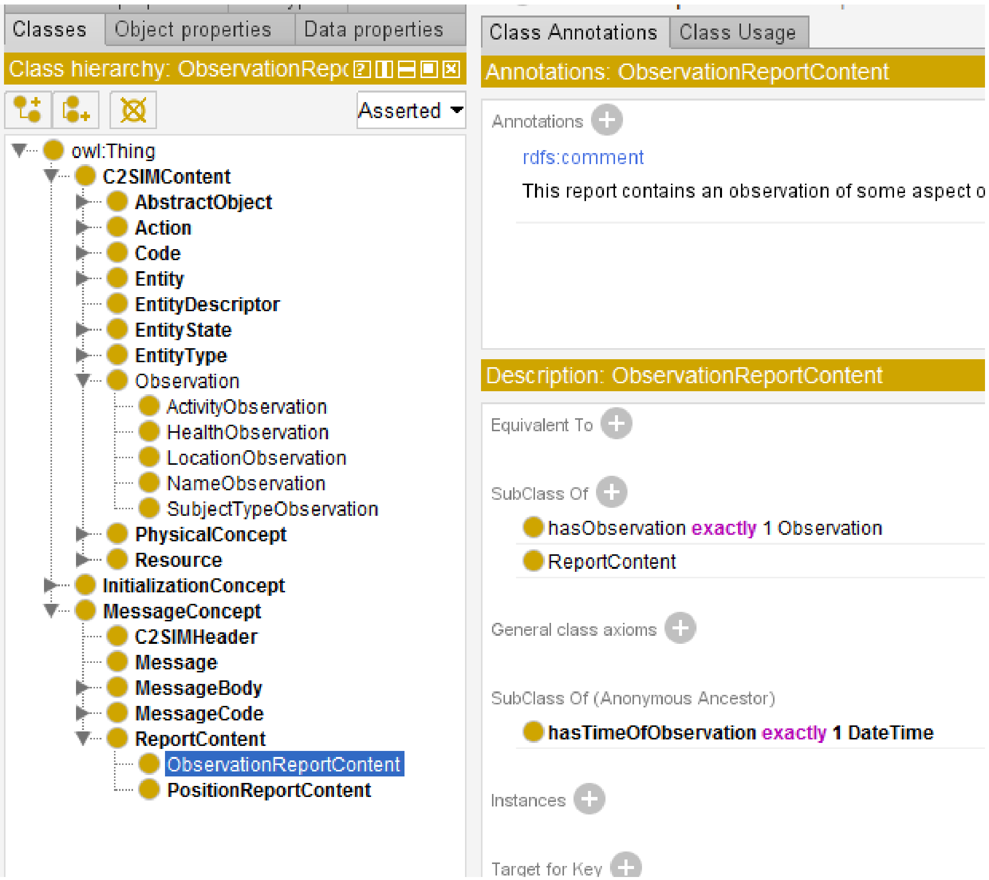
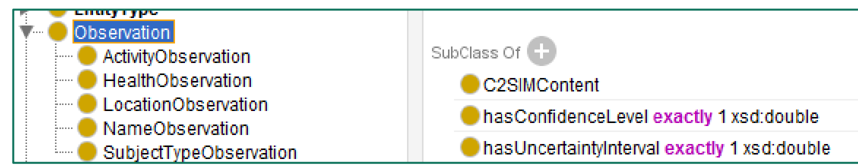
C2SIM SMX Ontology





Defining observation reports

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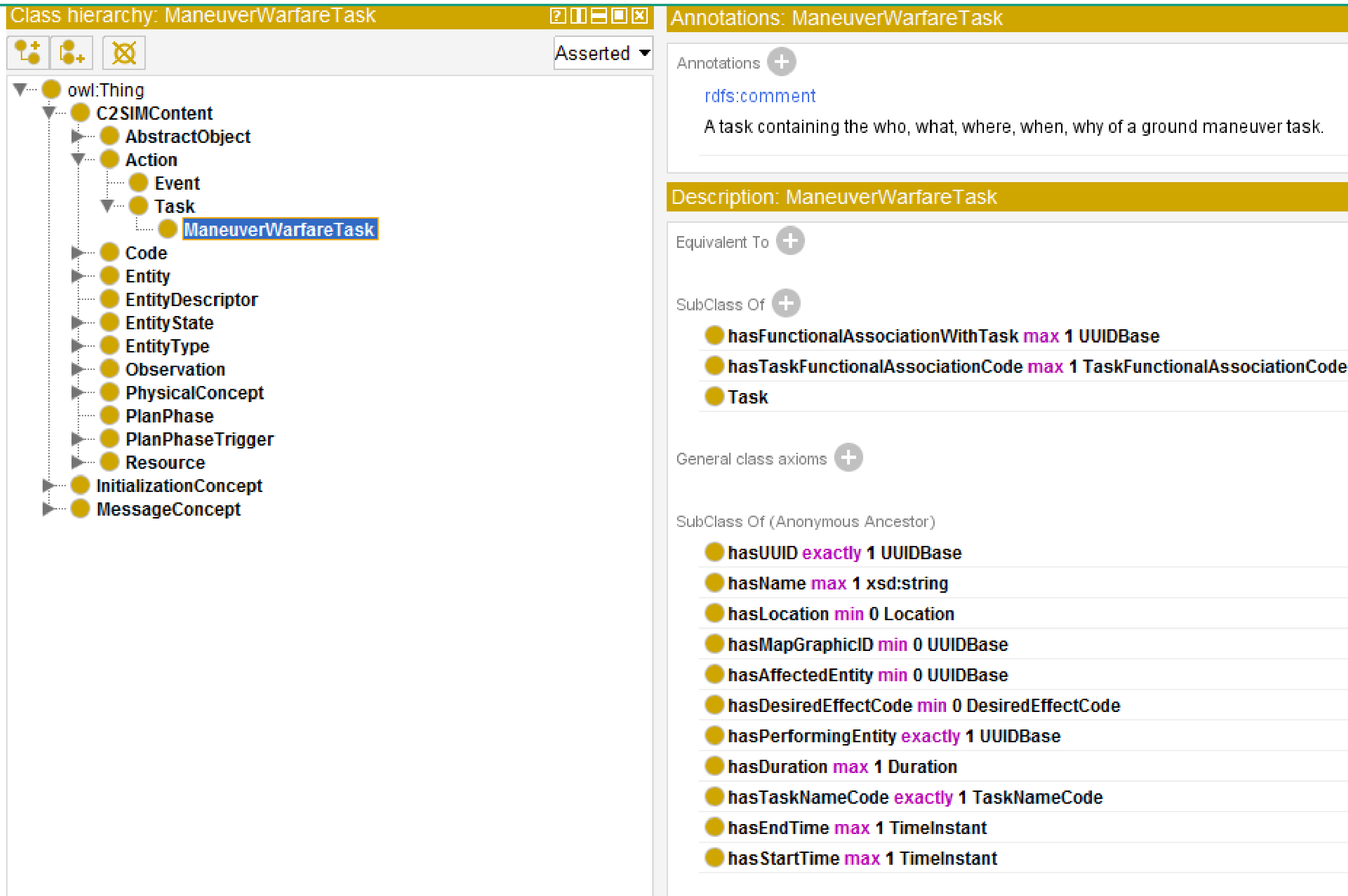
C2SIM LOX Ontology



