MBSE & SysML Applied to the Development of EGSE for Sattelites Assembly, Integration and Testing (AIT) - A Practical Case

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***Abstract*— This paper targets to present a proposal for the use of MBSE and SysML applied to a case study of the analysis in a component of a typical Electrical Ground Support Equipment (EGSE) used in Satellite Assembly, Integration and Testing (AIT).**

The approach aims to describe the process flow used in the analysis, providing a methodological background for the practical application of SysML notation for EGSE's development.

***Keywords*— Systems Engineering; Model Based Systems Engineering; MBSE; SysML; Electrical ground Support Equipment; EGSE.**

I. INTRODUCTION

Although SysML, in recent years, has become the *de facto* standard for MBSE, a supporting methodological basis is still needed, as SysML is just a graphical language and defines a set of diagrams, modeling elements, syntax and semantics. Like any language (formal or informal), it can be used in many different ways, including inappropriate ones. Most notably, it is possible to misuse the language for creating unrepresentative or even incorrect models.

The flow of the analysis processes used in this paper seeks to implement, as much as possible, the sequence presented in the GSE Integrated Development Guide proposed by Vintecinque (2017), respecting the limitations imposed by the SysML notation language and the modeling tool used. (Cameo Systems Modeller).

The added value of the methodology with the MBSE approach consists of:

- To select a suitable subset of SysML diagrams and artifacts to be generated conveniently and pragmatically;
- To define semantics to ensure meaningful diagrams and rules to check the model for consistency;
- To define an obvious sequence of diagrams that ensures modeling efficiency in relation to organizational processes, and is well understood by all stakeholders throughout the life cycle;

II. METHODOLOGY - MBSE APPROACH TO THE GSE INTEGRATED DEVELOPMENT GUIDE

The process flow that will be used seeks to follow the major process phases of the Total Vision Framework proposed by Loureiro (2010), as shown below, as well as the SysML diagrams that will be used:

Table 1 - Phases of Analysis Processes and Modeling Approach

Phase	Sub phase	SysML Diagrams	Modeling Approach
1. Mission Analysis	1.1 - Context / Concept of Operations	Block Definition Diagram (BDD)	Type Definitions (Parts Catalog)
		Internal Block Diagram (IBD)	Description of Structures (blocks), internal components, relationships and interfaces between Structures.
	1.2 - Life Cycle / Life Cycle Scenarios	Activity Diagram	Definition of the phasing of processes and subprocesses.

Phase	Sub phase	SysML Diagrams	Modeling Approach
2. Stakeholder analysis	2.1 - Stakeholder Identificatio	Block Definition Diagram (BDD)	Actors (used in Use-Case Diagrams) Are created as “types” in a BDD
	2.2 - Stakeholder Concerns	Use Case Diagrams	Description of stakeholder concerns in Use-Case diagrams, System or Interest Organization in various scenarios
	2.3 - Stakeholder Requirements	Requirements Diagrams	Stakeholder requirements and their dependencies are represented in Requirements Diagrams.
		Requirements Table	If there are no requirements dependencies, only SysML Requirements tables can be used.
	2.4 - Measures of Effectiveness	Definition Diagram (BDD) / Parametric	MoE's are represented as value types in Block Definition diagrams and allow for simulation using external tools in Parametric Diagrams.
3. Requirements Analysis	---	Requirements Diagrams	System requirements and their dependencies are represented in SysML requirements diagrams or requirements tables.
4. Functional Analysis	4.1 - Boundaries identification, interfaces and	Internal Block Diagram (IBD)	Scenarios and circumstances for the product and organization of interest are described as blocks and their interfaces with the environment.
	4.2 - Definition of functions	Generic Table	Tables with list of flows and events, MoEs and identified functions
4. Functional Analysis (cont.)	4.3 - Functional scope analysis	Internal Block Diagram (IBD)	Scenarios and circumstances for the product and organization of interest are described as blocks and their interfaces with the environment.
	4.4 - Functional Interfaces	Internal Block Diagram (IBD)	N^2 chart generated from interfaces defined in functional scope analysis
	4.5 - Definition of states and modes	Generic table	Tables with list of identified functions, modes, and states
	4.6 - Analysis of functional behavior	State Machine Diagram	Refinement of states and modes identified for functions
	4.7 - Establishment of the functional architecture	Use case diagram	Establishment of control, data and material flows between functions and functional elements of the system. (*1)
5. Implementation Analysis	5.1 - Establishment of physical	Block definition diagram (BDD and internal IBD)	Using both types of block diagrams for physical architecture proposals
	5.2 - Function Allocation	Allocation Matrix	Through "Allocate" type relationships and automatic generation by modeling tool
	5.3 - *Trade-Off* Analysis	TBD	TBD

NOTES *:

1. The Guide proposes the establishment of functional architecture via Data Flow Diagrams (DFD's), which are not part of SysML. Using the Use-Case Diagram instead implies implementation limitations that need to be further evaluated throughout the application of the guide.

III. CASE STUDY - UMB SCOE ANALYSIS

As proposed by Vintecinque (2017) UMB SCOE is an element of EGSE proposed for future PMM platform satellite missions, which allows use during both the AIT and the Satellite launch phases, and aims to reduce the amount and volume of equipment to be transported to the launch base. The mission of UMB SCOE can be stated as:

"To be the only satellite-connected element of EGSE that allows to power up, operate and monitor its vital signs during the AIT and launch phases" Vintecinque (2017)".

