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Overall System Modelling for System Engineering (OSMoSE) - Space System Ontology 1st Brainstorming Workshop Report

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1 SOLVING THE ECSS-E-TM-10-23A CHALLENGE

Industry and Agencies are confronted with the difficulty to exchange knowledge when working together in large projects such as our Space Systems development and Operations.

Although we have made a lot of progress in modelling information and developing information systems in the last decades, we still have difficulties in exchanging and reusing safely and efficiently the data and information.

Often, the reuse of the exchanged data is still negatively impacted by the lack of semantic compatibility between the processes used by the suppliers to generate and maintain the data to exchange, and those used by the customers, the users of the exchanged data.

Many attempts to address this problem have been taken in the past, but experience shows that in the usual setup of diverse and heterogeneous consortia in changing configurations it is not sufficient if one partner (e.g. a Prime, an Agency) is prescribing a specific view of the data (e.g. a single information system answering all partners' needs). It is also not sufficient to apply an exchange standard that one organization promotes to ensure that the quality of data is maintained through the exchange.

Through the years, discipline experts have solved a lot, and today exchanging discipline specific data between discipline experts is often going well. However, interoperating at "System" (or global) level is still highly problematic and complicated. The lack of adequate means to exchange knowledge/information/data results in additional tasks, such as re-qualification of the exchanged data, and therefore in additional risks and costs.

In 2010, within its E-TM-10-23A, ECSS has explained the difficulty of "working together" and raised the need for new languages/methods/processes to interoperate at the semantic level, implying the need for "Global" modelling. Since then, many of us have been working on finding solutions to the E-TM-10-23A expressed challenge.

2 BACKGROUND FOR THE WORKSHOP

The Space community has now got several experiences related to Model Based System Engineering (MBSE). These local experiences are done in the scope of one discipline, one phase or one stakeholder. However, the full deployment of MBSE in space projects requires exchanging data in the three dimensions (discipline, project phase and stakeholder). The lack of interoperability is an obstacle to the deployment of MBSE.

To address the issue, ESA has initiated a working group called Model Based For System Engineering (MB4SE), including five agencies (ESA, CNES, DLR, ASI, UKSA) and the three LSI's (ADS, TAS, OHB).

A couple of meetings have confirmed the need to address specifically two topics:

- the system engineering digital infrastructure (also called System Factory), whose main element is called "data hub", and
- a global conceptual model, called ontology, whose goal is to ensure, through automation, the needed interoperability.

The initiative to work on the Space System Ontology has been named the "Overall Semantic Modelling for System Engineering (OSMoSE)".

This workshop is the first brainstorming workshop organized. Its objective is:

- to gather the expert community on space ontology,
- to identify the various input available for the work and
- to think about the way forward.

3 OBJECTIVES OF THE WORKSHOP

Information about the Workshop can be found in:

https://indico.esa.int/event/310

The Agenda is also provided in Annex A.

The objectives, presented by ESA are:

Objective 1: to converge towards a Single European Ontology (and define what it is) for Space Projects

Objective 2: to specify what is required in term of ontology definition language

Objective 3: to identify the development steps

Objective 4: overall, to create the Space System Ontology governance

A set of questions are posted on Sli.Do for the audience to reply all along the workshop. See Annex B.

4 SUMMARY OF THE PRESENTATIONS

[ESA] ESA presented the background for this workshop:

- the MB4SE working group and
- the Harmonization dossier on System data Repository.

The workshop objectives and the question to which the workshop should reply were presented. The workshop intends to gather the relevant community, communicates the vision, and presents the existing experience in order to build on it to produce the ontology

Not all Industry has been invited, ESA intention being to first brainstorm with the National Agencies and the 3 Large Space Integrators.

[Bolzano] Bolzano introduced the principles of a formal (based on logic) ontology, with notions of Kinds, Roles, Mixin, etc.

