Using ISO-19450 to Describe and Simulate a Smallsat Operational Scenario

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Abstract. *Among the Concept Studies activities, one of the firsts is: Operational Scenarios Discovering. The scenarios allow the identification of the main functions and related entities to accomplish the desired space mission. Usually this activity is manually done, by hand drawing in paper/boards, and later using a drawing software tool. Discover entities and functions is not a trivial activity, not assessing, or even identifying, can cause rework and misguided architectures. The scenarios discovery requires successive refinements and the help of a methodology may turn this task feasible supported by a modelling tool. Entities and functions turn part of models that are refined until the architecture and concepts be delivered to the stakeholders. This paper presents an experiment using the Object Process Methodology, stated in ISO-19450, to describe an operational scenario of the first CTEE's program smallsat.*

Keywords: operational scenario, concept of operation, modelling and simulation, Object Process Methodology, concept studies.

1. Introduction

First phases of Space Engineering involve the study of the operational scenarios that the spacecraft system will pass through its operational phase, performing the designed mission. In Concept Studies, such operational scenarios provide the myriad of entities and functions that the system must deal with and accomplish, to later, compose the architecture and concepts design options. The Design Team, helped by the clients/stakeholders, identify scenarios available to: (i) identify the mission's elements, (ii) the entities, (iii) the infrastructure, and (iii) the operational processes. [ECSS, 2016]

These operational scenarios are usually build using loose modelled models, hand-drawn into paper, whiteboards, and so on. The information is then formalized in drawing tools, to later be submitted in the Mission Design Review (MDR). To reuse and be a seed to further designs, this loose model must be rewritten at a modelling environment, using some sort of modelling formalism, that allows retrieving the information and be transformed into other study domains. [CERQUEIRA 2016]

The branch of System Engineering (SE) that researches explicit modelling is the Model Based System Engineering (MBSE). INCOSE (International Council on Systems Engineering) has a chapter exclusively to research MBSE, and MBSE Methodologies, that can be used in System Engineering, researching a convergence of the best modelling practices. [INCOSE, 2015]

In this context, the Object Process Methodology (OPM), recently formalized as ISO – 19450 "*Automation systems and integration -- Object-Process Methodology*" [Dori, 2016], among other INCOSE's MBSE Methodologies was chosen, as an experience, to describe and simulate the small sat Alfa, a CubeSat in development by the INPE's alumni, the first of a series of upcoming smallsats under the CTEE (from the Portuguese "*Capacitação Técnica em Engenharia Espacial*") program [CTEE, 2017].

This paper aims at presenting the design steps until the simulation of an operational scenario, following the OPM from the seed to the complete tree unfold.

2. Methodology:

OPM has a top-down method. It usually starts from a function seed that is sequentially refined in zoom-ins or different viewpoints. These successive refinements from the main function seed helps to specify the inner processes and the specific entities (new or intern), that are consumed, transformed or yield. Simulation is a side helper, that improves the understanding of the modelled system. Simulation can be done any-time, to test the model behaviour. Finishing the model, the user might want to check-up the big picture by unfolding the structurally connected objects.

Out of the main OPM steps, OPM allows to define a metamodel to the objects and processes. This activity must be done prior to the start of the OPM steps. It indicates the "types" of the things that are created. Figure 1 summarizes the common OPM steps. [Dori, 2016]

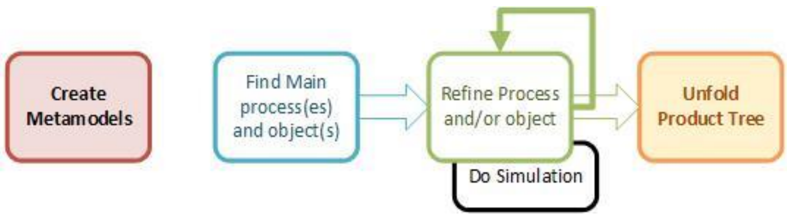
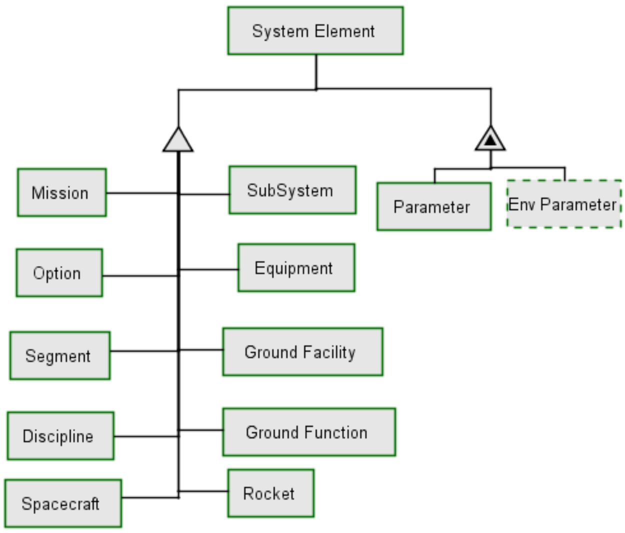


Figure 1. Common OPM steps.