The approach in the analysis and modeling to obtain UMB SCOE will be presented next.

a. Mission Analysis

Starting from the mission statement, the possible concepts of operation, as exemplified in Fig. 1, are analyzed for one of the situations.

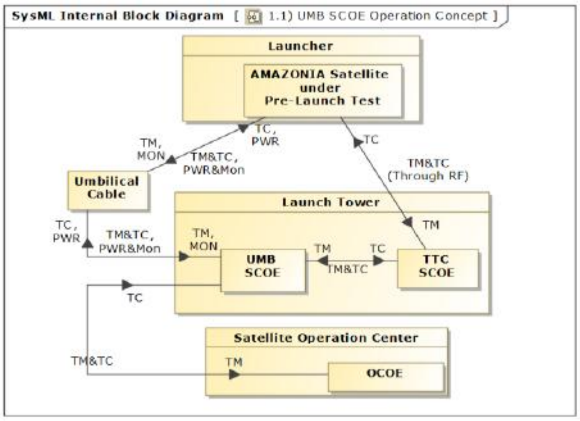


Fig. 1 - Example of UMB SCOE operation concept for telemetry and telecommand data link in the launch tower (internal block diagram).

Elements and their interactions are described textually through the appropriate fields of the model. Flows of energy, material or information from an early point of view are represented as "Information Item" stereotyped elements, denoting the directions of the flows. It does not matter at the moment the physical concept of interfaces.

b. UMB SCOE Life-cycle

This analysis only states and establishes the sequence of expected life-cycle processes, as exemplified in Fig. 2.

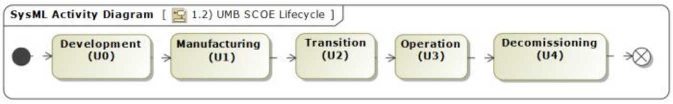


Fig. 2 - UMB SCOE (activity diagram) life-cycle example.

c. UMB SCOE life-cycle scenarios

The UMB SCO life cycle scenarios are shown in *Fig. 3*. The activity diagram was used, with the inputs or controls of the old IDEF0 being replaced by SysML "Accept Event Action" or "Time Event" type elements.

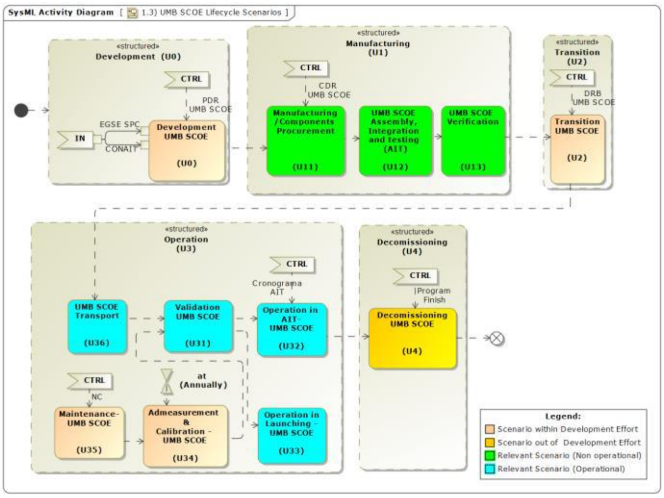

SysML Activity Diagram [1.3) UMB SCOE Lifecycle Scenarios]
«structured» Development (U0)
CTRL
PDR UMB SCOE
IN
EGSE SPC
CONAIT
Development UMB SCOE (U0)
«structured» Manufacturing (U1)
CTRL
CDR UMB SCOE
Manufacturing /Components Procurement (U11)
UMB SCOE Assembly, Integration and testing (AIT) (U12)
UMB SCOE Verification (U13)
«structured» Transition (U2)
CTRL
DRB UMB SCOE
Transition UMB SCOE (U2)
«structured» Operation (U3)
CTRL
Cronograma AIT
UMB SCOE Transport (U36)
Validation UMB SCOE (U31)
Operation in AIT- UMB SCOE (U32)
CTRL
NC
at (Annually)
Maintenance- UMB SCOE (U35)
Admeasurement & Calibration - UMB SCOE (U34)
Operation in Launching - UMB SCOE (U33)
«structured» Decomissioning (U4)
CTRL
Program Finish
Decomissioning UMB SCOE (U4)
Legend:
Scenario within Development Effort
Scenario out of Development Effort
Relevant Scenario (Non operational)
Relevant Scenario (Operational)

Fig. 3 - UMB SCOE life-cycle scenarios example (activity diagram).

Relevant scenarios within the development effort will be reviewed by the UMB SCOE developer organization.

d. Stakeholder Analysis

i. Identification of UMB SCOE Stakeholders

For identification of product and process stakeholders, block definition diagrams (BDD) will be used with SysML stereotyped actors, as illustrated in Fig. 4.