A UML profile has been designed for that purpose (OMUML). The advice is that the ontologist needs a tool that checks continuously the ontology at each step of its development and ensures its overall consistency and quality.

[Bolzano] A good ontology language must balance:

- expressiveness vs tractability,
- parsimony vs convenience.

The advice is don’t use OWL as a user, but let tools use OWL for you.

ORM is therefore preferred, as it is expressive, graphical & concise.

[ADS] Airbus confirmed that a common conceptual model is needed. BUT the end result must be concrete for the user, otherwise the user will reject it.

The ontology should include a skeleton plus “run-time categories”.

The ontology will certainly need update (therefore we need a governance), and we need a reliable solution.

[DLR] DLR showed a global ontology based on a core, a base, and an external ontology.

The advice is to do it by step, and that the pieces should be loosely coupled.

[Strath] Natural Language Processing and Neural Networks can support the production of an ontology.

The ontology can be generated from text documents in “cake layers”. The two first layers, terms & synonyms, are already difficult!

The result needs human consolidation and validation, but clearly accelerate the process.

[SatS] Ontology for data sheet as support to e-business and business analysis

[Cnes] A data ontology must come with a corpus.

Data alone is not useful. This was clarified in the coffee break and verified that ESA includes indeed a corpus under the name “data”. In addition, it was confirmed that ontology encourages innovation.

[IRT] The Electronic Data Sheet (EDS, in the SAVOIR version, but also the CCSDS version) contributes widely to the ontology, and basically addresses the interoperability (between LSI and Supplier).

The presentation proposed a process to co-fill it with the Supplier.

[IRT] The prototype tool TeePee was presented as an example of data hub, using a slice of an ontology to target a particular need, in this case a design analysis by the LSI.

[Rhea] The MARVL study was presented.

A metamodel combines the ones of 10-25, VSD and EGSCC in order to produce an exchange format used in another example of data hub.

The connexion with an ontology would be possible by “replacing” the metamodel of the exchange format by the ontology.

The CDP4 tool was also presented, as an open source implementation of 10-25 (like OCDT for CDF)

[Kobl] An ontology for the “requirement engineering” concept was presented. It can potentially be used for the skeleton.

The need for an ontology architecture (foundation, core, domain-specific) was also addressed.

[TasGor] Arcadia is perceived as “the best method that we have at the moment”.

The reverse engineering of the Capella meta model is on-going. An extension to the NORMA software able to transform a ECORE model in the ORM language (fact types) has been used. This was followed by a “cleaning” exercise, removing from the reversed model the object oriented specific constructs that reduced to around 50% the number of valid fact types (+/- 400).

This work is considered a good input for the skeleton.

[Bolzano] ORM is concise. Its logic-based foundation enable the possible to reason on the model, e.g. identifying missing constraints, fact types that do not accept any population due to the effect of declared constraints/derivations.

The ORM to OWL transformation enables the possibility to use the OWL tools/reasoners.

The QUELO tool can validate an ontology by generating examples of text compliant with it.

[Esa] 

SysMlv2 is being produced by a large group of Agencies and Industrials, including Europeans. The full specification should be available in a couple of years. Its success depends on the tool vendors, but as there is no competitor method, it should succeed.

SysMLv2 is object-oriented and include behaviour. There is an API for tool independence. It is validated.

SysMLv2 and OWL are mappable (both directions) providing means to transform related models in both directions.

[Esa] JPL has ontology experience: the IMCE ontology, the OpenCAESAR data hub, the MSR project run with ESA, the OML language build on top of OWL, the OpenMBEE; all this experience must be considered for commonalities with our needs, as a benchmark, and for reference.

[Esa] the concept of ontology governance is presented, with a steering board and a design authority, and their attributions.

The various R&D related to the ontology are presented.

The way to use an ontology to actually implement interoperability is presented.

It is pointed out that the ontology should not just reside in a modelling tool, in a data repository but should be fully verbalized and documented/published (with our without any graphical representation to satisfy all potential users).

