

Model Based System Engineering

IBM Symposium Systems
Astrium Space Transportation

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Presented by David LESENS

Tuesday, 26 March 2012

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Overview

- Introduction
- Model Based System Engineering
- SysML in practice
- What about the future of SysML?
- Conclusion



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Astrium: part of EADS, a global leader in aerospace and defence

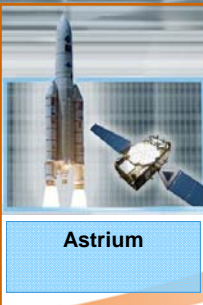
EADS



Airbus
Airbus Military



Eurocopter



Astrium



Cassidian

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Astrium Space Transportation

- Spacecraft
 - Complex System
 - Hard Real-Time
 - High level of criticality








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Table 4: Top Five Actions Taken to Improve Mechatronic Design

Actions	Response
Improve communication and collaboration across disciplines	71%
Increase visibility into status of requirements	49%
Increase ability to predict system behavior prior to testing	46%
Implement or alter new product development processes for a multi-disciplinary approach	43%
Increase real time visibility of product Bill of Materials (BOM) throughout the development process	39%

Source: Aberdeen Group, January 2008

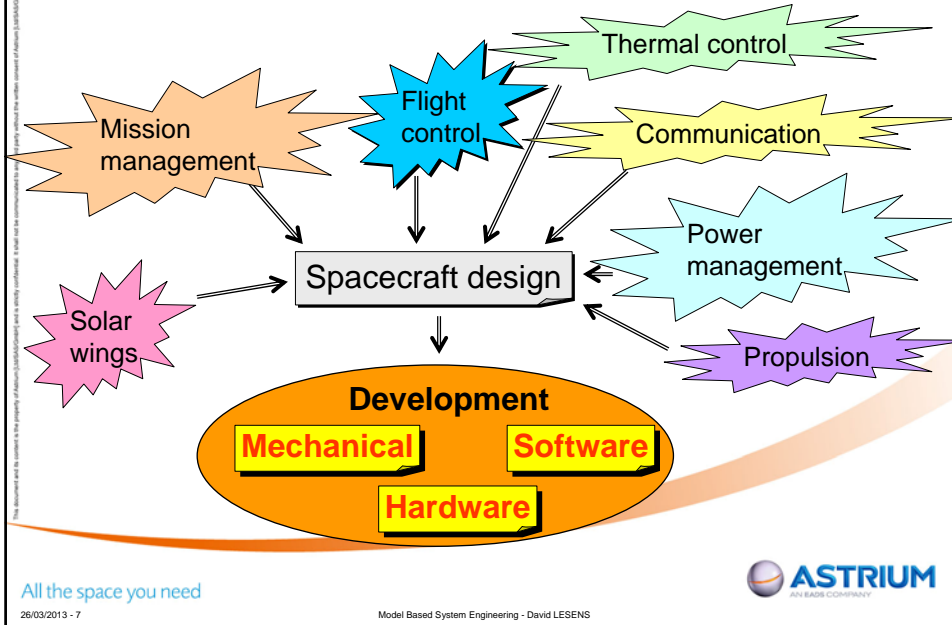
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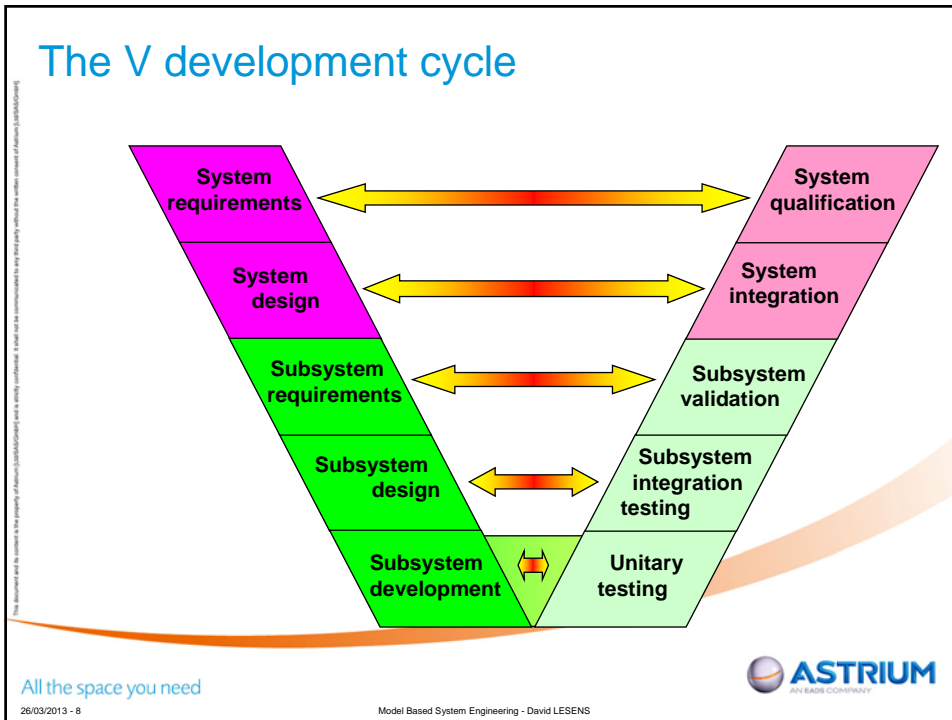
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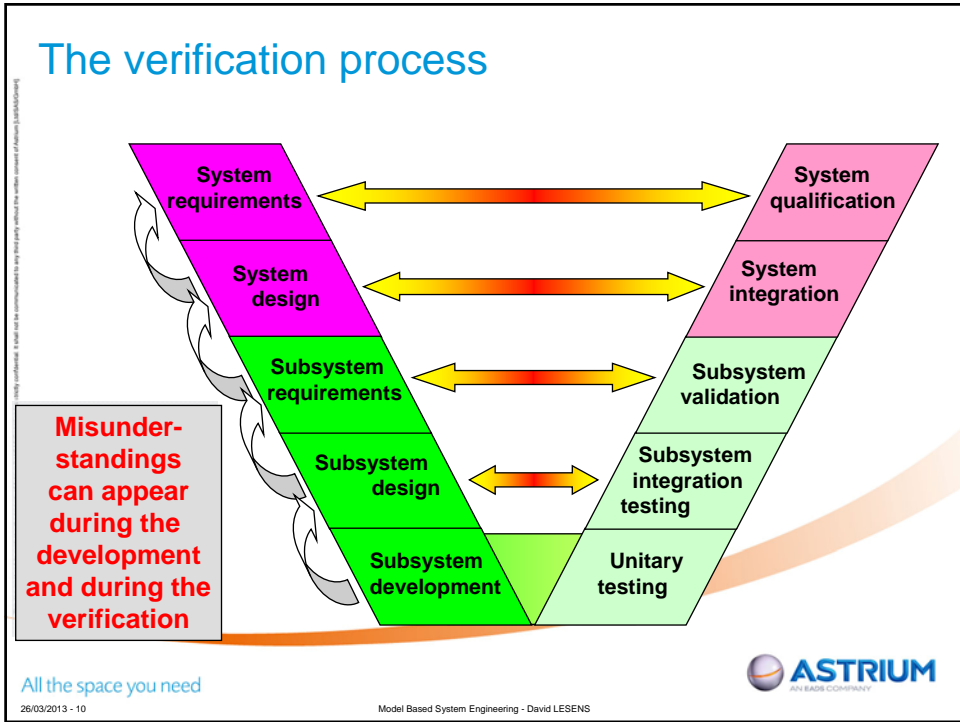
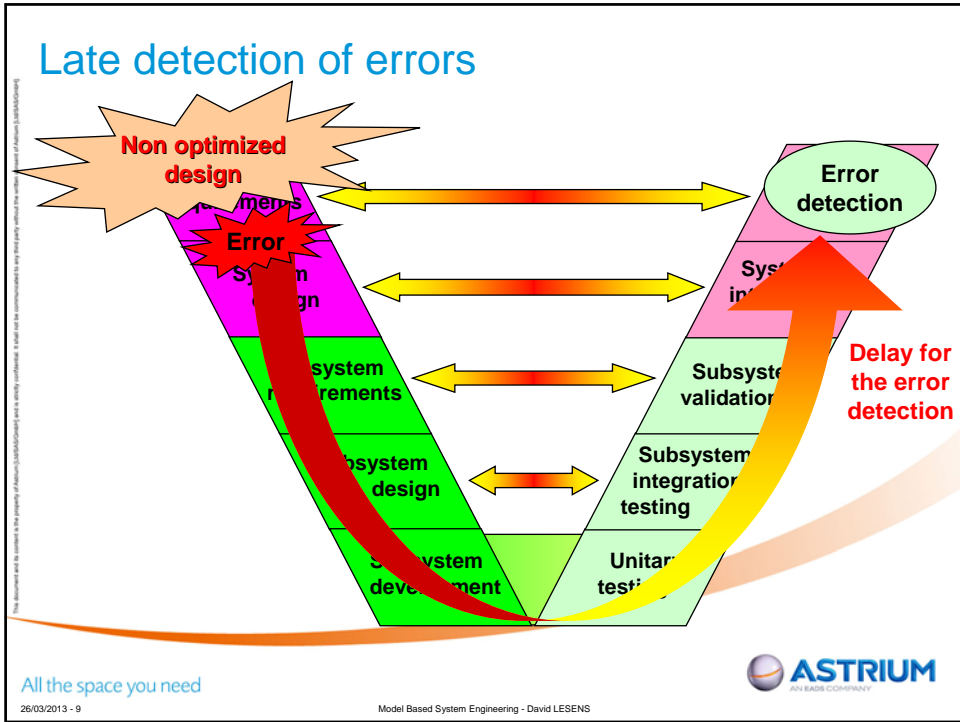


