DIGIPROC

EXECUTIVE SUMMARY REPORT

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1. INTRODUCTION

1.1. CONTEXT AND BACKGROUND

Model-Based Systems Engineering (MBSE) has demonstrated to bring significant advantages over traditional techniques. The goal is to extend its application to Space System developments, covering all lifecycle phases and processes. The underlying concept behind MBSE is the digitalisation of processes, which eliminates the need for manual actions that result in inefficient resource allocation, and streamlines workflows, making it easier to monitor and optimise tasks. Current engineering digitalisation activities mainly focus on the technical aspects of a project, namely specification, design, analyses, or V&V. Nonetheless, non-technical activities interfacing with technical processes are also vital for the correct development of a project, being Procurement processes part of this category.

DIGIPROC (Digital Engineering and Procurement across the Lifecycle) project contributes to the digitalisation of Space Systems by focusing on the Procurement side. Along these lines, a specific ontology for Procurement is defined, which is expected to be part of the global Space Systems Ontology (SSO) [RD.1].

1.2. OBJECTIVE

The primary goal of the DIGIPROC activity is to conceptualise the Space Systems Procurement Processes across Customer-Supplier boundaries throughout the space mission project lifecycle, using digital modelling technologies. This Ontology shall focus on exchanged information between the stakeholders involved in these processes, thus putting processes interfaces in the spotlight of the study.

Specifically, the objectives of the activity are:

1. To characterise Procurement processes, representing the current practices and state-of-the-art. This includes the identification of available tools, data representations, and archetypes (for example, a data template or standard).
2. To identify the main Procurement Use Cases that could benefit from digitalisation, and formally represent them using BPMN (Business Process Model and Notation) [RD.2].
3. To conceptualise the Procurement Universe of Discourse (UoD) using the ORM language [RD.3] and the NORMA Pro tool [RD.4], considering the scope and modelling conventions agreed with ESA and OSMoSE Governance group [RD.1].
4. To validate the Procurement UoD by Procurement experts' review and model population.

1.3. APPROACH

DIGIPROC is an ESA project carried by GMV Aerospace and Defence, S.A.U as prime contractor, and Airbus Defence and Space SAS, Thales Alenia Space France, and OHB System AG as subcontractors.

The approach adopted to achieve the project goals is characterised by a continuous collaborative work among the consortium to characterise and conceptualise Procurement processes. Several working sessions with experts in the field are held, resulting in active collaboration among the three Large System Integrators (LSIs) involved in the project, GMV and ESA. This collaboration has been in place throughout the project to gain feedback on the characterisation of processes and the semantics used to ensure accuracy.

2. PROJECT ACHIEVEMENTS AND RESULTS

2.1. CHARACTERISATION OF PROCUREMENT PROCESSES

DIGIPROC activity has carried out a comprehensive characterisation of the Procurement processes based on current practices and state-of-the-art. The scope of this characterisation has been defined to encompass all their relevant elements. Specifically, the following decisions were taken to define the scope:

- Procurement sub-processes characterisation shall focus on those involving more than one entity with different roles so that exchanges are performed during the process.
- Characterisation of Procurement sub-processes shall be generic enough to be applied to space, ground and operations, and launch segments.
- The characterisation of Procurement sub-processes shall be applicable at any Customer-Supplier level, ensuring an organisation-agnostic approach. The characterisation shall be able to include process recursiveness.
- Only current implementations of Procurement processes shall be considered, thus disregarding future digitalisations.

The sub-processes analysed are shown in Figure 2-1.