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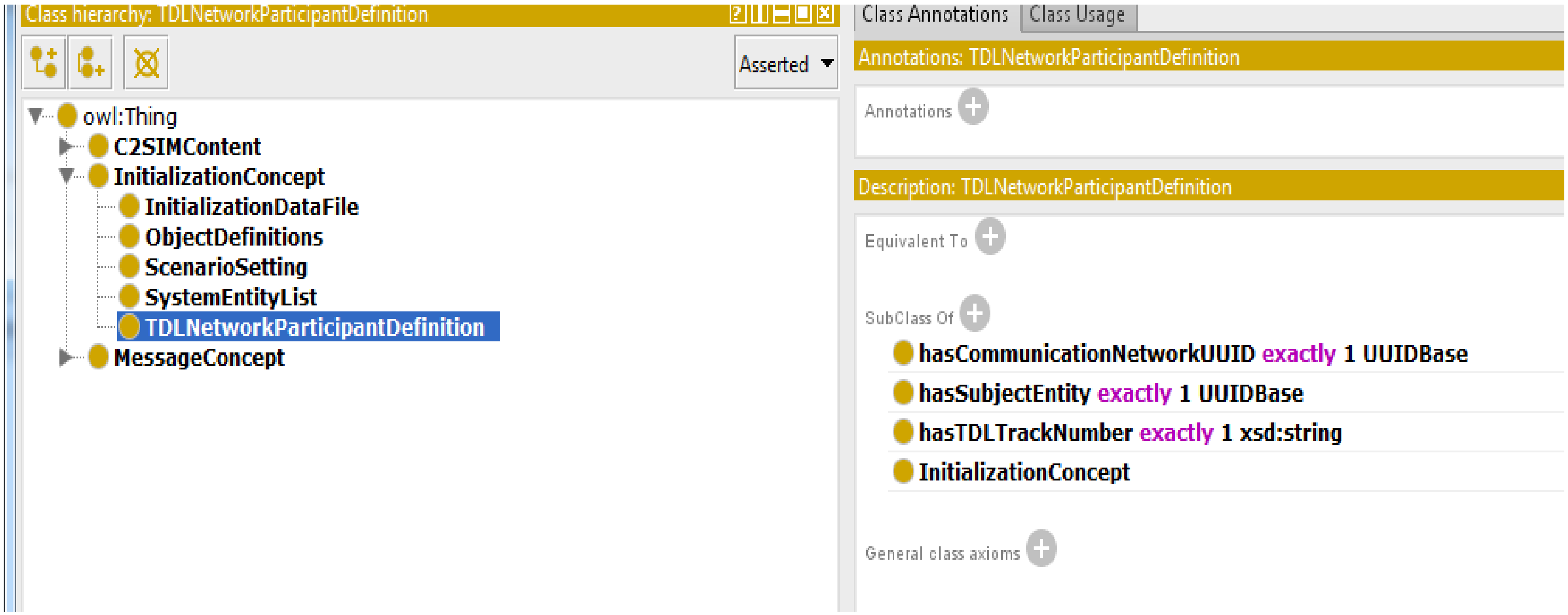
Air Operation specifics

Airborne entities move fast. → Automated position updates are generated by an airborne radar picket system, like an AWACS. This data form tracks. → Tracks numbers are used for units, but as well as for observations and targets

Messages are exchanged as TDL messages. (TDL = tactical data link, e.g. link 16).

A secure data network allows the exchange of TDL messages.