Why is System Engineering complicated?



The V development cycle





Model Based System Engineering (MBSE) main objectives

- Improving the communication between the teams
 - System: Guidance, Navigation, Control, thermal...
 - Software: specification, design, coding, verification & validation...
 - And also customers and external reviewers
- Developing the system
 - Performing a trade-off of design
 - Automatic code / parameters generation
- Improving the verification (ECSS definition)
 - (i.e. validation according to DO178 definition)
 - Syntax and semantics checking
 - Simulation and formal proof

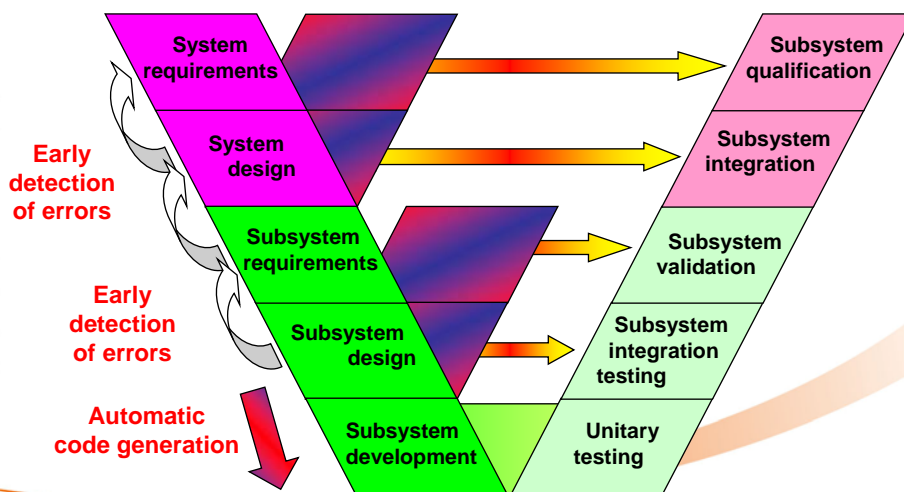
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Verification with model MBSE