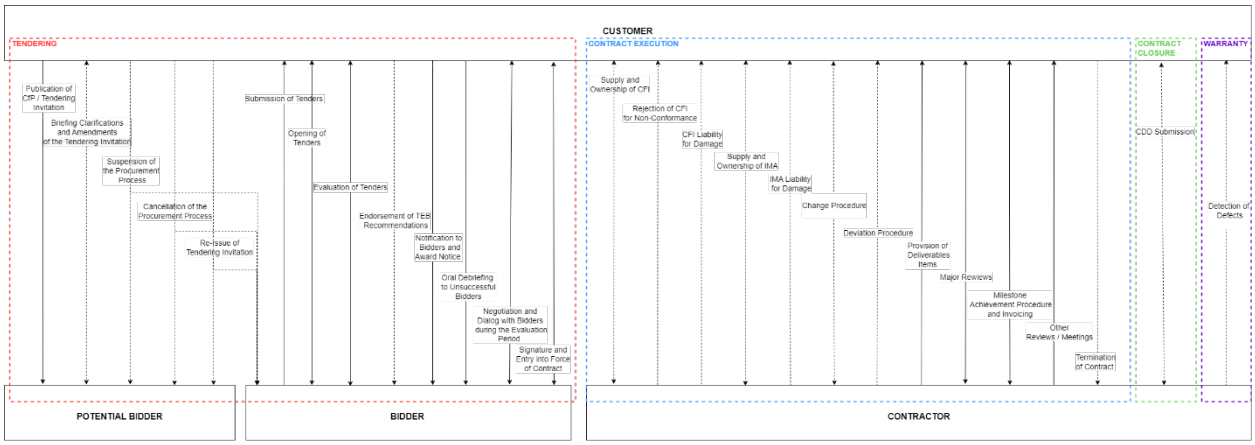

Figure 2-1: Overview of Procurement General Processes and Sub-processes

A detailed sub-process characterisation is elaborated, capturing the following information for each sub-process:

- Procurement general process associated to the subject Procurement sub-process.
- Type of sub-process, i.e. Mandatory or optional.
- Detailed description of the activities performed, including internal activities that do not involve any exchange.
- Identification of those roles involved in the sub-process.
- List of Procurement-related artefacts which are subjected to be exchanged among the roles.
- Identification of tools used to generate and/or deliver Exchange Artefacts.
- Identification of those areas of the Procurement sub-process in which digitalisation is seen as relevant and useful.
- Identification of the related Engineering Tasks and/or Milestones relevant to the subject Procurement sub-process.

This characterisation is then followed by a detailed analysis of data representations and domain-specific tools currently used in the Procurement sub-processes for the production and exchange of the identified Exchange Artefacts, including related ECSS templates, layouts, … used for formalising them.

The focus is then put on Legal and Contractual Aspects (LCAs) that appear when switching from a traditional document-based to a model-based approach in the engineering activities, leading to the exchange of digital Deliverable Items. The following LCAs are analysed.

Table 2-1: LCA for the exchange of digital Deliverable Items

ID	Legal & Contractual Aspect
LCA-01	The enforcement/recognition of a model as an applicable or deliverable item.
LCA-02	The acceptance of the related digital signature.
LCA-03	The definition of responsibilities and enhanced validation needs at different levels.
LCA-04	The remote access to models across the supply chain.
LCA-05	The legal issues (Intellectual Property Rights (IPR), licensing, compliance with export control regulations, etc.) associated to the level of access granted within such model(s).
LCA-06	The long-term preservation, accessibility, and readability of the models.

2.2. PROCUREMENT AND CONTRACT MANAGEMENT DIGITALISATION USE CASES

Taking the Procurement characterisation as input, a set of relevant Use Cases is identified - see Table 2-2. They represent common scenarios pertinent to Procurement digitalisation.

Table 2-2: Procurement and contract management digitalisation use cases

Process	Use Case ID	Use Case Name
Tendering	UC-TEN-010	Flow down of Tendering Invitation to Potential Subcontractors.
	UC-TEN-020	Management of Evaluation Grid when multiple organisations are involved in the TEB.
	UC-TEN-030	Management of Negotiation Items Record (NIR) elaboration and evolution through Contract Negotiation.
Contract Execution	UC-CEX-010	Generation of CCN from CR initiation and flow down to Subcontractors.
	UC-CEX-020	Management of Contract baseline evolution.
	UC-CEX-030	Management of contractual/technical milestone.
Contract Closure	UC-CCL-010	Elaboration of CCD and traceability to the Contract baseline and engineering artefacts.
Warranty	UC-WAR-010	Management of Warranty Deliverable Items during the maintenance period.