C2SIM Air Operation Ontology



Initialization: define the secure data network and its participants

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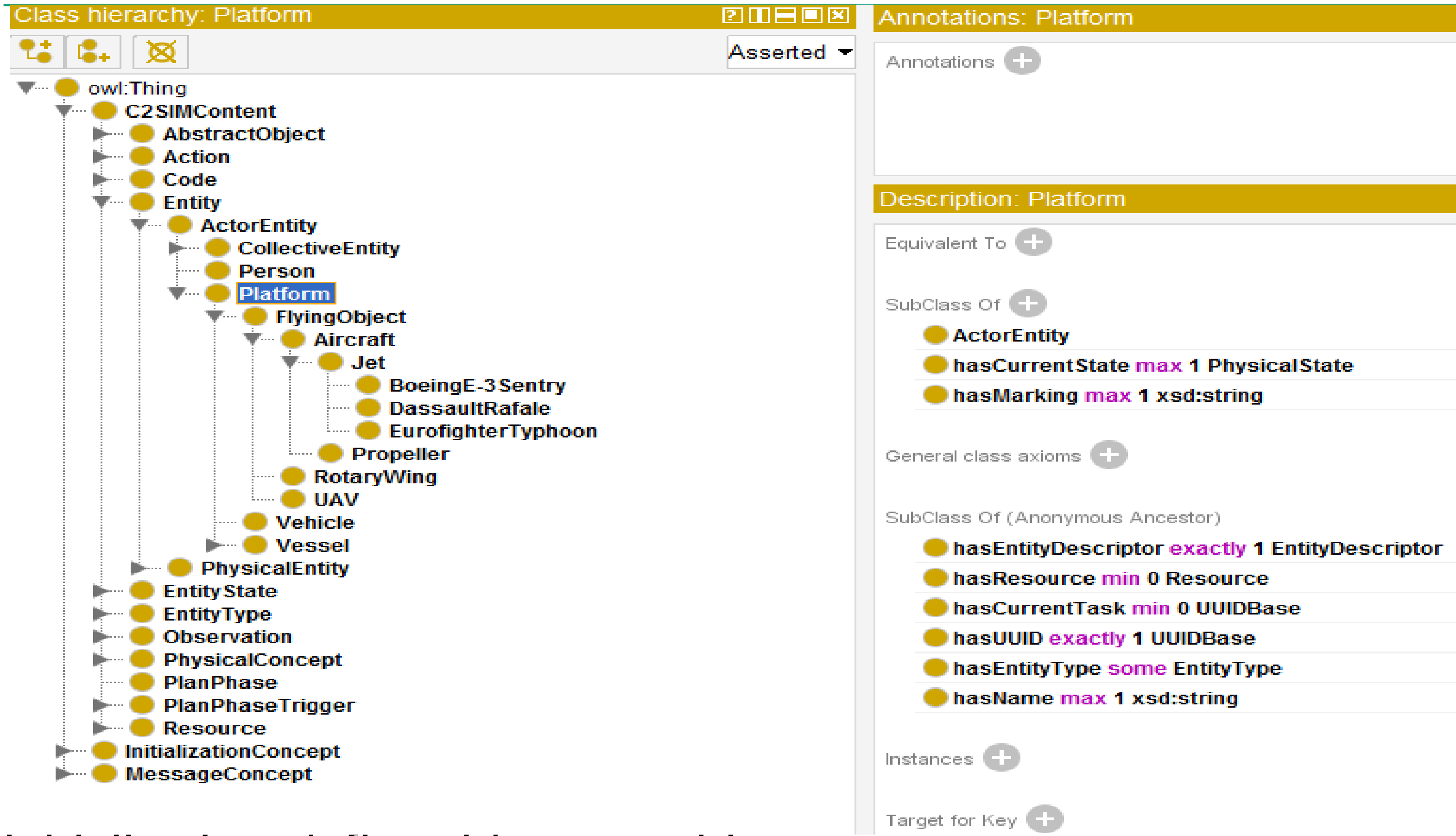
C2SIM Air Operation Ontology



Initialization: define airborne entities

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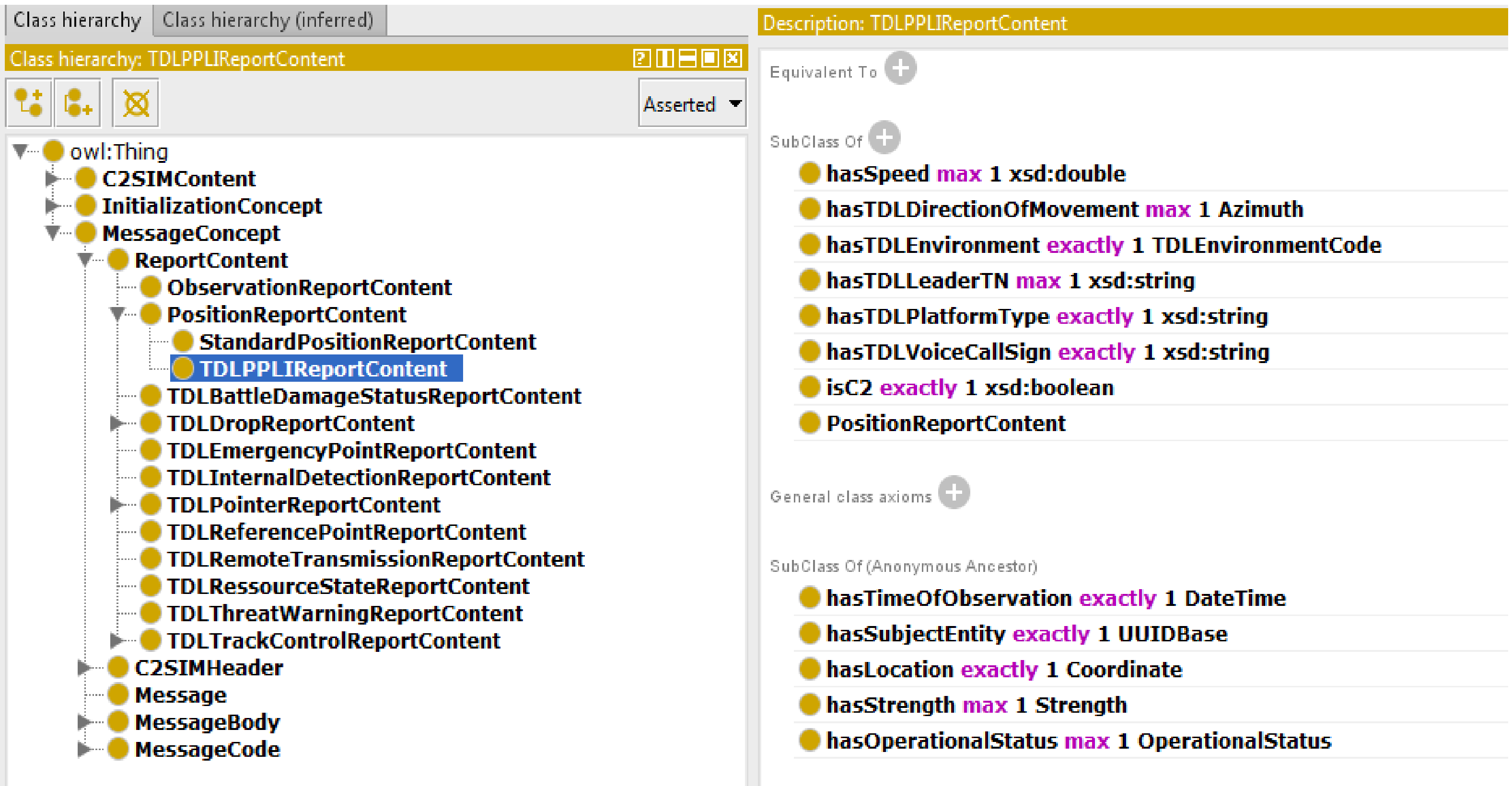
C2SIM Air Operation Ontology