MBSE = Model Based System Engineering

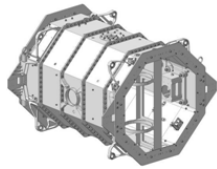
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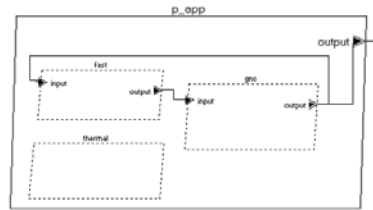
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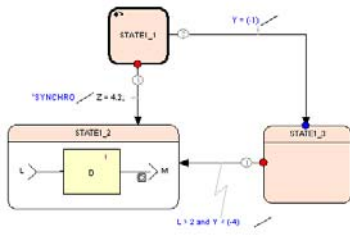
Some example of modelling languages



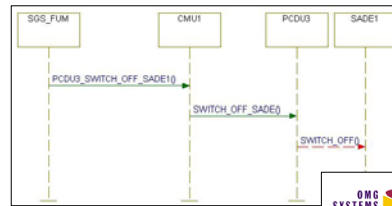
CATIA



AADL



SCADE



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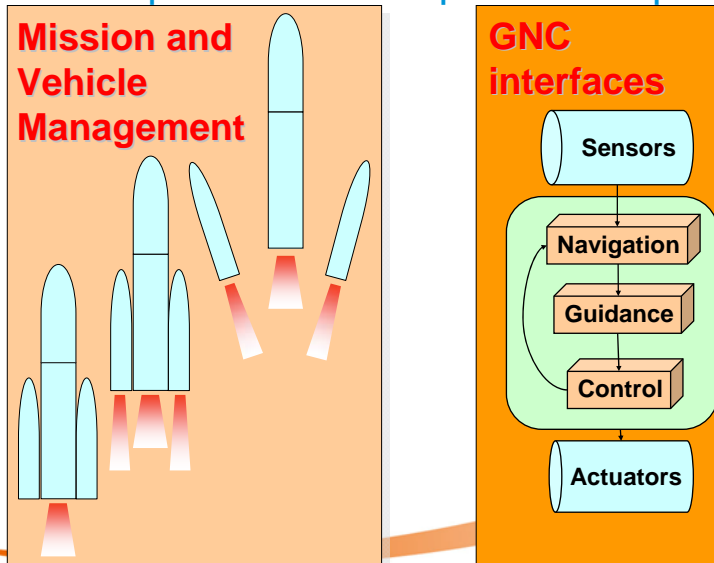
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SysML scope at Astrium Space Transportation



* GNC = Guidance, Navigation, Control

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Why SysML at Astrium Space Transportation?

- Avoiding information **duplication** on complex programs
- Improving **coherency** and **communication** among the various experts by using the same language
 - Electrical system, GNC(*), Software
- Formalizing and unifying the **best practices** already used "without specific tools"
 - Data flow, State-charts ...
- Extracting system and software **documentation** from a single model

* GNC = Guidance, Navigation, Control

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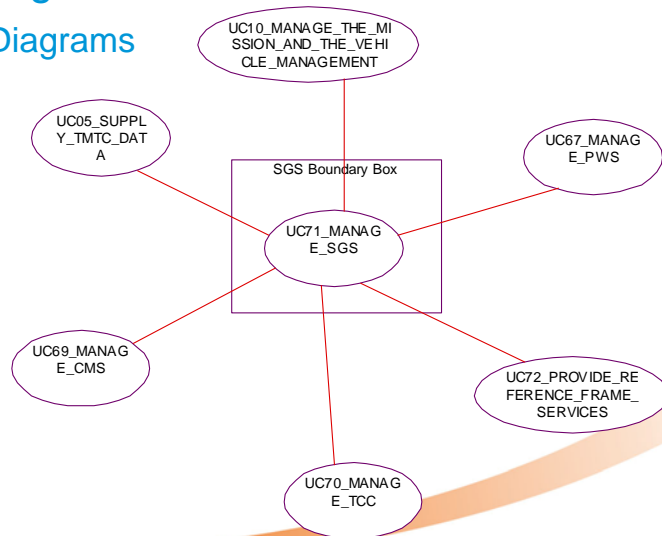
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SysML at a glance