A complete description of each Use Case is provided, identifying the roles involved and the actions taken. Special focus on the procurement-related Exchange Artefacts which are subjected to be exchanged across the involved roles.

Then, BPMN (Business Process Model and Notation) [RD.2] is used to formally represent these Use Cases. BPMN is a standardised notation, simple for all stakeholders to comprehend, which makes Procurement Use Cases easier to understand. Furthermore, this representation facilitates conveying the information in an unambiguous way as well as the identification of the artefacts exchanged and their evolution through the space system development lifecycle.

The production of BPMN Use Case diagrams follows the process outlined below:

1. The Procurement General Processes (see section 2.1) are modelled in BPMN from a high-level viewpoint, using different diagrams. These processes include *Tendering*, *Contract Execution*, *Contract Closure* and *Warranty*. Despite being created in separate diagrams, they represent a continuous flow as shown in Figure 2-2.

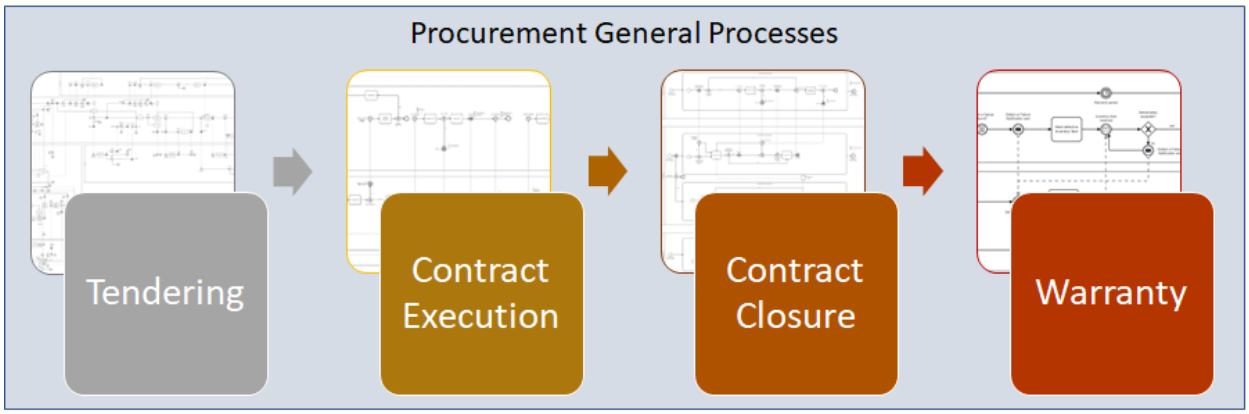

Figure 2-2: Procurement General Processes

When the flow transitions from one diagram to another, the end event name of the source diagram indicates the diagram that continues the flow upon reaching the event. For example, Figure 2-3 shows an extract of *tendering.bpmn* diagram. The end events indicate (using comments) that the flow continues in *contract_execution.bpmn* diagram.

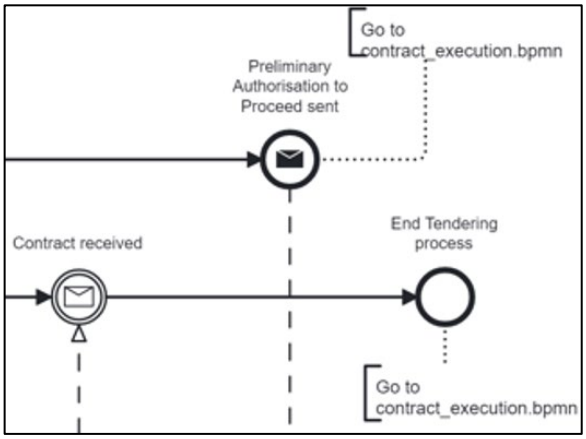

Figure 2-3: End events indicating the next diagram

2. Use Cases modelling in separate diagrams. This is accomplished by taking the BPMN Procurement General Processes as input and extracting the parts associated with each Use Case. Subsequently, Use Cases diagrams are refined and consolidated:
    - Irrelevant elements to the Use Case are removed.