Figure 1 is a schematic representation of what is to be done to enable the semantic interoperability between two information systems (depending on whether one of the two systems is "to develop/new" and the other being a system that needs to be reversed engineered.)

The availability of a conceptual model enables the capability to automate the production of the logical and physical models.

The availability of a conceptual model that represents the shared semantics between the conceptual models of the two information systems enables the capability to automate the production of the Interface Control Document (data model) and its implementation (e.g. XSD) and the involved exporters / importers.

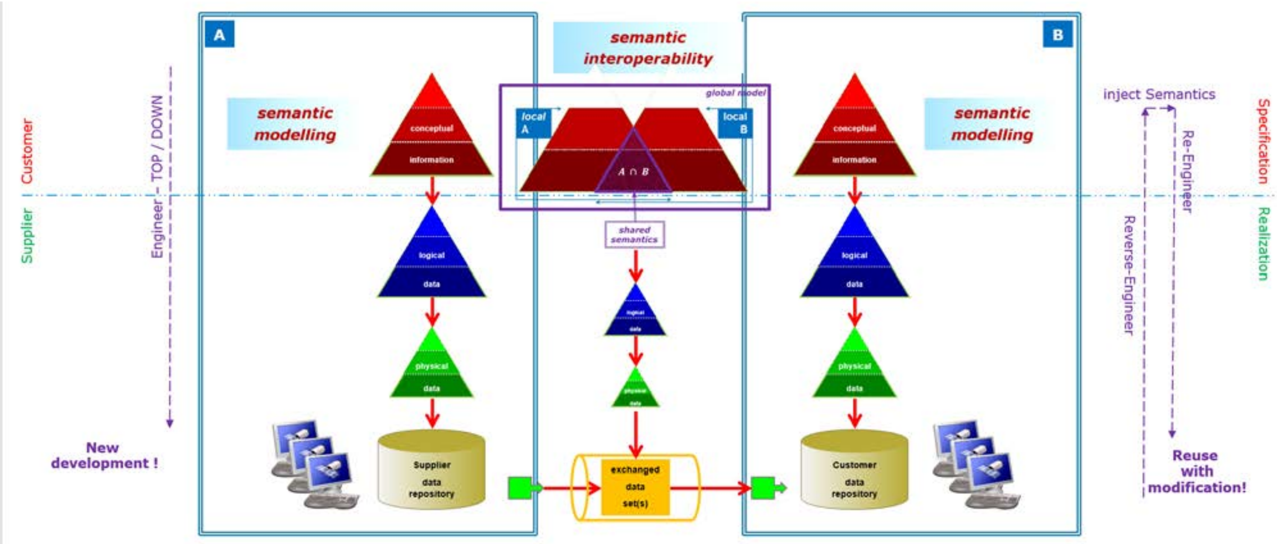


Figure 1 Semantic Modelling and Semantic Interoperability

Therefore, the engineers who will develop the system will never see the ontology itself. They will see their usual language. However, the ontology will be used to improve the tools that they use. As such, the ontology is transparent for them.

5 TAKE AWAY FROM THE PRESENTATIONS

- A global conceptual model is indeed needed [ADS].
- Developing an ontology needs a tool to check each step of its development. OWL, although it is conceptual, seems to be too low level (in terms of usability). This has been confirmed by JPL. OWL required a higher modelling language. JPL has produced OML for that purpose.
- OWL may be generated from ORM [Bolz].
- SysMLv2 is a major improvement of SysML, but will be available in two years. The ontology language is not to be exposed to the end-user engineer, who should still work with his familiar environment [ADS].
- The ontology must have a skeleton plus "categories"[ADS], or a core and a base and external ontologies [DLR], or a foundation and a core and a domain ontologies [Kobl], and pieces must be loosely coupled [DLR]