Use case Diagrams



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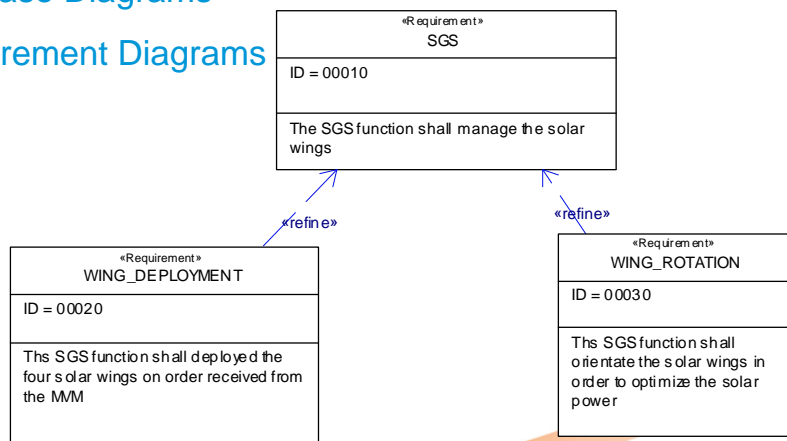
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SysML at a glance

Use case Diagrams Requirement Diagrams



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SysML at a glance

- Use case Diagrams
- Requirement Diagrams
- Internal Block Diagram



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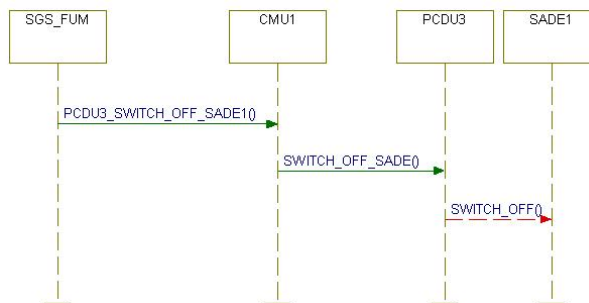
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SysML at a glance

- Use case Diagrams
- Requirement Diagrams
- Internal Block Diagram
- Sequence Diagram



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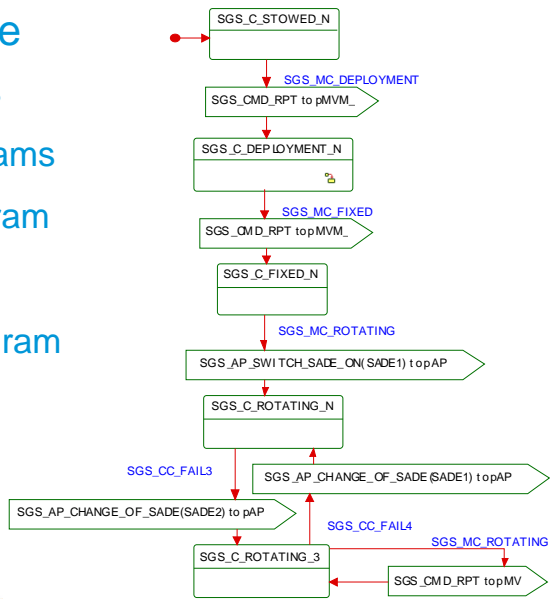
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SysML at a glance

- Use case Diagrams
- Requirement Diagrams
- Internal Block Diagram
- Sequence Diagram
- State Machine Diagram



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SysML at a glance

- Use case Diagrams
- Requirement Diagrams
- Internal Block Diagram
- Sequence Diagram
- State Machine Diagram
- ...

Very complex language

Can it be used by non modelling experts?

- ✓ GNC
- ✓ Propulsion
- ✓ Mission management
- ✓ Power
- ✓ ...