      For example, Use Cases assume specific scenarios (e.g. there are Subcontractors, a milestone is achieved, etc.) to focus on and detail the processes performed in that particular scenario. As a result, some decisions, tasks, etc., are removed, while keeping the logic of the Use Case (i.e. if the BPMN elements are not relevant but they are required for understanding the flow of information in the Use Case, then they are kept).
    - Additional details are incorporated.

      The Procurement Global Processes are modelled from a high-level perspective. Nevertheless, Use Cases are more concrete, enabling the modelling of additional information, e.g. data objects, work performed within the activities, etc.
3. Finally, Use Case diagrams are validated by Procurement domain experts. Figure 2-4 illustrates an example of a Use Case BPMN model, the *Generation of CCN from CR initiation and flow down to Subcontractors* Use Case.

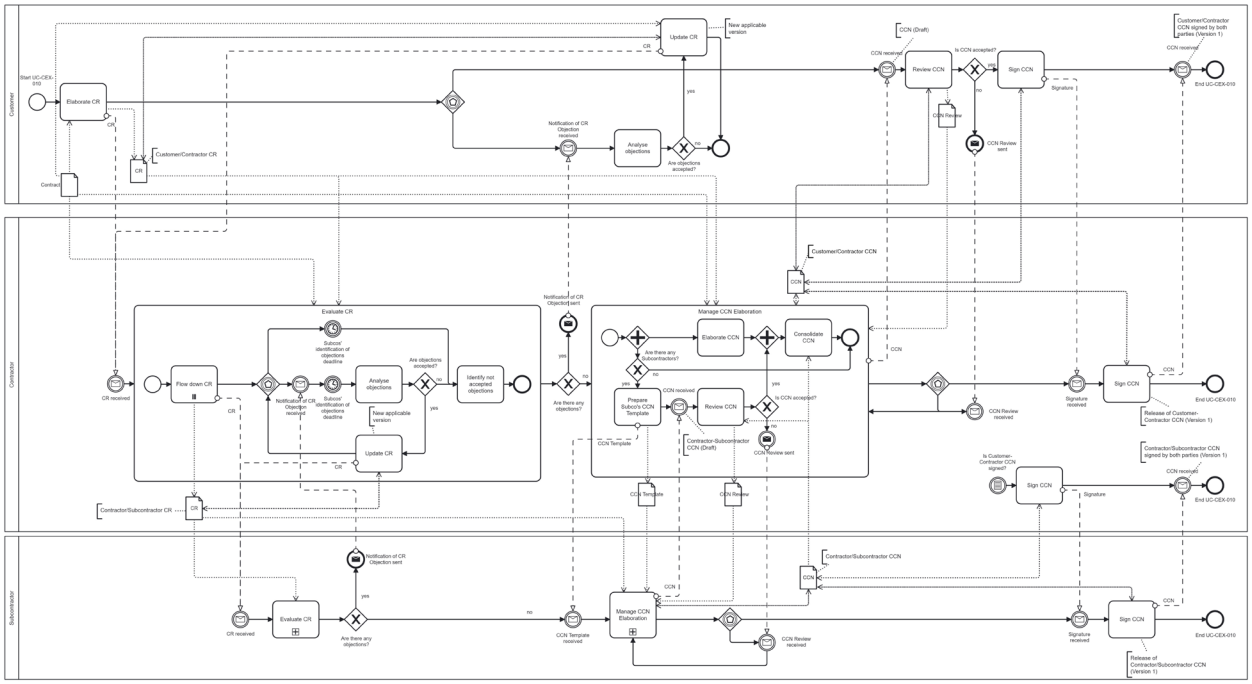

Figure 2-4: UC-CEX-010 BPMN representation

2.3. PROCUREMENT UNIVERSE OF DISCOURSE

2.3.1. SCOPE

The formalisation of Procurement Use Cases is the stepping stone upon which the Procurement UoD is built. Before starting the conceptualisation, the scope of this UoD is defined.