Message Exchange: define TDL messages (example PPLI)

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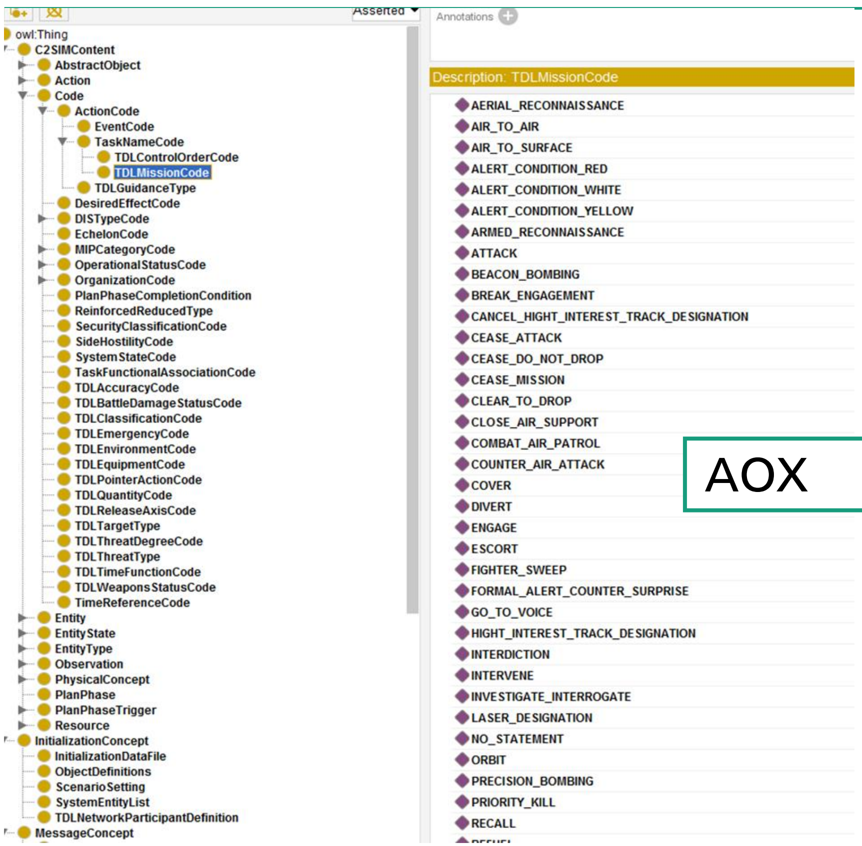
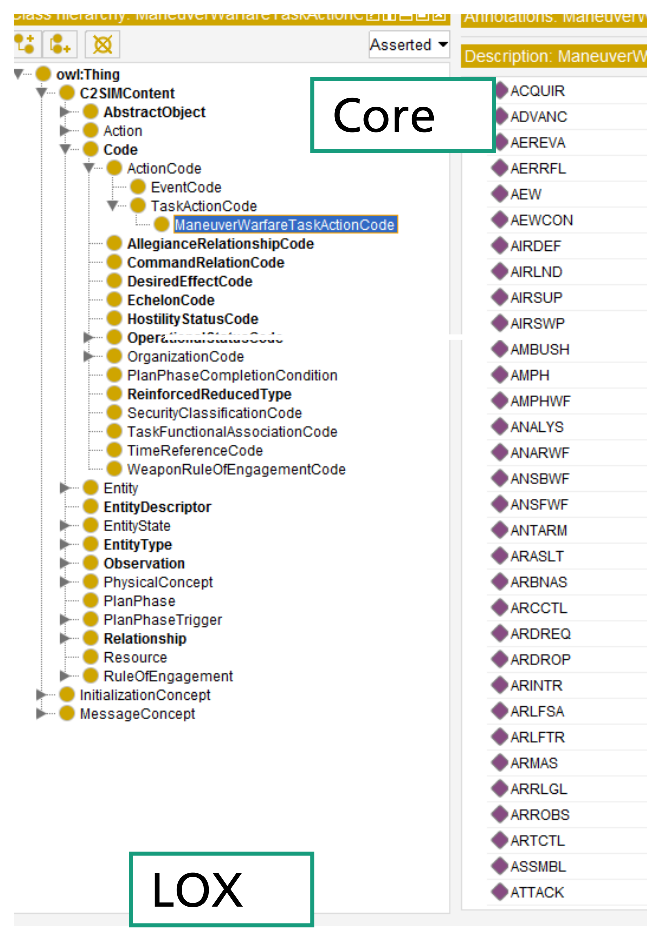
C2SIM Air Operation Ontology

TDL MissionCode





Message Exchange: TDLMissionCode

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C2SIM Air Operation Ontology

- **Defined in extension and experimented**
  - PPLI (J2.x)
  - RemoteTransmission (J3.2, J3.3, J3.4, J3.5, J3.6)
  - Drop (J7.0)
  - MissionAssignment (J12.0)