Precise guidelines are mandatory

* GNC = Guidance, Navigation, Control

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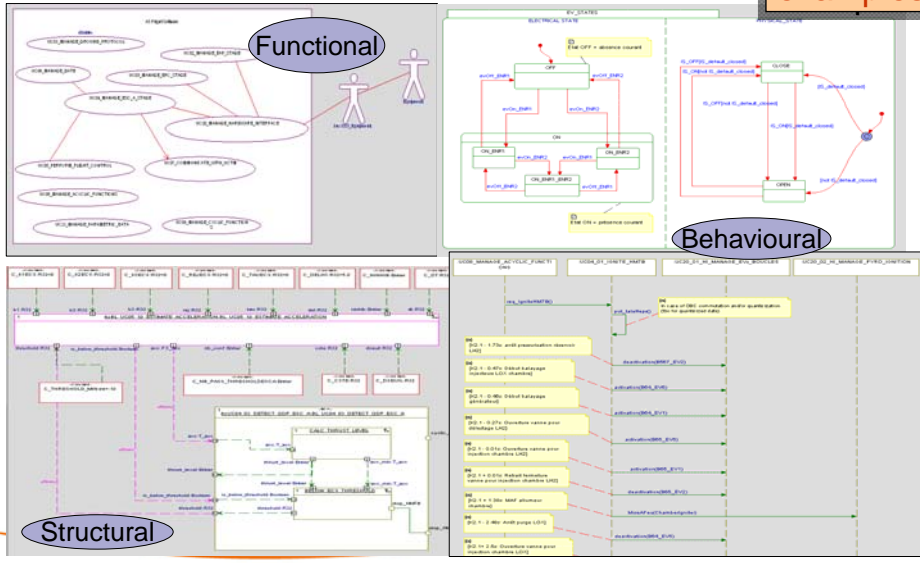
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Functional/Behavioural/Structural views

Guidelines examples



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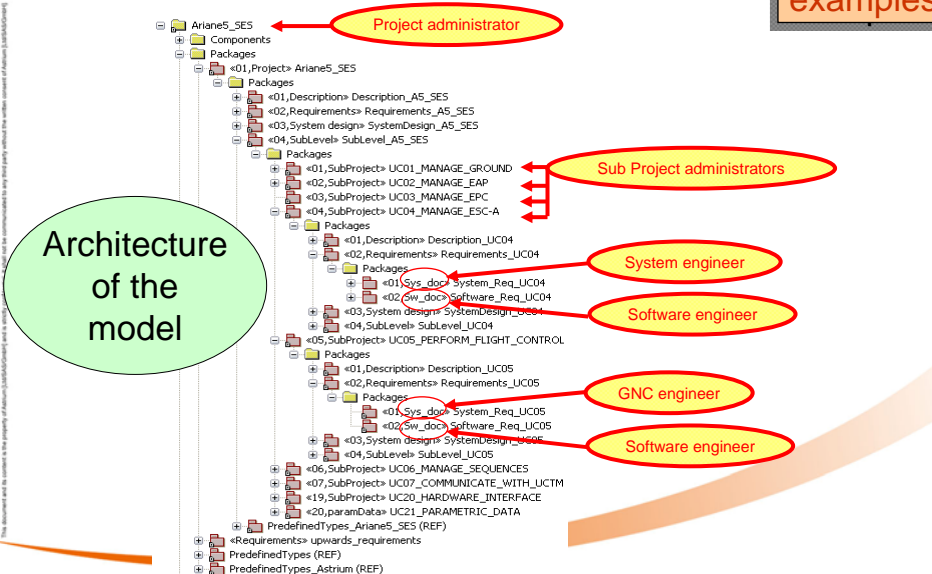


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Architecture and contributors

Guidelines examples



Architecture of the model

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Naming convention

Guidelines
examples

For instance

- Package names shall be in upper case
- Block names shall start with BL_
- Use Case names shall start with UCXX_ where XX is a number
- ...