3. System Operational Scenarios Design

This section presents an example of the common OPM steps to create Operational Scenarios, using as study case the System Elements' Operational Scenarios Discovery of the Alfa Mission.

Create Metamodels: This step is not on the standard obligatory, but an optional OPM approach to organize the resulting model. So, every model must conform with a higher defined metamodel (a model of a model). Metamodeling helps in the discoverability and the passage of pre-set proprieties and behaviours. The same concept of metamodels must be created to define the different types of model, discipline's information, mission definition, different application views, etc. Figure 2 presents the OPD (Object Process Diagram) and OPL (Object Process Language) of a metamodel to classify all system elements (discoverable entities in this "Mission Alfa" case) and their parameters for the small sat Alfa.

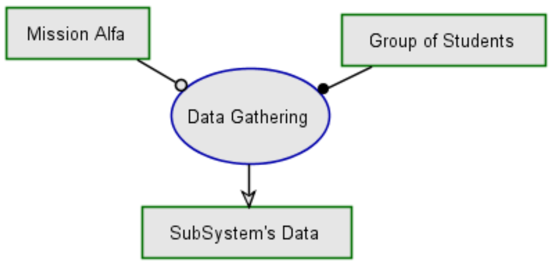


System Element exhibits Parameter and Env Parameter.
Env Parameter is environmental.
Mission is a System Element.
Equipment is a System Element.
Segment is a System Element.
Option is a System Element.
Ground Facility is a System Element.
Ground Function is a System Element.
Rocket is a System Element.
Spacecraft is a System Element.
Discipline is a System Element.
SubSystem is a System Element.

Figure 2. Alfa's "System Elements" Metamodel

Note: The metamodel or metamodels, must be imported into the new project file to be used. Every new discovery entity into the refining process must be of one of those types. This procedure guarantees that the new entities conforms with a meta-type.

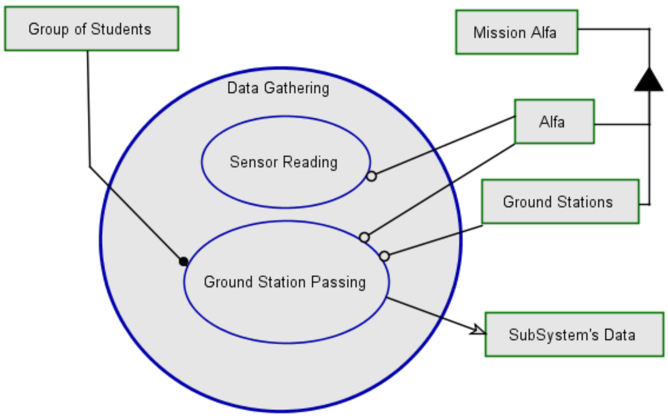
Function as a Seed: The first step of the OPM is the identification of the main system function, which is represented by the main process/processes and the main entities. Alfa's Mission main function is to gather subsystems data of a satellite to be developed by the ETE' Group of Students. Figure 3 presents the first System Design Seed.



Group of Students handles Data Gathering.
Data Gathering requires Mission Alfa.
Data Gathering yields SubSystem's Data.

Figure 3. Alpha's primary function: data gathering.

Refining the process and objects: The "Data Gathering" process is too abstract to represent the functions, so a series of zoom-ins should be done to describe the process. In this case, "Data Gathering", shown in Figure 4, is divides into "Sensor Reading" and "Ground Station Passing" processes. The objects are also refinable, indicating inner processes or other objects.



Mission Alfa consists of Ground Stations and Alfa.
Group of Students handles Ground Station Passing.
Data Gathering consists of Ground Station Passing and Sensor Reading.
Data Gathering zooms into Sensor Reading and Ground Station Passing.
Sensor Reading requires Alfa.
Ground Station Passing requires Alfa and Ground Stations.
Ground Station Passing yields SubSystem's Data.

Figure 4. Data Gathering process refinement into Sensor Reading and Ground Station Passing.

Multiple refinements in the processes and objects should be done until the scenarios covered provides the amount of information required to the next Concept Studies activities.