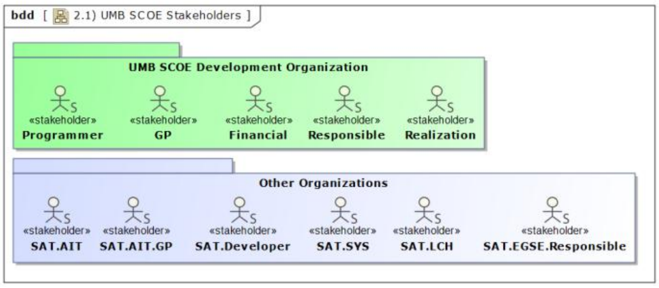

bdd [2.1) UMB SCOE Stakeholders]
UMB SCOE Development Organization
«stakeholder» Programmer
«stakeholder» GP
«stakeholder» Financial
«stakeholder» Responsible
«stakeholder» Realization
Other Organizations
«stakeholder» SAT.AIT
«stakeholder» SAT.AIT.GP
«stakeholder» SAT.Developer
«stakeholder» SAT.SYS
«stakeholder» SAT.LCH
«stakeholder» SAT.EGSE.Responsible

Fig. 4 - UMB SCOE stakeholder identification example (block definition diagram).

ii. UMB SCOE stakeholders concerns

Product and process stakeholder concerns raised previously are analyzed together with the System or Organization of Interest in various scenarios.

The result is described through Use Case diagrams stereotyped as "Concern". Fig. 5 illustrates an example of how this will be done.

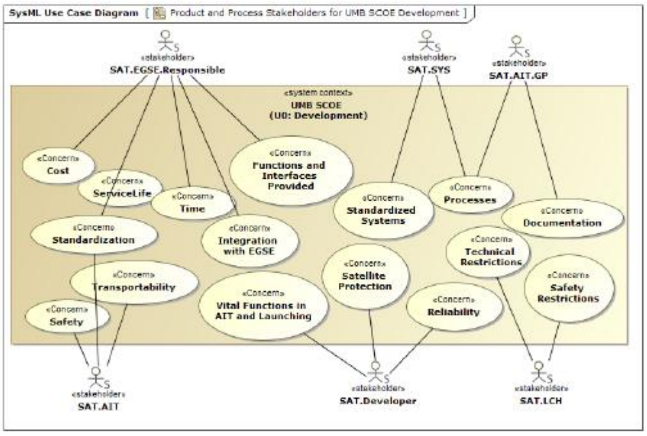

SysML Use Case Diagram [Product and Process Stakeholders for UMB SCOE Development]
«stakeholder» SAT.EGSE.Responsible
«stakeholder» SAT.SYS
«stakeholder» SAT.AIT.GP
«system context» UMB SCOE (U0: Development)
«Concern» Cost
«Concern» ServiceLife
«Concern» Time
«Concern» Functions and Interfaces Provided
«Concern» Standardized Systems
«Concern» Processes
«Concern» Documentation
«Concern» Standardization
«Concern» Integration with EGSE
«Concern» Technical Restrictions
«Concern» Satellite Protection
«Concern» Transportability
«Concern» Vital Functions in AIT and Launching
«Concern» Reliability
«Concern» Safety Restrictions
«Concern» Safety
«stakeholder» SAT.AIT
«stakeholder» SAT.Developer
«stakeholder» SAT.LCH

Fig. 5 - UMB SCOE Stakeholder Concerns Example In the UMB SCOE scenario under development (Use Case Diagram).

iii. UMB SCOE stakeholder requirements

Stakeholder requirements derived from the concerns raised before are analyzed and the outcome is described through requirements diagrams or requirements table as exemplified in Fig. 6. Dependency or trace-ability relationships between requirements and stakeholder concerns can be made explicit in this kind of diagram. Additional attributes can be added to the requirements by the use of Tagged Values provided by the SysML notation.

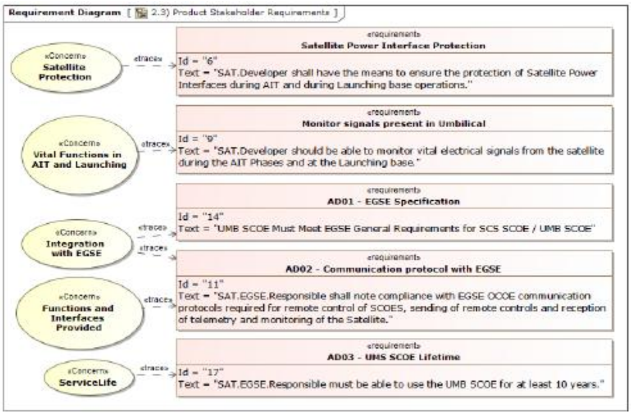

Requirement Diagram [2.3) Product Stakeholder Requirements]
«Concern» Satellite Protection
«Concern» Vital Functions in AIT and Launching
«Concern» Integration with EGSE
«Concern» Functions and Interfaces Provided
«Concern» ServiceLife
«trace»
«requirement» Satellite Power Interface Protection
Id = "6"
Text = "SAT.Developer shall have the means to ensure the protection of Satellite Power Interfaces during AIT and during Launching base operations."
«requirement» Monitor signals present in Umbilical
Id = "9"
Text = "SAT.Developer should be able to monitor vital electrical signals from the satellite during the AIT Phases and at the Launching base."
«requirement» AD01 - EGSE Specification
Id = "14"
Text = "UMB SCOE Must Meet EGSE General Requirements for SCS SCOE / UMB SCOE"
«requirement» AD02 - Communication protocol with EGSE
Id = "11"
Text = "SAT.EGSE.Responsible shall note compliance with EGSE OCOE communication protocols required for remote control of SCOES, sending of remote controls and reception of telemetry and monitoring of the Satellite."
«requirement» AD03 - UMS SCOE Lifetime
Id = "17"
Text = "SAT.EGSE.Responsible must be able to use the UMB SCOE for at least 10 years."