Message	Severity	Category	Status
The element does not fit the name convention: Block shall start with BL_ (1)	Warning	AstriumCheck	Complete
block : A5_FS in Ariane5_FS::Ariane5_FS_OVERVIEW::SystemDesign_A5_FS	Warning	AstriumCheck	Complete
The element does not fit the name convention: Internal Block Diagram shall start with IBDXX_ (8)	Warning	AstriumCheck	Complete
Internal Block Diagram : IBD_UC20 in Ariane5_FS::UC20_HARDWARE_INTERFACE::HARDWARE_...	Warning	AstriumCheck	Complete
Internal Block Diagram : IBD_UC05_01 in Ariane5_FS::UC05_PERFORM_FLIGHT_CONTROL::UC0...	Warning	AstriumCheck	Complete

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Requirements checks (1/2)

Guidelines
examples

- Check if a requirement satisfy at least another one
- Check that every requirement appears at least once in a requirement diagram
- Check the requirement location i.e. it is not possible to put requirements at any place in the browser

Checks	Count
Errors (8)	8
A requirement dependencies shall be stereotyped by decompose or satisfy (or both) (2)	2
Dependency : DF04_200_X_Estimate acceleration in Ariane5_FS::UC05_PERFORM_FLIGHT_CONTROL::UC05_01_ESTIMATE_ACCELERATION::Requirements_UC05_01::Software_Req_UC05_01-ST-555_2_X...	2
Requirement : ST-555_2_X,Initialisation for Estimate Acceleration in Ariane5_FS::UC05_PERFORM_FLIGHT_CONTROL::UC05_01_ESTIMATE_ACCELERATION::Requirements_UC05_01::Software_Req_UC05_01	2
Every Requirement shall appear at least one time in a diag (1)	1
Every Requirement specification shall not be empty (5)	5
Warnings (6)	6
A requirement shall refine at least another requirement (4)	4
This Requirement is not allowed at this level (1)	1
This requirement does not have a satisfy stereotype: there must be missing some requirements (1)	1
Info (0)	0

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Requirements checks (2/2)

Guidelines
examples

<<01,Description>>Description_XX

Use Cases/Actors & Use Cases diagrams except for 2nd level functions

<<02,Requirements>> Requirements_XX

<<01, Sys_doc>> System_Req_XX

Requirements & requirements diagrams

<<01, Sw_doc>> Software_Req_XX

Requirements & requirements diagrams

<<03, System design>> SystemDesign_XX

<<01, Scenarios>> Scenarios_XX

Requirements & Sequence diagrams

<<02, Archi design>> ArchitecturalDesign_XX

Internal block diagrams

<<03, Config data>> ConfigurableData_XX

Usage of configurable data (constants, mission data ...)

<<04, Sublevel>> SubLevel_XX

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Empty description

Guidelines
examples

- Some elements shall have their description filled with some information.

- Constants
- Blocks
- Flow ports
- Parts
- Standard ports
- Some Use Cases

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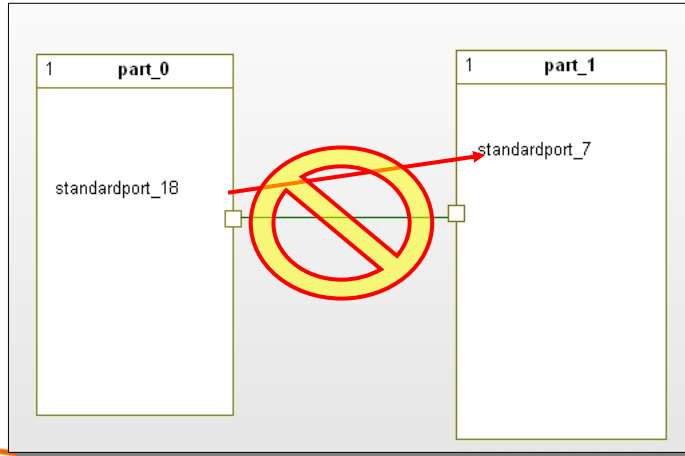
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Standard ports (1)