Adding States: The objects in OPM can have states that represent inner behaviours. Stateful objects allows to better describe the evolution of an object – designing state machines. Parts of the objects can be exhibited to improve the model's description, for example, "Ground Station" exhibits the "GS Visibility" Object, shown in Figure 5 OPD and Figure 6 OPL.

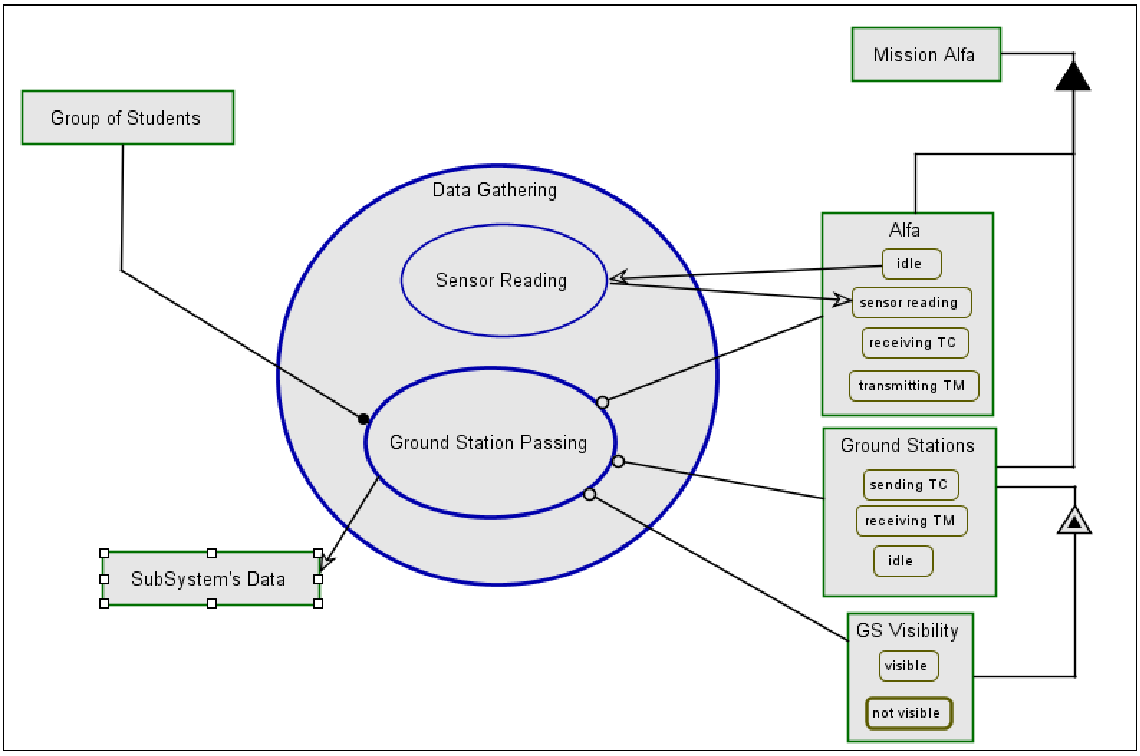


Figure 5. OPD of an Object refinement with states and exhibition of parameters.

Mission Alfa consists of Ground Stations and Alfa.
Ground Stations can be sending TC, receiving TM, or idle.
Ground Stations exhibits GS Visibility.
GS Visibility can be visible or not visible.
not visible is initial.
Alfa can be sensor reading, receiving TC, transmitting TM, or idle.

Group of Students handles Ground Station Passing.
Data Gathering consists of Ground Station Passing and Sensor Reading.
Data Gathering zooms into Sensor Reading and Ground Station Passing.
Sensor Reading changes Alfa from idle to sensor reading.
Ground Station Passing requires Alfa, GS Visibility, and Ground Stations.
Ground Station Passing yields SubSystem's Data.

Figure 6. Object refinement in OPL.

Simulation of the Scenario: OPM models creates event-driven simulations, allowing to to check if the model behaviour was correctly designed. The OPM simulation visually represents the steps of the situation, indicating the processes involved, the objects acting, and the current events. Figure 7 shows the state transition (red balls in the link line) of the small sat "Alfa", from "idle" to "sensor reading", due the process "Sensor Reading".