The main constituting elements of the Procurement UoD are the artefacts exchanged in the Procurement and Contract Management Use Cases. A detailed analysis on these Exchange Artefacts is conducted to identify those that are more suitable for conceptualisation. As a result the Exchange Artefacts are prioritised according to the artefact's digitalisation impact, their relevance, monitoring needs and complexity. This prioritization is then refined by the LSIs, GMV and ESA, considering the preferences of domain experts and the scope of the project. The final Exchange Artefacts prioritisation is provided in Table 2-3.

Table 2-3: Priorities considered during the conceptualisation

Exchange Artefact	Score
Contract	12
Applicability Matrix Statement of Compliance Matrix	11
CCD CCN CR NIR	10
PMAC Proposal SoW TEB Report	8
Invoice Minutes of Meeting SCOT Tendering Cover Letter	7

Later, a glossary of terms is defined following ECSS drafting rules. Its elaboration considers existing definitions in ESA Regulations and ECSS. In case of inexistent or non-adequate definitions, the Oxford dictionary's definitions are used. Finally, new definitions are agreed by the consortium for cases where the Oxford definitions are not valid.

Finally, a Workshop at ESTEC is held to present to the OSMoSE Governance [RD.1] the scope of the Procurement UoD, its characteristics, the main differences with respect to other UoDs and the design conventions that will be adopted for their approval.

2.3.2. CONCEPTUAL MODELLING

The Procurement UoD is modelled in an ORM model [RD.3] similar to the Space System Ontology. The model is organised around the small set of concepts defined in the Context diagram - Figure 2-5.