Fig. 6 - UMB SCOE Product stakeholder requirements example (Requirements Diagram).

iv. UMB SCOE measures (MoE / MoP / TpM)

Measures of Effectiveness (MoE) are operational measures of success closely related to the achievement of the mission objective being evaluated and they are derived from the mission objectives related to the stakeholders concerns.

Measures of Performance (MoP) are measures that characterize physical or functional attributes relating to system operation, measured or estimated under specified testing and/or operational environment conditions.

Technical Performance Measures (TPM) measure attributes of a system element to determine how well that element is satisfying, or expected to satisfy, a technical requirement.

The SysML parametric diagrams will be used for the MoEs, MoPs and TpMs. It is desired that the measures could be quantitatively assessed, in a form that could be estimated or even simulated in supporting tools, integrated with the modeling tool. In order to allow this, the default SysML meta-model needs to be extended in order to allow then to be expressed in Value Types, but also in a textual description, which can be traced back to the Stakeholders Concerns and Requirements. This can be achieved by a Custom Profile which extends the SysML meta-model, with MoEs, MoPs and TpMs Specification elements, as shown in *Fig. 7*.

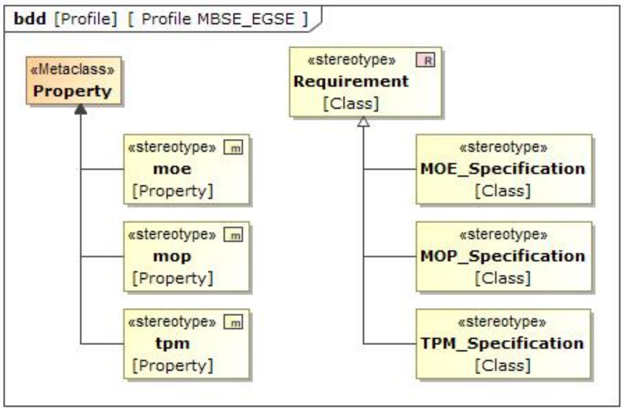

bdd [Profile] [Profile MBSE_EGSE]
«Metaclass» Property
«stereotype» Requirement [Class]
«stereotype» moe [Property]
«stereotype» mop [Property]
«stereotype» tpm [Property]
«stereotype» MOE_Specification [Class]
«stereotype» MOP_Specification [Class]
«stereotype» TPM_Specification [Class]

Fig. 7 - MoEs, MoPs and TpMs Specification Meta-Model.

The MoE, MoP and TpM specifications can be traced back to its source as the example shown in *Fig. 8*.

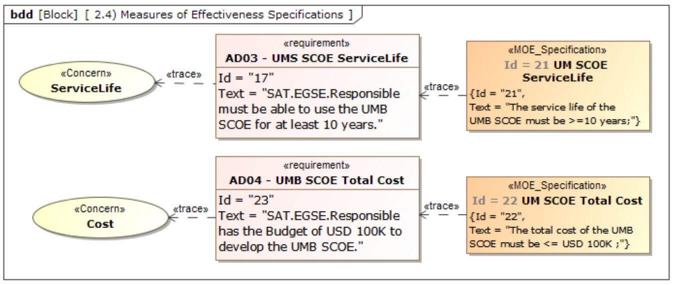

bdd [Block] [2.4) Measures of Effectiveness Specifications]
«Concern» ServiceLife
«Concern» Cost
«trace»
«requirement» AD03 - UMS SCOE ServiceLife
Id = "17"
Text = "SAT.EGSE.Responsible must be able to use the UMB SCOE for at least 10 years."
«requirement» AD04 - UMB SCOE Total Cost
Id = "23"
Text = "SAT.EGSE.Responsible has the Budget of USD 100K to develop the UMB SCOE."
«MOE_Specification» Id = 21 UM SCOE ServiceLife
{Id = "21", Text = "The service life of the UMB SCOE must be >=10 years;"}
«MOE_Specification» Id = 22 UM SCOE Total Cost
{Id = "22", Text = "The total cost of the UMB SCOE must be <= USD 100K ;"}

Fig. 8 - Deriving Specification for MoEs Example.

Finally, the Moe, MoP or TpM quantitative metrics can be expressed by Value Types (Properties), as shown in *Fig. 9*.