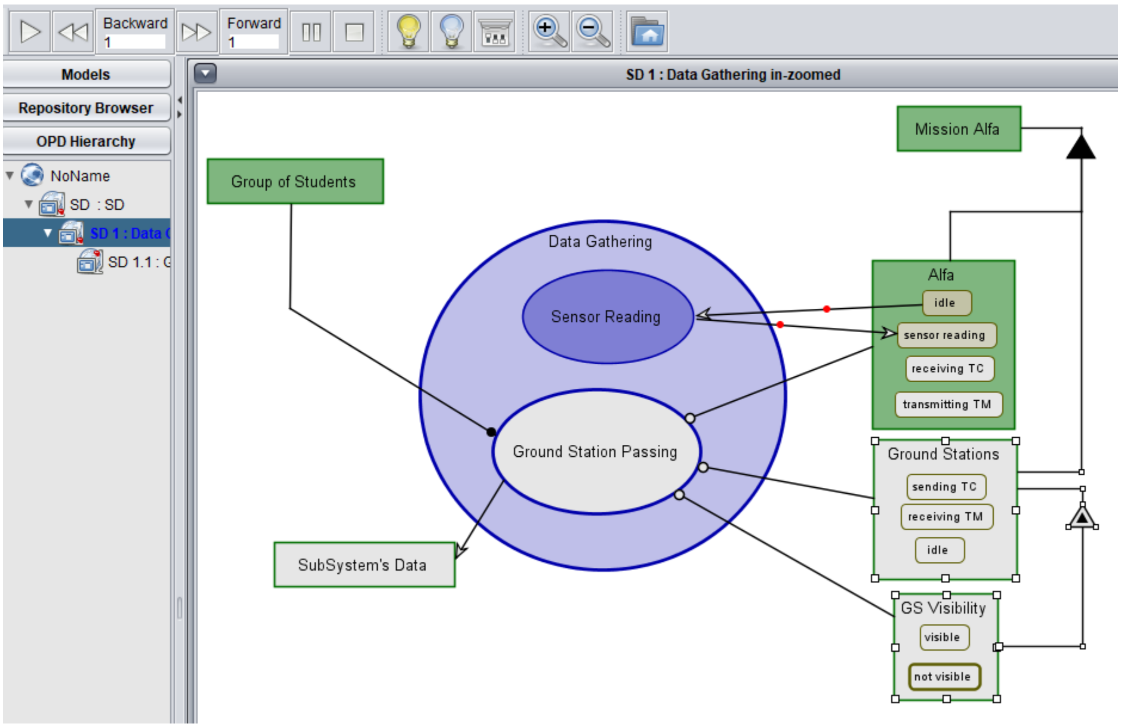


Figure 7. Simulation Example

Unfolding Product Tree: Each refinement might add extra entities into the Mission Alfa tree of products. As the entities are spread through the diagrams, team might "loose" the big picture of the discovered entities. To retrieve those entities, OPM provides the *Unfold* command. Unfold search through all inner diagrams trying to gather all the structural relations among the seed Unfold object. Figure 8 illustrates the result of "Mission Alfa" unfolding.

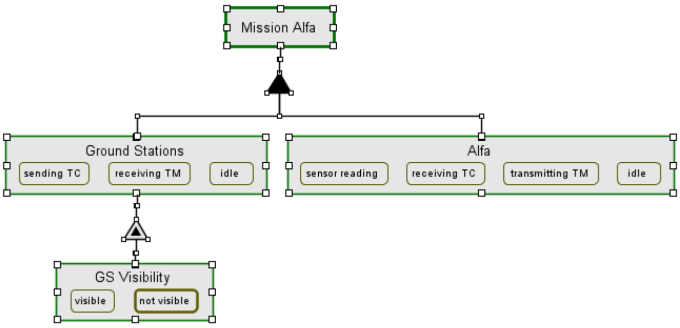


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Figure 8. Unfolding Mission Alfa entities

3. Conclusion

OPM itself provides a satisfactory repertoire of symbols and relations that allows describing and simulating Operational Scenarios. On doing successive refinements in the models, permits the stakeholders to evaluate: different levels of information and different views, to consequently, improve the identification and description of the scenarios' context functions and entities.

Paper/board tooling, or static modelling (as SysML), have their own strategies to this task, which this paper did not compared. Nevertheless, the OPM top-down methodology to iteratively explore the scenarios, added by the possibility of continuously simulate the changes, offering a very powerful approach, specially to non-software specialist. Later works could transverse this simulatability into other modelling strategies.

The experience described into this paper only demonstrates the first steps of the Alfa's scenario description. The complete operational scenarios will be public available into the Alfa's MDR documents at the Concept of Operations section of the Mission Description Document.

Note that OPM has only one type of diagram, which is both a pro and cons, as it provides a single set of building elements which are easier to learn, but comes with the complexity of a lack of specific meaning symbols. OPCat, even with the 2017 build, is still a very poor tool regarding usability and connectiveness with other tools. A new OPM tool is certainly welcome, and would improve the use of this methodology.

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