C-BML - Task

- **Defined in extension**
  - InternalDetection (J12.6, J12.7)
  - BattleDamageStatus (J10.2, J12.6)
  - ControlChange (J12.4, J12.3, J10.5)
  - Correlation (J7.2, J12.5)
  - EmergencyPoint (J3.1)
  - FlightPlan (J12.3)
  - FreeText (J28.2)
  - GuidanceOrder (J9.0)
  - Pointer (J7.3, J12.6)
  - ReferencePoint (J3.0)
  - RessourceState (J13.2, J13.3, J13.4, J13.5)
  - ThreatWarning (J15.0)

Battle Damage Status: The report content is

Control Change: A request from the air

Correlation: The report content is used by

Pointer: The report content is used to transmit

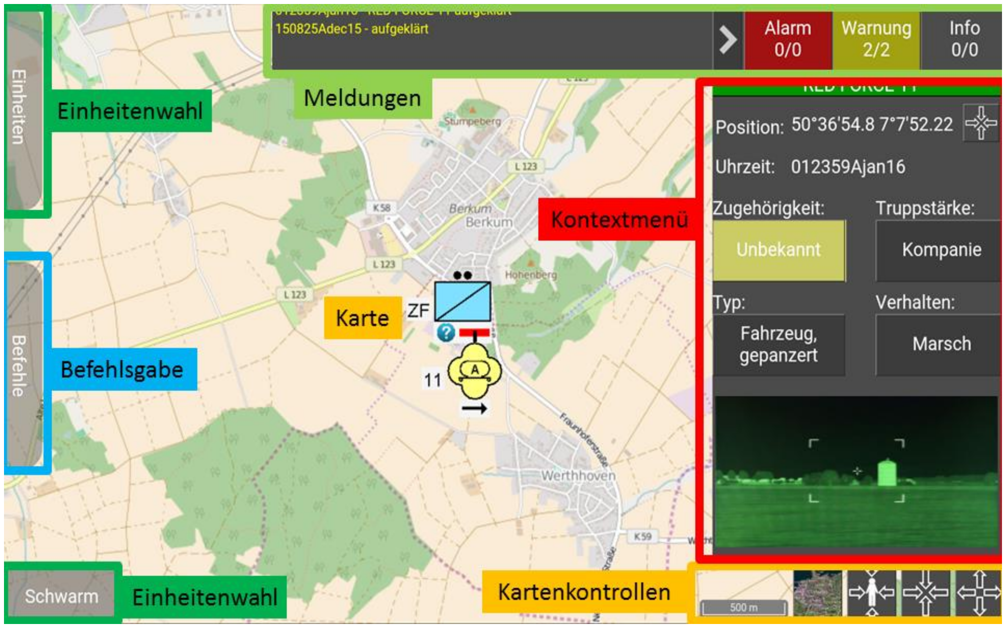
Reference Point: The report content is used to

Ressource State: The report content provides

Threat Warning: The report content provides the capability for threat warning to targeted friendly platforms to include threat type and threat posture.

Ground Operations with UAV deployment

- See LOX + UAVs (Italian expertise)



Unmanned systems send report about

- their position,
- their status,
- values measured by their sensors and
- images and video streams they have taken

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Rules for Tasking for UAVs

Rules for task (part of OrderBody):

- *[task] Defend* Tasker Taskee Affected AtWhere StartWhen (EndWhen) Mod Why Label
- *[task] Advance* Tasker Taskee RouteWhere StartWhen (EndWhen) Mod Why Label

Rules for reports:

- *[report] own image* Who URL AtWhere When Certainty Label
- *[report] own measurement* **Phenomenon** Who SensorIdentifier MeasuredValue UnitOfMeasurement AtWhere When Certainty Label

Example of report:

- [*report*] *own* ***measurement*** *Temperature* Longcross Weather-Sensor0815 16.5 degree Celsius **at** Hades **ongoing at** 20140131120000 RPTFCT report-256q