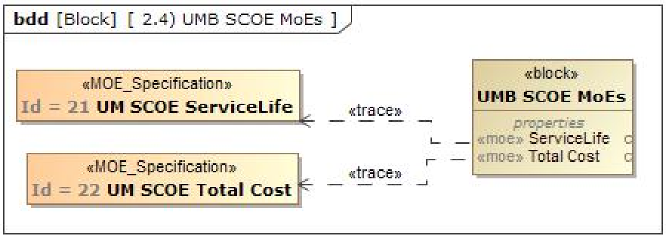
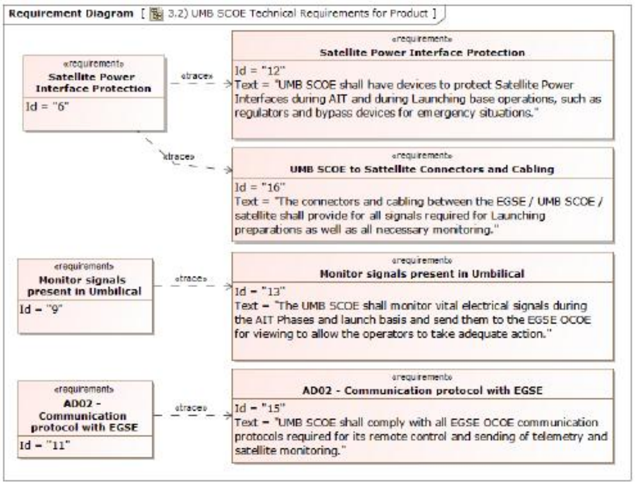

bdd [Block] [2.4) UMB SCOE MoEs]
«MOE_Specification» Id = 21 UM SCOE ServiceLife
«MOE_Specification» Id = 22 UM SCOE Total Cost
«trace»
«trace»
«block» UMB SCOE MoEs
properties
«moe» ServiceLife
«moe» Total Cost

Fig. 9 - Parametric Diagram for MoEs of interest.

e. UMB SCOE Requirements Analysis

From the stakeholder requirements and MoEs defined before, as well as the assumptions that emerged during their analysis, the technical requirements (both for product and organization) are derived, but now from the UMB SCOE point of view. Similarly, requirements analysis is described through requirements diagrams or requirements table, as exemplified in Fig. 10.


Requirement Diagram [3.2) UMB SCOE Technical Requirements for Product]
«requirement»
Satellite Power Interface Protection
Id = "6"
«trace»
«trace»
«requirement»
Monitor signals present in Umbilical
Id – "9"
«trace»
«requirement»
AD02 - Communication protocol with EGSE
Id – "11"
«trace»

«requirement»
Satellite Power Interface Protection
Id = "12"
Text = "UMB SCOE shall have devices to protect Satellite Power Interfaces during AIT and during Launching base operations, such as regulators and bypass devices for emergency situations."

«requirement»
UMB SCOE to Sattellite Connectors and Cabling
Id = "16"
Text = "The connectors and cabling between the EGSE / UMB SCOE / satellite shall provide for all signals required for Launching preparations as well as all necessary monitoring."

«requirement»
Monitor signals present in Umbilical
Id – "13"
Text – "The UMB SCOE shall monitor vital electrical signals during the AIT Phases and launch basis and send them to the EGSE OCOE for viewing to allow the operators to take adequate action."

«requirement»
AD02 - Communication protocol with EGSE
Id – "15"
Text – "UMB SCOE shall comply with all EGSE OCOE communication protocols required for its remote control and sending of telemetry and satellite monitoring."

Fig. 10 - UMB SCOE Product Technical Requirements Example (Requirements Diagram).

f. UMB SCOE Functional Analysis

i. UMB SCOE boundaries/interfaces identification and environment modeling

To identify system boundaries, relevant scenarios are chosen within the product and organization life cycle of interest (Vintecinque, 2018).

Scenarios and circumstances for the product and organization of interest will then be described as blocks and their interfaces with the environment by using internal block diagram (IBD), as illustrated in Fig. 11.

From the analysis of circumstances, it is possible to identify the events and expected responses of the system, as well as the associated measures of effectiveness.

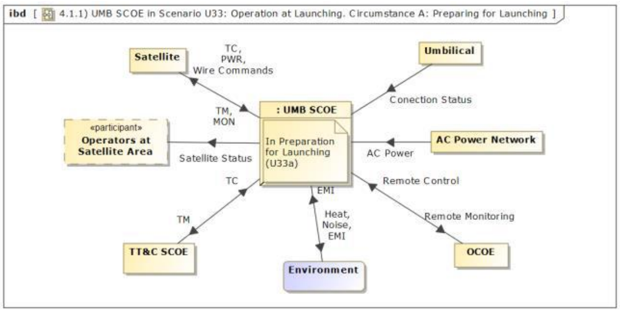
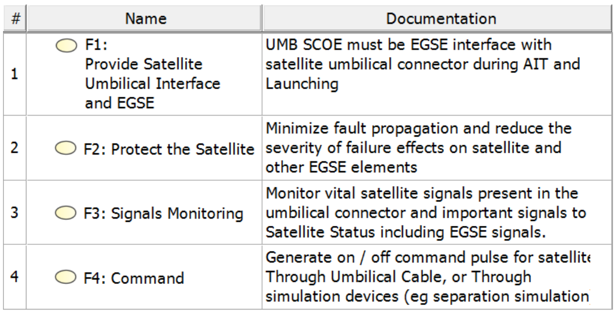


Fig. 11 - UMB SCOE Environment Modeling Example during scenario U33: Launch Operation and its Circumstances (Requirements Diagram).

ii. UMB SCOE functions definition

For each scenario and circumstance identified, all flows of energy, material and information are gathered and, from them, the system's external functions are identified, which can then be listed in a generic SysML table, as exemplified below:

Table 2 - Example of definition list of functions identified for UMB SCOE (generic SysML table)



#	Name	Documentation
1	○ F1: Provide Satellite Umbilical Interface and EGSE	UMB SCOE must be EGSE interface with satellite umbilical connector during AIT and Launching
2	○ F2: Protect the Satellite	Minimize fault propagation and reduce the severity of failure effects on satellite and other EGSE elements
3	○ F3: Signals Monitoring	Monitor vital satellite signals present in the umbilical connector and important signals to Satellite Status including EGSE signals.
4	○ F4: Command	Generate on / off command pulse for satellite Through Umbilical Cable, or Through simulation devices (eg separation simulation

iii. Scope analysis of UMB SCOE functions

Scope analysis of each function helps to identify inputs and outputs and scope limits for previously identified functions, as shown in Fig. 12.