- The Capella data model is a major starting point of the skeleton [TASGor]. The Electronic Data Sheet is an essential element of the ontology [IRT], as well as the requirement ontology [Kobl].
- An ontology needs a governance, without which it becomes a risk [ADS].
- A use case of ontology is for products commercialization and selection, filtering, sorting of products on a merchant website [SatS], where EDS are needed, although with less information than the SAVOIR EDS [IRT].
- Ontologies can be used to configure data hubs [IRT; Rhea]

6 ACHIEVEMENT OF THE WORKSHOP OBJECTIVES

6.1 Obj.1 - To converge towards a Single European Ontology (and define what it is) for Space Projects

At the end of the workshop, the audience has a better idea of what it is, through the various examples and experiences, and what it is for, through the presentation on generating interface exchange format from ontologies.

6.2 Obj.2 – To specify what is required in term of ontology definition language

An ontology language must balance expressiveness vs tractability, parsimony vs convenience.

Several presentations have been made related to OWL, ORM and SysMLv2.

The preferred language from the presentation is ORM, as OWL is difficult to manipulate and needs anyhow a higher-level language, and SysMLv2 is not yet ready.

At the moment, there is no showstopper for the use of ORM. However, the ORM ecosystem in Europe is fragile and needs to be consolidated.

6.3 Obj.3 - To identify the development steps

The presentations have shown an increased confidence in a development based on a “skeleton”, followed by complementary elements, possibly loosely coupled, or “loadable”.

The ontology architecture is important, in terms of a base/foundation ontology (considered part of the tooling), a core ontology (the skeleton) and external/domain ontologies.

Each ontology development steps must be immediately verified and validated by the Stakeholders. Having reasoners available for ORM is key for supporting the verification of the model.

The NORMA tool, proposed to be used, do not yet implement all engineering and reverse-engineering support functionality required. Relational to ORM to Relational is supported (for the major RDBMS), ECORE to ORM to ECORE and Hierarchical to ORM to Hierarchical are under prototyping. Code generators exist but not yet for all required implementations.

The NORMA tool serializes the conceptual model in XML. Some parts of the model (e.g. verbalization) is calculated whenever required. Access to the full data model (conceptual, logical) is a mandatory need to enable the development of tools...

For ORM and NORMA, see Appendix C

6.4 Obj-4 - Overall, to create the Space System Ontology governance

The need for a governance has been clearly identified. It includes:

- a management governance for objectives, priorities, approval of plans, deployment, dissemination, legal, roadmap, schedule, risk,..
- a design authority for language, scope, development plan and development, validation, impact analysis on existing, tooling needs and development, configuration management, baseline and maintenance.

This requires the redaction of a document as a result of interactions within the community, which describes the management and technical governance. This include the ontology development plan and the ontology tools development together with the consolidation of the technology ecosystem.

APPENDIX A. PROGRAMME

Tuesday, 25 June

08:00	→ 09:00	**Registration**	1h
09:00	→ 09:10	**Welcome** Speaker: Serge Valera (ESA/ESTEC) Presentation - 0900 ...	10m
09:10	→ 09:30	**Model based for System Engineering (MB4SE) advisory group** Speaker: Jean-Loup TERRAILLON (ESA) Presentation - 0910 ...	20m
09:30	→ 10:10	**ECSS-E-TM-10-23A / ECSS-E-TM-10-25A and their recommendations on how to address information modelling and interoperability** Speakers: Mr Hans-Peter de Koning (ESA/ESTEC), Serge Valera (ESA/ESTEC) Presentation - 0930... Presentation - 0930...	40m
10:10	→ 10:50	**Foundations and Methodologies for conceptual modelling** Speaker: Prof. Giancarlo Guizzardi (Free University of Bozen-Bolzano)	40m
10:50	→ 11:20	**Coffee Break**	30m
11:20	→ 11:50	**Introduction to ORM "Object Role Modelling" language** Speaker: Prof. Enrico Franconi (Free University of Bozen-Bolzano) Presentation - 1120 ...	30m
11:50	→ 12:20	**Introduction to OWL "Web Ontology Language"** Speaker: Prof. Enrico Franconi (Free University of Bozen-Bolzano) Presentation - 1120 ...	30m
12:20	→ 12:50	**Applying ECSS-E-TM-10-23A – Lessons learned** Speakers: Mr Claude Cazenave (Airbus DS), Mr Harald Eisenmann (Airbus DS) Presentation - 1220 ...	30m
12:50	→ 14:00	**Lunch Break**	1h 10m