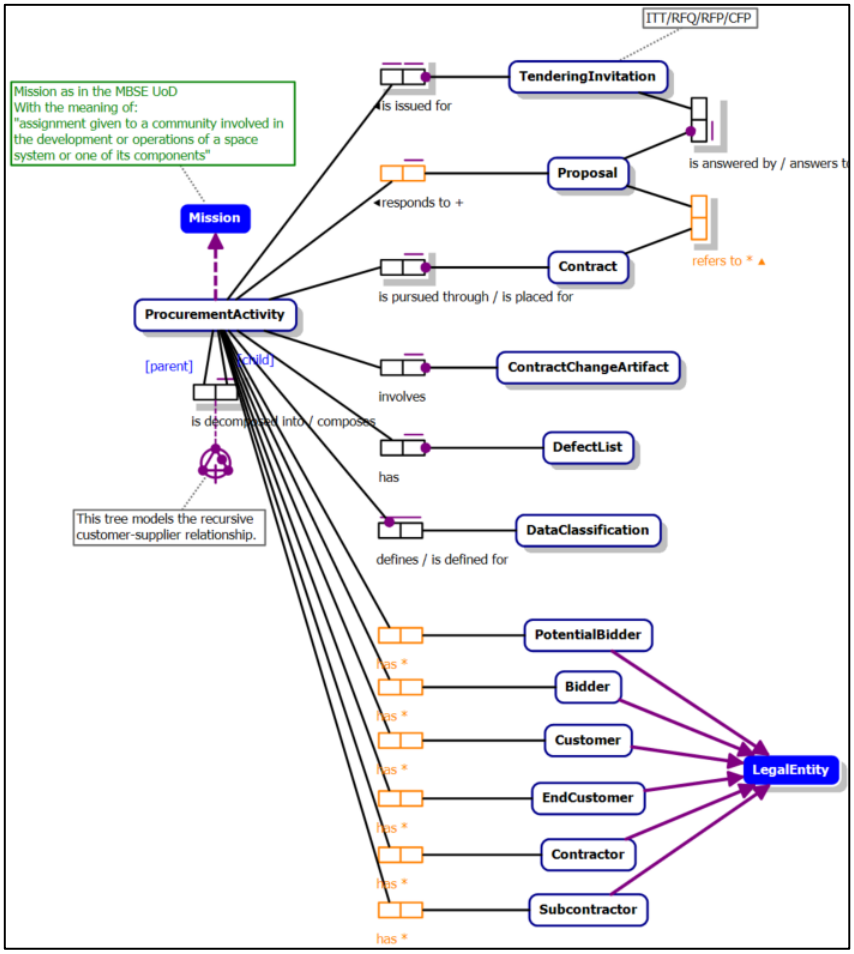

Figure 2-5: Context diagram

Each concept and its relationships have been developed in the model. However, the focus has been the Contract, and the rest of the model does not reach the same level of detail as for that concept.

In particular, the following features related to Contracts have been considered of big importance for Procurement and as such the model provides specific mechanisms for:

- Configuration management of the Contract, to record each change that is done to it with traceability to the origin of the change, and definition of baselines.
- Customer-supplier flow-down of the Contract, recording the links between the main contract and subcontracts.
- Identification of contract elements of especial interest, for which detailed models have been developed.
- Generation of the Contract Closure Documentation, as much automatically as possible.

2.3.3. VALIDATION

Validation of the ORM model was performed by Procurement domain experts, who reviewed the model through multiple working sessions.

Additionally, the model was populated with real examples to ensure its adequacy. The population partially covers the model, focusing on the most important parts. This has led to adjustments of elements in the model such as cardinalities, constraints and relationships.

The following figure shows the coverage of the population by analysing the ORM file using an Xquery to find the orm:Instances elements. BaseX has been used for the querying and visualisation. Reddish colours show where population has been entered.

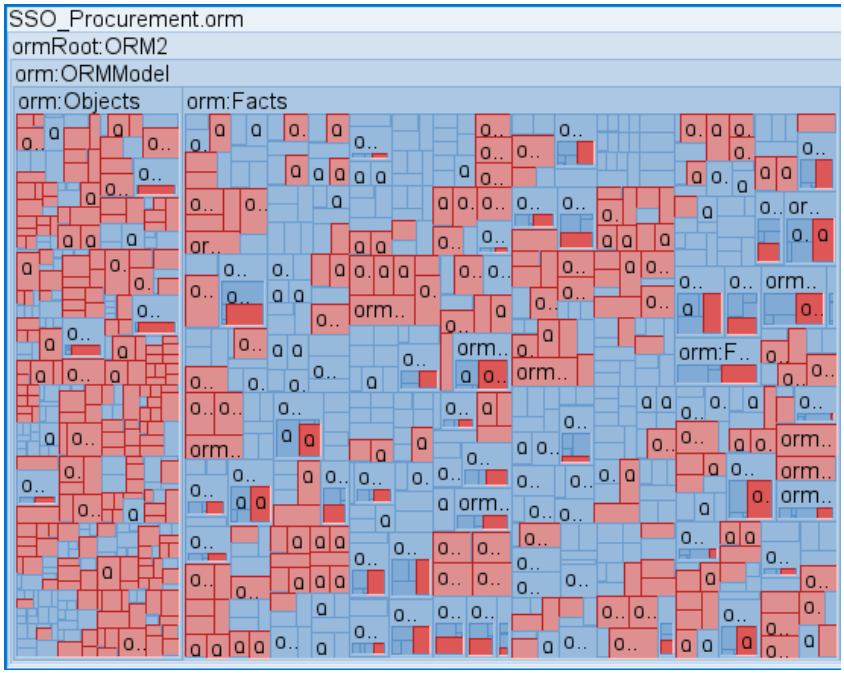

Figure 2-6: Validation coverage

This population has been done directly in NORMA using the "Sample Population Editor" feature which allows fact type per fact type, to enter examples of the population.