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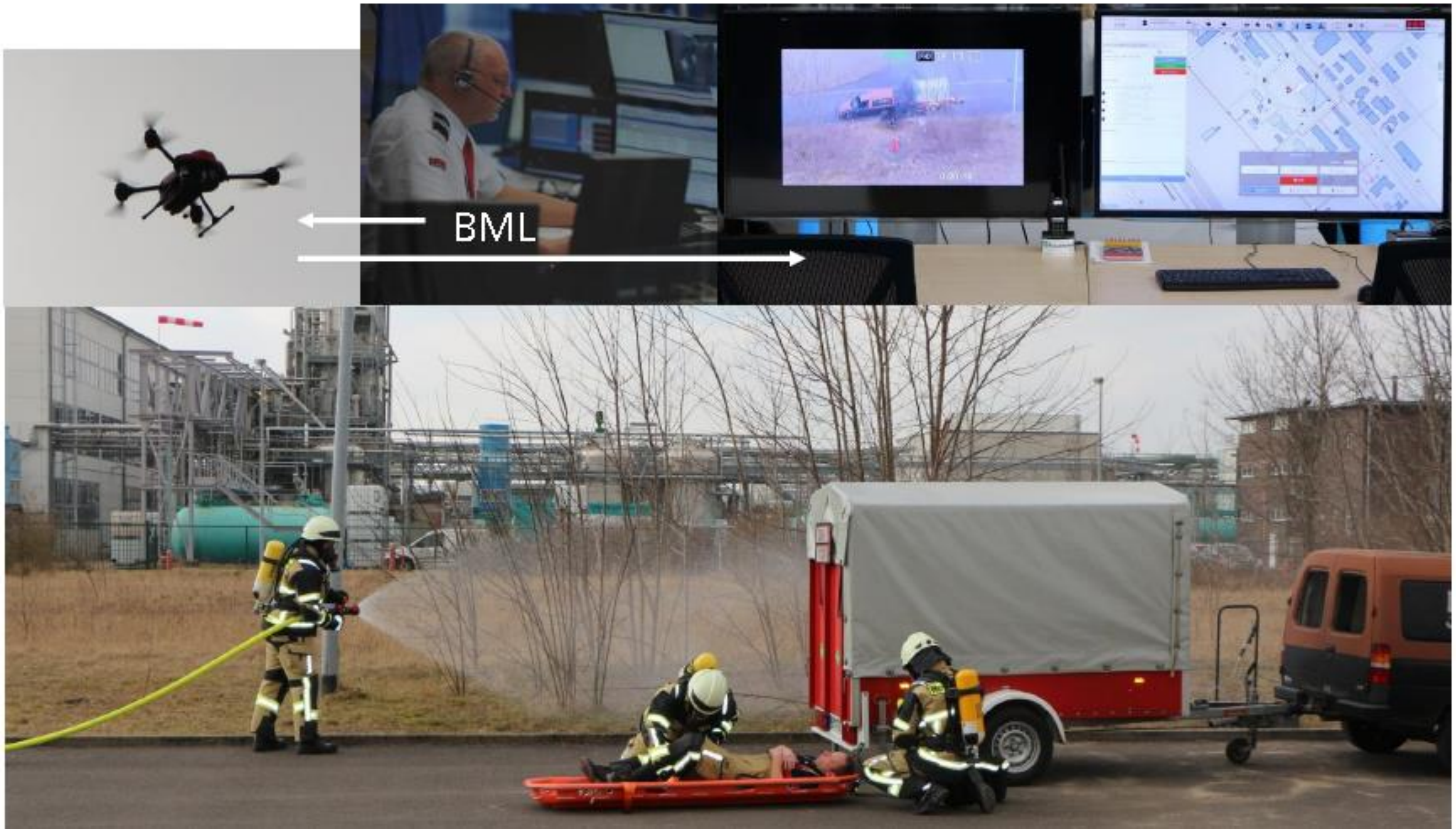
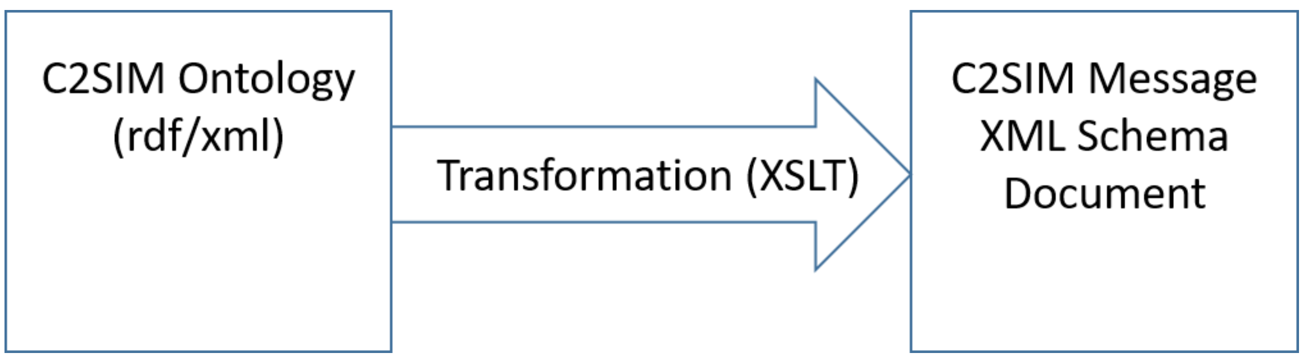
Another possible Use Case : Fireworker support



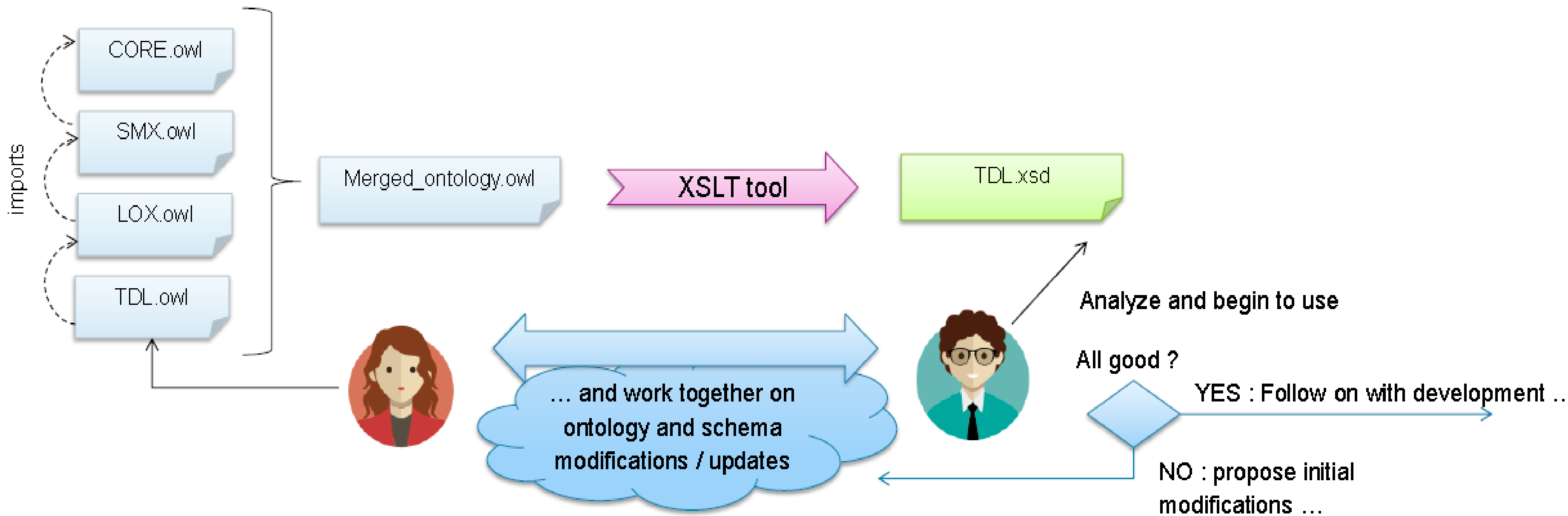
The Transformation to schema – to use information from ontology to systems

Extensible Stylesheet Language Transformations (XSLT) document to transform the ontology (the source) and generate an XML schema file (the output). Tool by Curt Blais (2019)