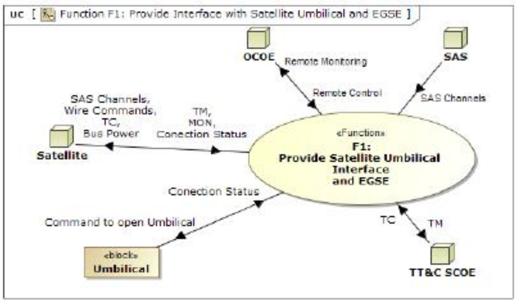


Fig. 12 - F1 Function Scope Analysis Example for UMB SCOE (Use Case Diagram).

iv. UMB SCOE functional interfaces identification

From the analysis of the inputs and outputs of each function it is possible to establish the interfaces between the functions.

Normally, this is represented through an N^2 chart (a.k.a N^2 diagram) which are not part of the SysML standard. But the main idea can be achieved through the use of internal block diagrams (IBD), in a matrix form, with te same rules of an N2 chart:

1. All Functions (or sub-functions) are on diagonal;
2. All Inputs are vertical (to down or to up)
3. All Outputs are Horizontal (to left or to right);
4. Inputs and outputs are items, not functions;

Fig. 13 Gives an example of this diagram used for some of the UMB SCOE functions.

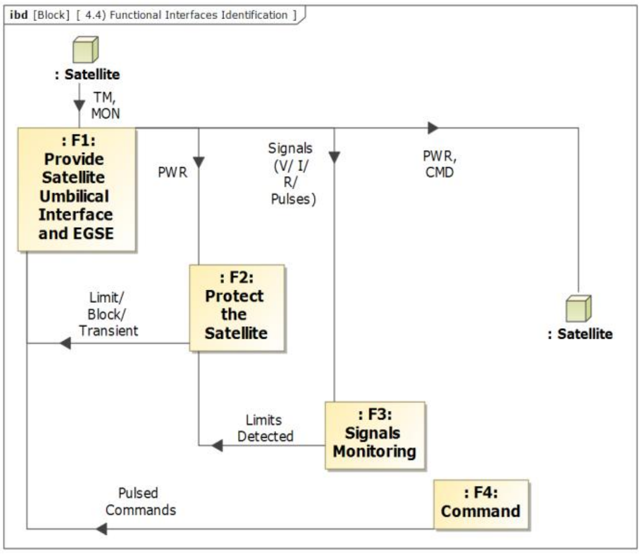
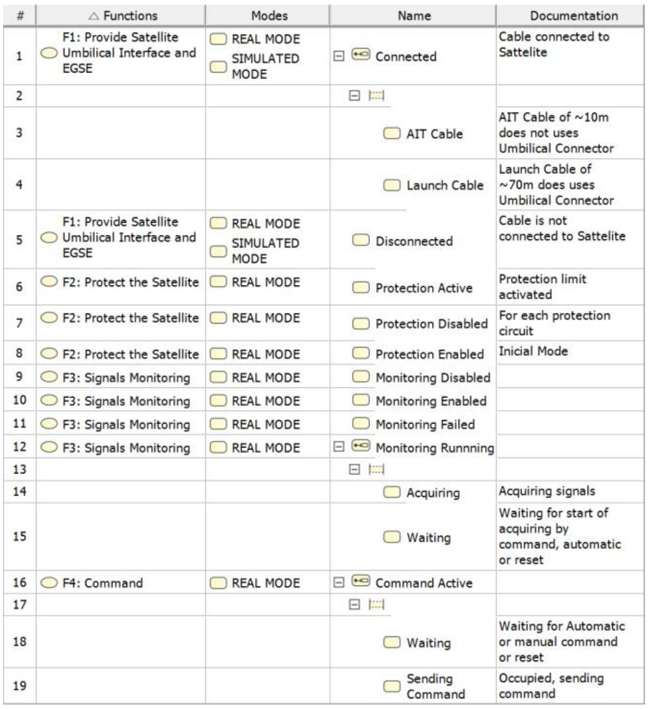

ibd [Block] [4.4) Functional Interfaces Identification]
: Satellite
TM,
MON
: F1: Provide Satellite Umbilical Interface and EGSE
PWR
Signals (V/ I/ R/ Pulses)
PWR, CMD
: F2: Protect the Satellite
Limit/ Block/ Transient
: Satellite
Limits Detected
: F3: Signals Monitoring
Pulsed Commands
: F4: Command

Fig. 13 - UMB SCOE Functional Interfaces (Internal Block Diagram as N2 Chart).

v. UMB SCOE states and modes definition

From the functions identification, it is possible to identify states and modes of each function external to UMB SCOE. The definition is made by State Machine diagrams, for the purposes of tracing the states and modes to the functions defined before. The final representation is made by using a generic SysML table, as the example shown in *Table 3*.