14:00 → 14:30 **Satellite products ontology development in DLR** 30m
Speaker: Dr Kobkaew Opasjumruskit (DLR)
Abstract - Kobkaew ... Presentation - 1400 ...

14:30 → 15:00 **Applying Ontology learning to the generation of a Space Mission Ontology** 30m
Speaker: Ms Audrey Berquand (University of Strathclyde)
Abstract - Audrey B... Presentation - 1430 ...

15:00 → 15:30 **Development of a universal ontology for the global space supply chain** 30m
Speaker: Mr Kartik Kumar (SatSearch)
Abstract - Kartik Ku... Presentation - 1500 ...

15:30 → 16:00 **Coffee Break** 30m

16:00 → 16:30 **ECSS eGlossary WG and eGlossary proof of concept** 30m
Speaker: Mr Marcel Henriquez (RedData Search)
Presentation - 1600 ...

16:30 → 17:00 **Inter-Agency cooperation for the sharing and production of Semantic resources** 30m
Speaker: Mr Daniel Galarreta (CNES)
Presentation - 1630 ...

17:00 → 17:30 **SAVOIR Electronic Data Sheet: A digital capability for avionics architecture co-design + Teepee** 30m
Speakers: Ms Marie-Hélène Deredempt (Airbus DS), Mr Pierre Gaufillet (Airbus DS)
Presentation - 1700 ...