Design of the Air Operation extension: from ontology to schema

- Schema is generated with XSLT tool provided by SISO PDG (explained in Curt et. al, 2019)



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Schema generation

The SISO PDG found that representing information in an ontology and also exchanging that information in a standard way with a schema requires **compromise**. They agreed to constrain C2SIM ontology features somewhat in order to

- allow the schema resulting out of a transformation (ontology into schema) rendered possible by the tool developed by Curt Blais,
- achieve a workable standard in a reasonable time.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<Message xmlns="http://www.sisostds.org/schemas/C2SIM/1.1" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.sisostds.org/schemas/C2SIM/1.1 file:///C:/C2SIM/Comelec/Airbus/C2SIM_SMX_LOX_TDL.xsd">
    <C2SIMHeader>
        <StandardC2SIMHeader>
            <CommunicativeActTypeCode>Inform</CommunicativeActTypeCode>
            <MessageID>cd1d895f-ea3e-4858-906d-6abc93907a5d</MessageID>
            <Protocol>C2SIM</Protocol>
            <ProtocolVersion>1.1</ProtocolVersion>
            <SendingTime>2019-07-30T13:36:30:Z</SendingTime>
            <FromSendingSystem>C2LG</FromSendingSystem>
            <ToReceivingSystem>DirectCGF</ToReceivingSystem>
            <ConversationID>d10f9a43-e4ea-4edc-9ede-ebde7d5e1eb2</ConversationID>
        </StandardC2SIMHeader>
    </C2SIMHeader>
    <MessageBody>
        <DomainMessageBody>
            <OrderBody>
                <FromSender>00000000-0001-0001-1000-000000000000</FromSender>
                <ToReceiver>00000000-0000-0001-2000-000000000000</ToReceiver>
                <Task>
                    <TDLTask>
                        <TDLMissionTask>
                            <TaskNameCode>ATTACK</TaskNameCode>
                            <PerformingEntity>00000000-0000-0001-2000-000000000000</PerformingEntity>
                            <UUID>cd1d895f-ea3e-4858-906d-6abc93907a5e</UUID>
                            <Name>TDLMissionTask_1</Name>
                            <TDLMissionType>ATTACK</TDLMissionType>
                            <TDLTargetType>AIR_DEFENSES</TDLTargetType>
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                                <Angle>90</Angle>
                            </TDLAttackAxis>
                            <TDLClearanceAxis>LEFT</TDLClearanceAxis>
                            <TDLTargetPosition>
                                <Latitude>50.397138</Latitude>
                                <Longitude>9.862633</Longitude>
                            </TDLTargetPosition>
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                            <TDLTargetTN>501</TDLTargetTN>
                        </TDLMissionTask>
                    </TDLTask>
                </Task>
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                        <IsoDateTime>2019-07-30T13:36:30:Z</IsoDateTime>
                    </DateTime>
                </IssuedTime>
                <OrderID>cd1d895f-ea3e-4858-906d-6abc93907a5f</OrderID>
            </OrderBody>
        </DomainMessageBody>
    </MessageBody>
</Message>
```


TDL mission order as completed schema

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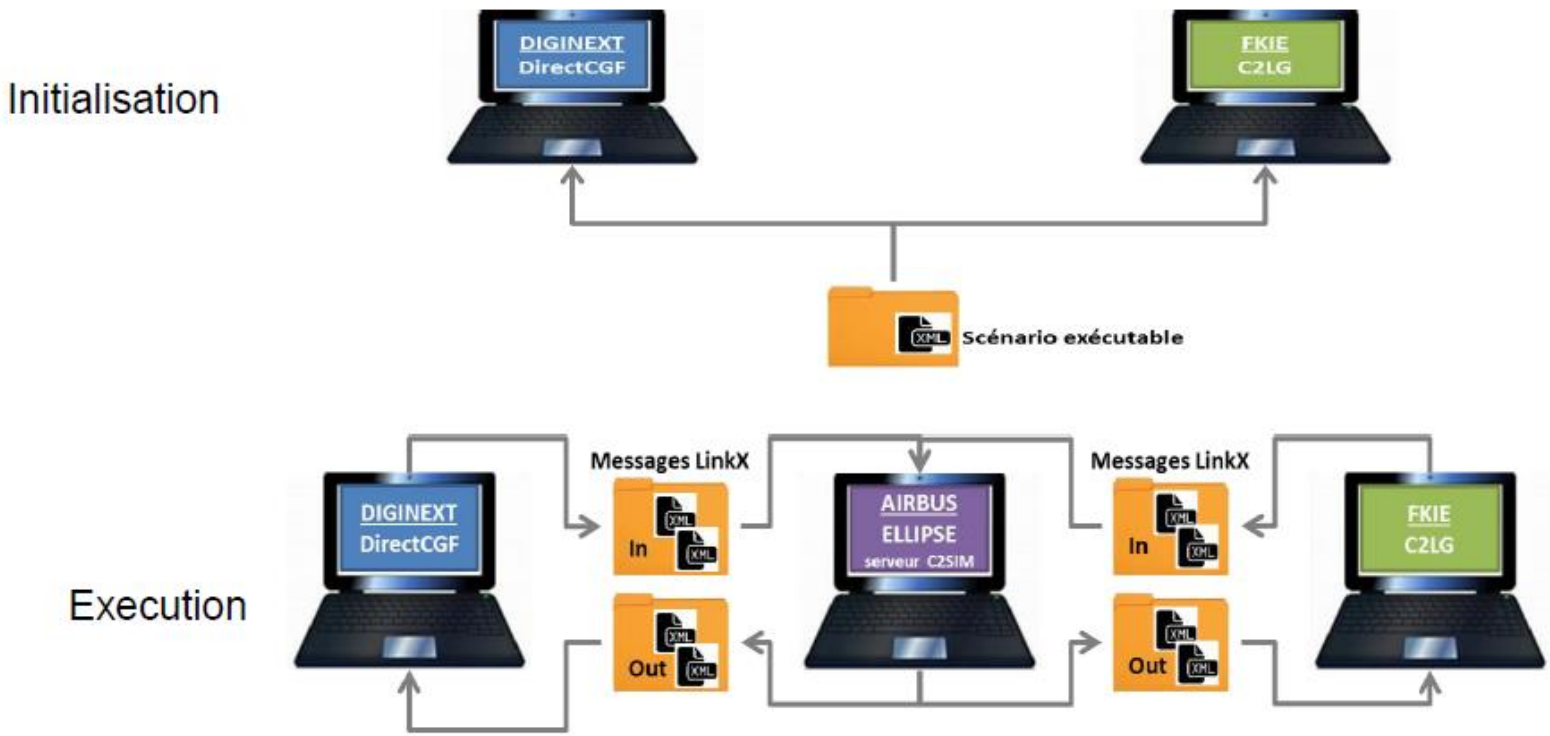
The Air Operation Demonstration's Architecture for I/ITSEC 2019