Table 3 - UMB SCOE Function State Analysis Example (Generic SysML Table)



#	△ Functions	Modes	Name	Documentation
1	F1: Provide Satellite Umbilical Interface and EGSE	REAL MODE SIMULATED MODE	⊟ Connected	Cable connected to Sattelite
2			⊟	
3			AIT Cable	AIT Cable of ~10m does not uses Umbilical Connector
4			Launch Cable	Launch Cable of ~70m does uses Umbilical Connector
5	F1: Provide Satellite Umbilical Interface and EGSE	REAL MODE SIMULATED MODE	Disconnected	Cable is not connected to Sattelite
6	F2: Protect the Satellite	REAL MODE	Protection Active	Protection limit activated
7	F2: Protect the Satellite	REAL MODE	Protection Disabled	For each protection circuit
8	F2: Protect the Satellite	REAL MODE	Protection Enabled	Inicial Mode
9	F3: Signals Monitoring	REAL MODE	Monitoring Disabled	
10	F3: Signals Monitoring	REAL MODE	Monitoring Enabled	
11	F3: Signals Monitoring	REAL MODE	Monitoring Failed	
12	F3: Signals Monitoring	REAL MODE	⊟ Monitoring Runnning	
13			⊟	
14			Acquiring	Acquiring signals
15			Waiting	Waiting for start of acquiring by command, automatic or reset
16	F4: Command	REAL MODE	⊟ Command Active	
17			⊟	
18			Waiting	Waiting for Automatic or manual command or reset
19			Sending Command	Occupied, sending command

vi. UMB SCOE functional behavior analysis

After identifying the states and modes of operation, they are then refined using SysML state machine diagrams for each function external to the UMB SCOE. The Fig. 14 shows an example of that.

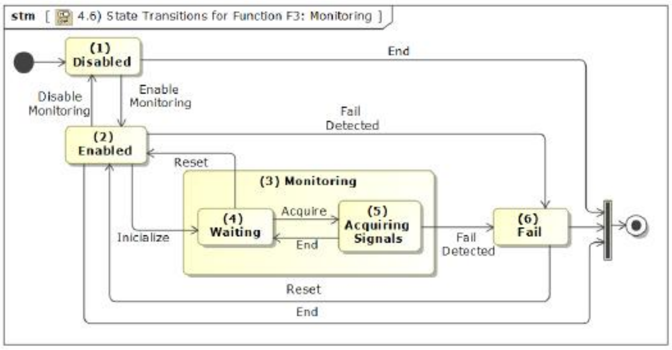


Fig. 14 - UMB SCOE Function State Analysis Example (State Machine Diagram).

vii. UMB SCOE functional architecture establishment

During functional behavior analysis, it is possible to identify the possible failures in each of the flows and thereby identify preventive and protective functions for the failures. (Vintecinque, 2017). After that, it will be possible to map how functions interact, and perform functional partitioning that will provide an "allocable" generic functional architecture, allowing architectural decisions to be taken, for the product and organization of interest. In the guide proposed by Vintecinque (2017) DFD diagram is used. With SysML, the use case diagram will be used, with some restrictions, use of stereotypes and minor implementation differences, as illustrated in Fig. 15.

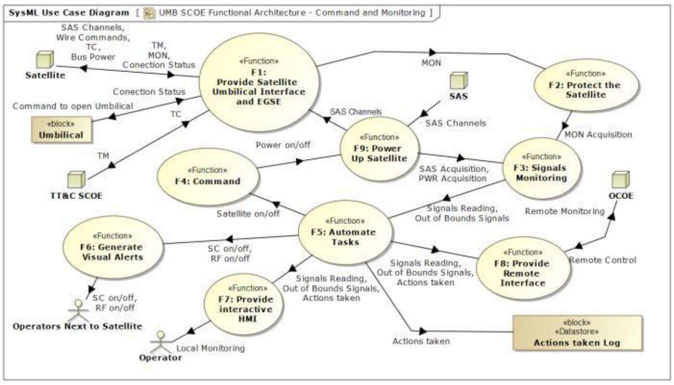

SysML Use Case Diagram [UMB SCOE Functional Architecture - Command and Monitoring]
SAS Channels, Wire Commands, TC, Bus Power
TM, MON, Conection Status
Satellite
«Function» F1: Provide Satellite Umbilical Interface and EGSE
MON
«Function» F2: Protect the Satellite
SAS
Conection Status
Command to open Umbilical
TC
«block» Umbilical
SAS Channels
SAS Channels
MON Acquisition
TM
Power on/off
«Function» F9: Power Up Satellite
«Function» F4: Command
SAS Acquisition, PWR Acquisition
«Function» F3: Signals Monitoring
TT&C SCOE
OCOE
Satellite on/off
Signals Reading, Out of Bounds Signals
Remote Monitoring
«Function» F5: Automate Tasks
«Function» F6: Generate Visual Alerts
SC on/off, RF on/off
Signals Reading, Out of Bounds Signals, Actions taken
«Function» F8: Provide Remote Interface
Remote Control
SC on/off, RF on/off
Signals Reading, Out of Bounds Signals, Actions taken
«Function» F7: Provide interactive HMI
Operators Next to Satellite
Actions taken
«block» «Datastore» Actions taken Log
Local Monitoring
Operator

Fig. 15 - UMB SCOE functional architecture example - Command and Monitoring (Use Case Diagram).

g. Implementation Analysis

i. UMB SCOE physical architecture establishment

At this stage, from the functional architecture, through the two types of block diagrams from SysML (BDD and IBD), it is possible to propose a viable generic architecture that seeks to satisfy all that has been raised before, and Fig. 16 represents this step. In the Guide proposed by Vintecinque (2017), the physical architecture for UMB SCOE was not proposed, which will then be done from now on.