Additionally, the SQL representation of the conceptual model has been generated using NORMA and created in a PostgreSQL database, to verify e.g. that the length of identifiers is adequate. No population of this model has been done.

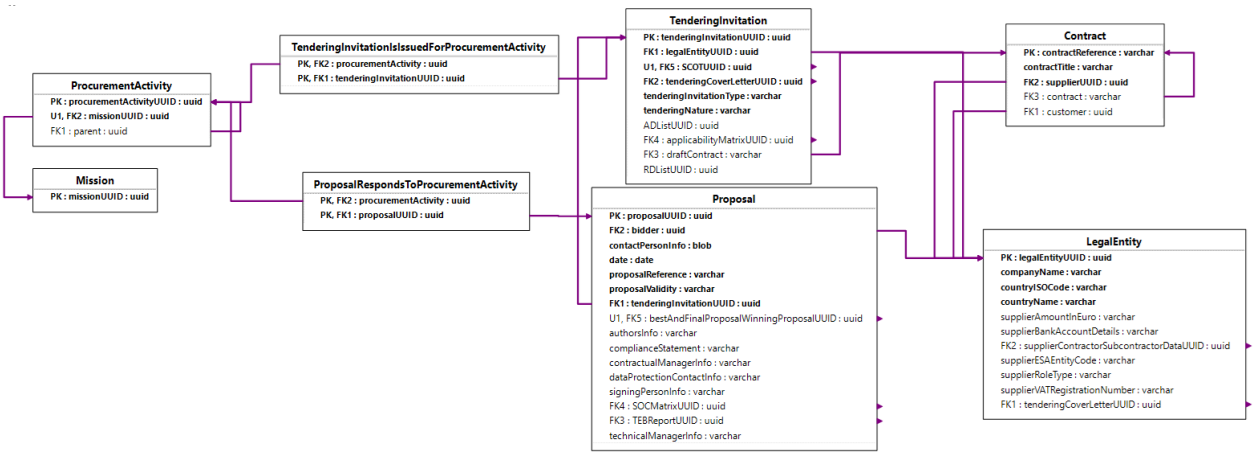

Figure 2-7: Partial view of the relational model generated by NORMA

Finally, a hierarchy has been defined for the model using the NORMA capabilities to deduce existential dependencies between entities from the relationships and constraints in the model. This step may discover missing fact types or wrong cardinalities that can be adjusted to obtain a conceptually sound hierarchy.

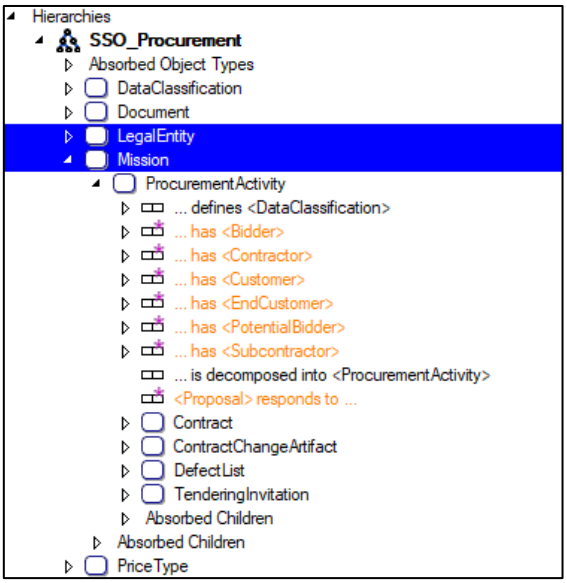

Figure 2-8: Conceptual Hierarchy of the model

Thanks to the creation of the hierarchy, it is possible to generate, using NORMA, an XSD representation of the model. No population has been provided in XML format due to NORMA limitations to generate sample XML files using the sample population.