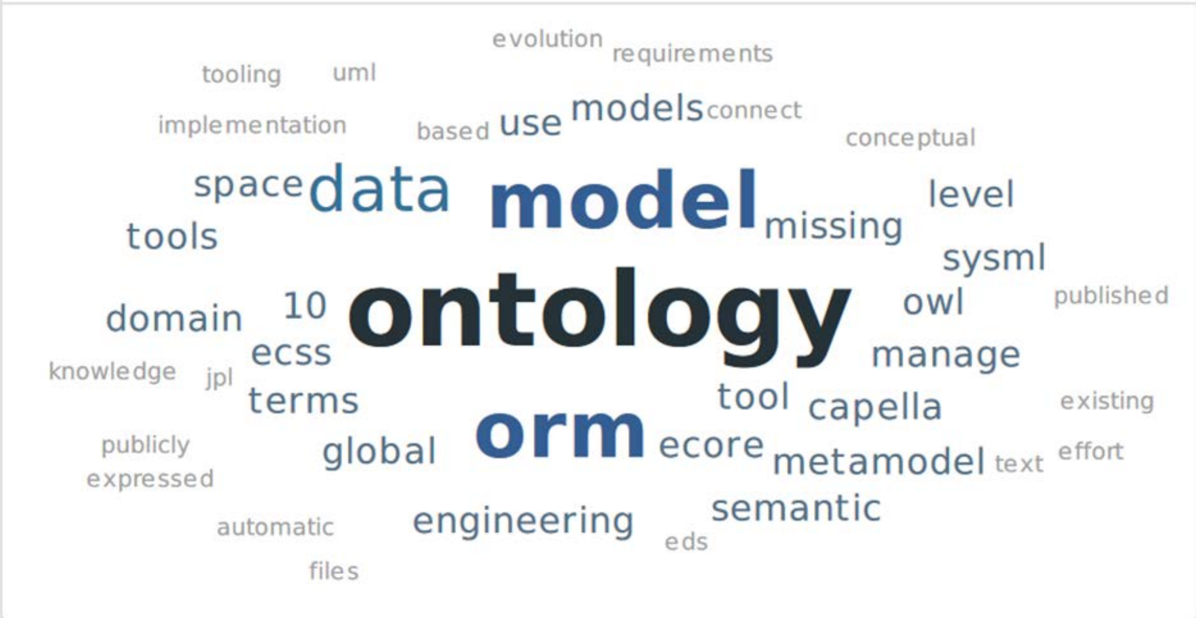
17:30 → 18:30 **Cocktail Drink** 1h

Wednesday, 26 June

09:00	→ 09:30	**Registration**	30m
09:30	→ 10:00	**Model-Based Requirements Verification Lifecycle – MARVL** **Speaker**: Mr Sam Gerené (RHEA Group) Presentation - 0930 ...	30m
10:00	→ 10:30	**Conceptualizing requirements- Developing a requirements meta-model for European Space with ORM** **Speaker**: Ms Katharina Grosser (University of Koblenz) Presentation - 1000 ...	30m
10:30	→ 11:00	**Coffee Break**	30m
11:00	→ 11:30	**ECORE to ORM - Reverse Engineering Capella** **Speakers**: Mr Gérald Garcia (Thales Alenia Space), Mr Kaiton Buitendijk (GorillaIT) Presentation - 1100 ...	30m
11:30	→ 12:00	**OWL-based reasoning supporting ORM conceptual modelling with rules** **Speaker**: Prof. Enrico Franconi (Free University of Bozen-Bolzano)	30m
12:00	→ 14:00	**Lunch Break**	2h
14:00	→ 14:30	**SysML and on-going SysML v2 evolution** **Speaker**: Mr Hans-Peter de Koning (ESA/ESTEC) Presentation - 1400 ...	30m
14:30	→ 15:00	**Learning from NASA JPL's Ontology development using OWL and OML** **Speaker**: Mr Hans-Peter de Koning (ESA/ESTEC) Presentation - 1430 ...	30m
15:00	→ 15:30	**Coffee Break**	30m
15:30	→ 16:30	**Space System Ontology TRP and OSMoSE governance** **Speakers**: Jean-Loup TERRAILLON (ESA), Serge Valera (ESA/ESTEC) Presentation & Con...	1h
16:30	→ 17:00	**Conclusion** **Speakers**: Mr Hans-Peter de Koning (ESA/ESTEC), Jean-Loup TERRAILLON (ESA), Serge Valera (ESA/ESTEC)	30m

APPENDIX B. SLI.DO

The workshop showed 39 active Sli.Do users for an engagement score of 145 (3.7 per user), 100 questions have been asked (for 121 like) and the questions were replied by 56 users.



Space System Ontology Workshop

25 - 26 Jun 2019

Poll results

SURVEY (1/11)

What are the use cases of interoperability?

What do we need to exchange?

- Requirements, tests, piece of Capella model, PBS, FBS, Life Cycle, MAIT operations, data with their uncertainties (such as geometry, costing, performance, thermal...)
- External for extended enterprise simplifying exchange and providing detailed access to supplier catalogue but also for e review
- Parameters, units, interfaces, models
- All engineering data used to design and validate a system.
- I would start with what is already exchanged with documents
- Shared definitions of requirement relevant terms and constraints, necessary inputs for next step developments

- Exchange of information across distinct organizations within the value chain, for a given project.

SURVEY (2/11)

Is the ontology to be limited to what we want to exchange (only system, also domain-specific,...) ?

- Begin with the system and then add domain one by one because it will be too difficult to do directly the whole ontology.
- Exchange should be the focus, anything else is an incidental benefit
- No a priori limit
- Yes, the standardized ontology should be limited to the exchange, with the capability to extend it if necessary
- Each ontology is also driven by its purpose. It will not work to create the one and for all model. To address this several interlinked ontologies should be developed with defined scope.
- I see rather many ontologies, so e.g. one per domain, but connected by a "base ontology" or at least a "base vocabulary". "system alone" is not enough

SURVEY (3/11)

What is the perimeter of the ontology (segment,...)?