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Lessons Learned

- Since this is a project in which different members have different expertise,
- we learned from each other. We learned a lot from other colleagues from the SISO C2SIM PDG and the NATO MSG-145.
- Our FKIE group, for example, learned a lot about air operations, TDLs, tracks, and how to represent all this ontologically.
- We also learned some specifics on ontologies and how to build an extension to an already existing core.

Lessons Learned

Consistent ontologies do not work for the transformation tool if they are too complex:

- **Classes**
  - A class cannot be subclass of two different classes (vehicle as platform or resource)
  - No equivalent classes possible (just one name for a concept possible)
- **Properties**
  - Ambiguities can occur between object and datatype restrictions
  - Object Properties must have **ranges** filled (not necessary for owl)

Lessons Learned

- **Restriction**
  - If a class inherits a property from its superclass, it might happen that the range for that property is restricted more closely in comparison to the property’s range in the superclass:
  - For example, class “Task” has the property “hasTaskNameCode”.

  Its range is an enumeration of the codes for all assumed tasks, e.g. “move”.

  “Task” has the subclass “TDLTask” like “TakeControl”.

  “TDLTask” inherits “hasTaskNameCode” but is supposed only to use codes that are codes for TDL tasks.

Lessons Learned

- **Restriction**
  - Adding a (“new”) restriction to the subclass (“hasTDLTaskNameCode”) results in two lines in the schema (after transformation).
  - In order to achieve a working prototype, we currently have not added restricted restrictions to respective subclasses.
  - Instead, we trust the users to only generate messages that are meaningful.

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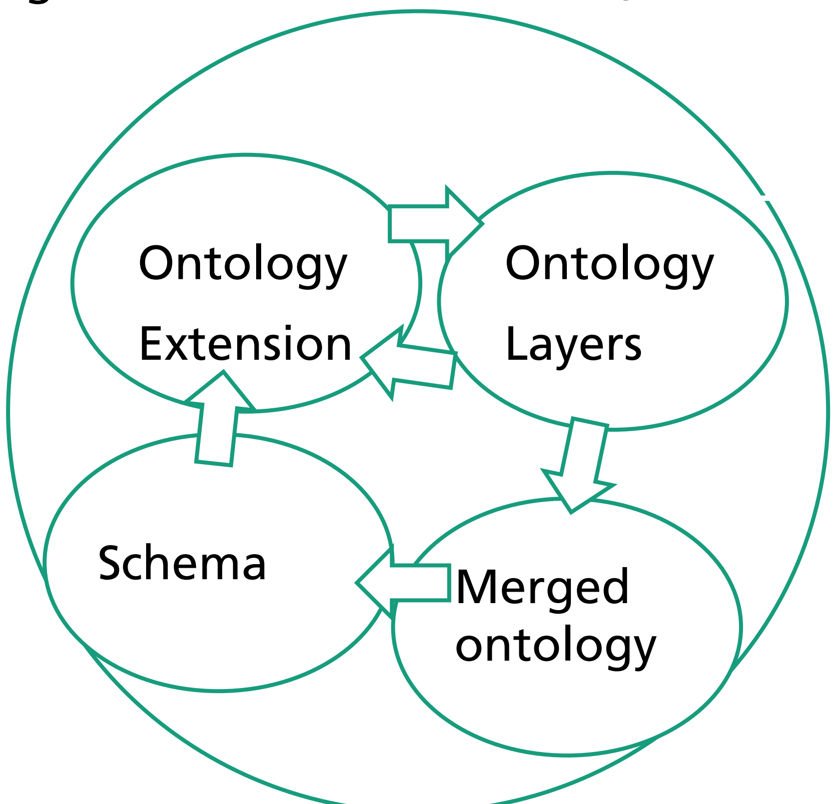
Lessons Learned

- Two ways to handle xslt limitations:
  1) Simplification of ontology (-> information loss)
  2) Propose PDG how information should be transformed into schema

  (Remember: ontology represents semantics
  schema represents syntax)

Lessons Learned

- Every step in the working cycle can affect every other step (ontology – ontology merging – schema transformation)



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Future Work: Reasoning Capabilites

- Reasoning derives knowledge from modelled knowledge
- Taxonomy actually does not have to be modelled manually ->
  - But correct and complete definitions of restricted classes will automatically be subsumed under the right classes

  - Reasoning in the C2SIM context:
    - Check unit hierarchy in messaging
    - Check entities and their capabilities
    - Check, if messages are semantically complete
    - Check if they are semantically consistent

Conclusion

Air Operation extension succeeded as:

- We were able to abide by Core + SMX structure
- We merged Core + SMX + Air Operation Extension
- We were able to automatically generate a schema out of the merged ontologies

-> Process evaluated to get a schema of ontology as proposed by PDG

- We created a schema that works for C2LG and for DirectCGF

-> Evaluation of exchange of C2LG and DirectCGF will be demonstrated at I/ITSEC 2019 in Orlando

Literature

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Thanks for Your attention!

Questions are appreciated.