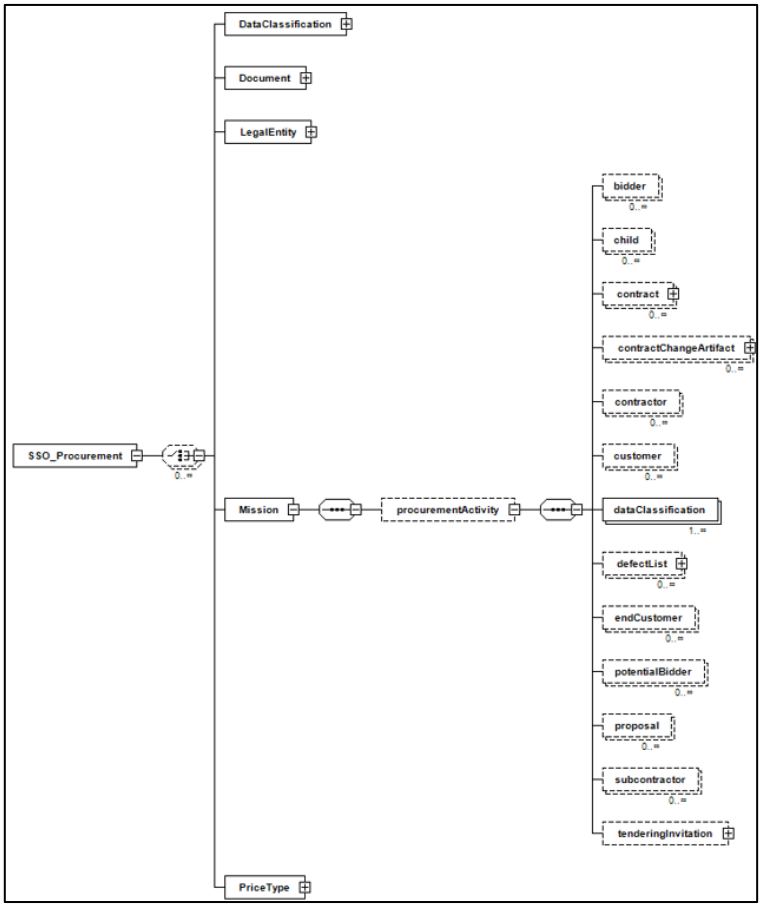

Figure 2-9: XSD representation of the model

3. CONCLUSION

Despite current engineering digitalisation effort especially focuses on the technical activities associated to each of the major stages of a system's lifecycle (namely conceptualisation, design, manufacturing, operation and disposal), it is also at the interface with other non-technical activities that are equally necessary for the successful completion of a project. One of these non-technical activities is indeed Procurement.

DIGIPROC activity has provided a complete characterisation of Procurement processes based on current state-of-the-art and best practices, identifying those parts that can benefit from digitalisation, which will improve the overall effectiveness of digital continuity due to the existing links between both technical and non-technical realms. The Procurement processes characterisation required a strong involvement of domain experts to understand and detail the current way of working to later envisage this future digitalisation.

Then, BPMN was used to formalise those Procurement scenarios that are pertinent to Procurement digitalisation. The usage of BPMN has been found to be extremely useful in discussing the appropriate characterisation of the Procurements processes by both domain experts and non-Procurement experts, such as the ORM specialists responsible for the later conceptualisation of the Procurement UoD

Finally, the Procurement UoD was conceptualised, with a focus on those constituting elements relevant to DIGIPROC goals. The conceptualisation was performed following the OSMoSE conventions and modelling rules in order to facilitate the future integration of this UoD into the Space System Ontology.

References

[RD.1] OSMoSE Website: https://mb4se.esa.int/OSMOSE_Main.html

[RD.2] Business Process Model and Notation (BPMN) Specification. Website: https://www.omg.org/spec/BPMN/2.0.2/PDF

[RD.3] Object Role Modelling, refer to www.orm.net

[RD.4] NORMA software for Microsoft Visual Studio 2017 and 2019:

https://marketplace.visualstudio.com/items?itemName=ORMSolutions.NORMA2017
https://marketplace.visualstudio.com/items?itemName=ORMSolutions.NORMA2019

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