Do we need a “skeleton” that can be used by all?

What is in it?

Does it include e.g. a “requirement model”? (1/3)

- If it's for an ECSS it should be applicable to each segment ground launcher and payload (manned spacecraft or not).
- Moreover as a new space run is starting to go back to the Moon or Mars maybe some new segments will be added. These new missions will need more complex studies so an ontology will be more necessary.
- Transcribing existing standards into ontology form should be enough to be going on with. Skeleton based on Etm1023 has proven to be useful from industry point of view
- In the long term, everything that is currently exchanged in documents should be exchanged with models. As a starting point a skeleton shall include at least product structure, function tree, mission data, relevant properties, requirements and geometry. Skeleton based on Etm1023 has proven to be useful from industry point of view Skeleton based on Etm1023 has proven to be useful from industry point of view
- The system hast to be modular and layered. What you call a skeleton here is a foundation ontology which concepts are used in most other more specialized ontologies. This makes sense. I don’t think, that the requirement (management) is necessarily part of that, but the building blocks of requirements are.
- We need a basis to ensure interoperability between domains and a universal "design" of the ontologies. Also, concepts that are relevant for all domains should be defined for all (e.g. each component has a "weight" - it then must be "weight" everywhere, not "mass" sometimes

Survey (4/11)

After the skeleton, how to define priorities in the development?

- I like the comparison that has been made with open source projects. The skeleton need to be done first to organize everything. But then each user can fill it if he needs something that is not available yet.
- Volume and criticality of data exchanged. 20,000 parameters or 500 test data sets are more in need of automation support than things there are only a few examples of.
- M&C first, then electrical domain (because of the relationship with M&C), then other domains like thermal, mechanical, system... Priority on elec is also due to amount of data exchange with suppliers.
- I would see what happens at project level during the deployment of the "skeleton", capture needs, set priorities on the basis of the needs and work on those.
- What is easy to achieve, easy to agree on most urgently needed

Survey (5/11)

Are current modelling tools adequate? Do we need to extend their capabilities?

- They are probably not adequate. Even if an ontology is made to define an organization schema for data. Tools are currently not able to use it.
- No. Someone probably does, not sure about the 'we'.
- UML has been proven to be good enough for digitalisation at Airbus. Nothing more is expected to achieve our modeling activities
- The user interface of the current tool is discouraging the tools to be used by everybody.
- Too much focus is given to the method and the data model, while nothing on the user side. Moreover, the "uml-like" tool is not easy to use by any type of user.
- All tools for ontology modelling are more or less academic prototypes that are hard to handle or only supporting a fraction of capabilities

Survey (6/11)

What does semantic interoperability mean? Do we need to change our way to model? How can the existing be reused?

- It's being able to reuse something in another context without too much effort. We need to have tools that are consistent with a define ontology and then to map each data with this ontology so that it can be reuse by any other tool/team. To reuse the existing the best would be to use the closest ontology to the most used tool.
- Something is either interoperable or not. Semantic interoperability would mean interoperability driven by 'semantic' technologies, as opposed to relational, model- based, or whatever.
- Semantic interoperability means to share information, how it is structured and which conventions, simplification and assumptions have been used.
- Good question! Looks very difficult to achieve automatic translation between conceptual data models. A common language for engineers based on a common data model sounds to be a more

realistic approach. However it is difficult to have a unique one but a step by step approach starting with a good skeleton is achievable

- Clearly separate reusable from instance specific knowledge make existing things available so it's easier to reuse than to reinvent

Survey (7/11)

What reverse-engineering steps are required to allow a reused system to be integrated to the "Space System Ontology qualified tools" How can tools support each partner in the qualification process of their to-be-reused solutions?