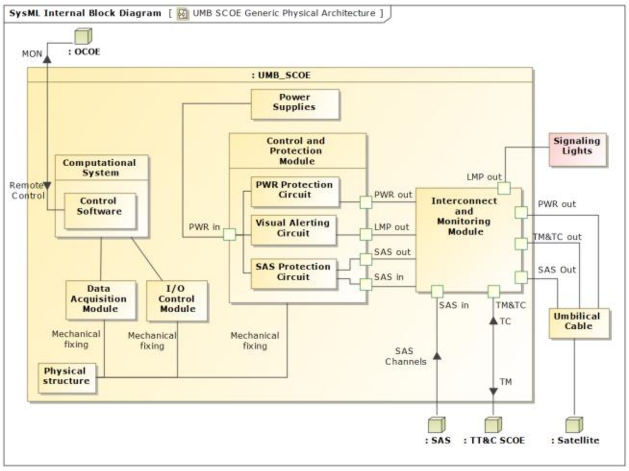
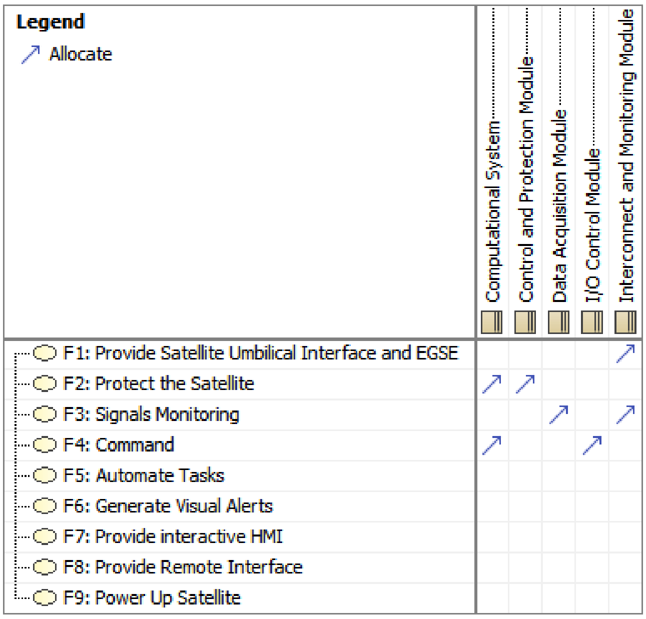


Fig. 16 - UMB SCOE Generic Physical Architecture Example (Use Case Diagram).

ii. UMB SCOE physical architecture's functions allocation

Function allocation can be done through "allocate" SysML connectors, in block definition diagrams, which do not necessarily need to be documented (they can be temporary). From the relationships made between the functions and blocks of the physical architecture, the allocation matrix can be generated directly from the modeling tool, as illustrated by Table 4.

Table 4 - UMB SCOE Function Allocation Example - (Allocation Matrix)



Legend
↗ Allocate

	Computational System	Control and Protection Module	Data Acquisition Module	I/O Control Module	Interconnect and Monitoring Module
F1: Provide Satellite Umbilical Interface and EGSE					↗
F2: Protect the Satellite	↗	↗			
F3: Signals Monitoring			↗		↗
F4: Command	↗			↗	
F5: Automate Tasks					
F6: Generate Visual Alerts					
F7: Provide interactive HMI					
F8: Provide Remote Interface					
F9: Power Up Satellite					

iii. Trade-off analysis

This type of analysis is still open in the ongoing study. At first, the intention is to make the trade-off analyzes for "product" by using several block definition diagrams with different practical solutions (Product BreakDown Structures) for the same physical architecture, with estimates and simulations for different vendors / data acquisition solutions, protection systems, etc.

The approach most appropriate in this case seems to be taking advantage of the characteristics of SysML parametric diagrams, as well as external tools integration and simulation, in order to simulate various scenarios of cost, ease of implementation, material availability, technical performance, etc., besides of morphological charts with adequate criteria and weights for each component in order to achieve a balanced Product Specific Physical Architecture, but this issue is beyond the scope of this study effort.

IV. CONCLUSION

The use of MBSE through the notation language SysML, supported by the use of appropriate modeling tools, allows to cover virtually the entire product and organization systems engineering life-cycle, obviously while respecting the limitations of the notation itself and maturity of its utilization, as well as the different methodological implementations that make use of it.

There are still difficulties in applying the notation fluidly with respect to the non MBSE approaches used in previous working frameworks, but future versions of the notation itself, such as SysML V2, as well as its future adoption by vendor modeling tools can simplify and better tailor their use more widely.

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