- That would depend on the tool functionality and the requirements it had for interoperability.. Provision reference implementations and full test data sets is helpful.
- Not so much a matter of tooling but rather to share the knowledge, be open to a common modelling thanks to the acknowledgment of the benefits it brings
- More than reverse engineering, the key could be the required effort to model legacy system and to recover the missing information from the documentation
- We have the idea to create API and DB schemas from ontology, which should enable a good interoperability to existing systems.

Survey (8/11)

What dimensions the Ontology shall support? Project Phases [Time], Branches and Disciplines [Scope], Stakeholders [Geography]

- Also project management (kpi, access, baseline, update,...) Pretty much all.
- Branches and disciplines rather than time since time will refine the data and complement the structure rather than changing it
- More than phases I would talk about activities and objectives, ok for the disciplines. More than geography I would talk about organizational dimension (customer, supplier, partner, etc.)
- Extendable

Survey (9/11)

Does the ontology language and methodology support intrinsically the semantic interoperability?

How to implement semantic interoperability e.g. when stakeholders are not presents at the same time?

- By writing down documents saying what things mean.
- Using standards and schemes means this needs to be done less times, instead of exposing the concept of 'byte order' in every ICD.
- Not yet convinced about that but I would like to know more about it thanks to this workshop
- Not all the needed pieces of information can be captured in a data structure. A way for to capture assumptions, concerns, comments could help Difficult. There is always room for misunderstandings, because already the name of a concept puts a different idea in each stakeholders head. There is always the need for further description and discussion.

Survey (10/11)

Can we use ontology learning to generate our ontology from ECSS?

- Probably and to maintain it. Probably not.
- I am a bit skeptical but it can help to check the consistency and the coverage of the model Yes, but it is not trivial. First, ECSS is not completely machine interpretable. It requires human interaction and interpretation. Second, not all manufacturers are following the standard. This can get complicated when we want to apply the ontology to a model associated with the existing components in the market.
- I would use many examples coming from real projects and capture the feedback of the project teams. Can it be done with ontology learning in an easy way?
- Maybe for parts, but it is always at least semi- automatic and building a new ontology the "classic way" also allows to rethink a few things

Survey (11/11)

What is in the OSMoSE project plan / in the OSMoSE governance: the IPR management, the design authority, the deployment policy, etc.?

- No idea
- The OSMoSE should provide the governance of the ontology (IPR, DA, deployment, etc.), but also capture and analyze needs and feedbacks from the projects (the customers of the OSMoSE), without adding additional effort to them

APPENDIX C. NORMA FREEWARE

NORMA software runs on Microsoft Visual Basic.

The 2017 and 2019 builds are in the Visual Studio Marketplace.

You can download the .vsix files (which you double-click to install) from:

https://marketplace.visualstudio.com/items?itemName=ORMSolutions.NORMA2017

https://marketplace.visualstudio.com/items?itemName=ORMSolutions.NORMA2019

The information pages for the extensions also have links to the tutorials on orm.net but it is easiest to just install from inside Visual Studio.

In VS2017 use the Tools/Extensions and Updates dialog, click 'Online' on the left, then search for NORMA.

In VS2019 the dialog has moved to Extensions/Manage Extensions.

The code is linked from the extension dialog and is at https://github.com/ORMSolutions/NORMA

VS 2015 and earlier are still available for download at https://sourceforge.net/projects/orm

The Object-Role Modeling Fundamentals – A Practical Guide in Data Modelling with ORM from Terry Halpin is a good guide to start learning about ORM and NORMA, refer to www.orm.net.

APPENDIX D. AN EXAMPLE OF HOW ORM CAN BE USED IN SUPPORT TO THE PRODUCTION OF REQUIREMENTS SPECIFICATIONS

See ECSS-E-TM-10-23A Requirement model - A FBM use case with ORM Notation.pdf