Guidelines examples

Different names → NOK



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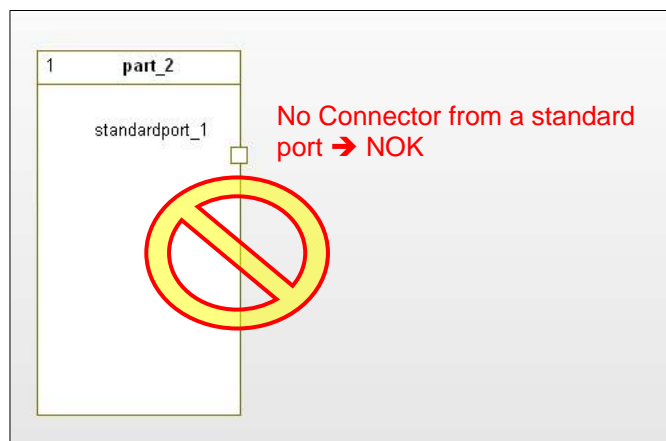
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Standard ports (2)

Guidelines examples

No Connector from a standard port → NOK



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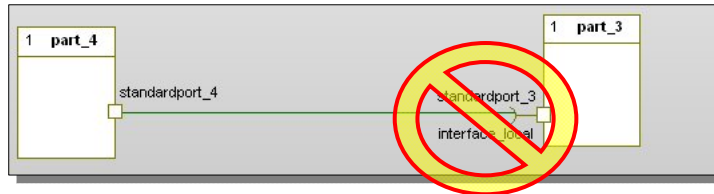
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Standard ports (3)

Guidelines examples

Connector between standard ports with a required interface, without provided → NOK



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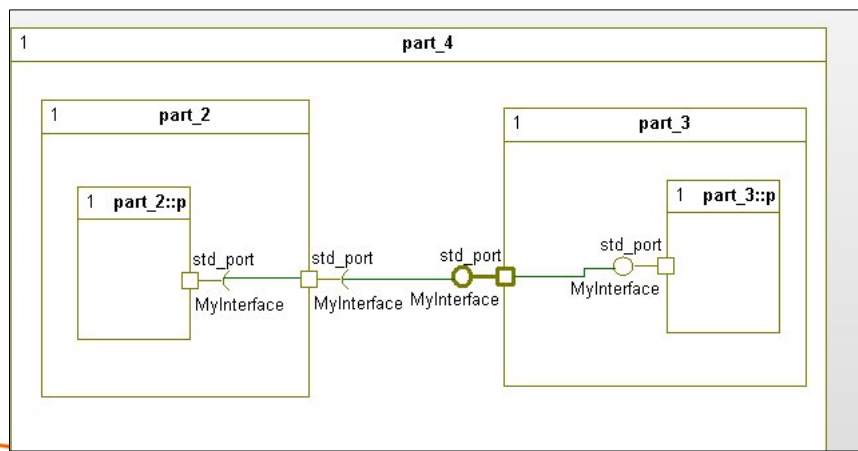
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Standard ports (4):

Guidelines examples

Connector with provided and required interface with intermediate interface → Ok



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Some modelling tools

SysML is a graphical language

→ Need of a graphical editor



■ Rhapsody



■ System Architect



■ Papyrus



■ Magicdraw



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Some needed features

- Configuration management
- Multi-user
- Traceability
- Documentation generation
- Simulation
- Research
- Differences between models
- ...

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Documentation generation

8.2.1 Architectural Design

8.2.1.1 Block name: BL_UC04_MANAGE_ESCA

Block Description: <<To Be Defined>>
 IBD Description: <<To Be Defined>>

Standard port name	Description	Receipt Events	MVM Activation Description	Sent Events
valves_pilot				
pyro_ignition				
sequence_access				

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Differences between models

Attribute	Left Value	Right Value
isStub	0	0
persistAs		
displayName		
description		
legalDisclaimer		
isReference	0	0
license		
name	SD1_IgniteHM7B	SD1_IgniteHM7B
persistAsGenerated	0	0
language		
properties	Subject.Format: Metaclass Anchor...	Subject.Format: Metaclass Anchor...

Graphical differences Different items on the left... Different items on the right...

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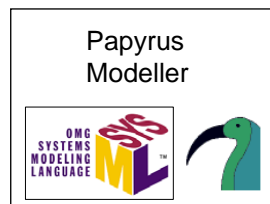
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Use of open source tools

- Open Source tools for the development of embedded software and business model to support long term availability
- ➔ Polarsys Eclipse Industrial Working Group



- **Maturity issue**

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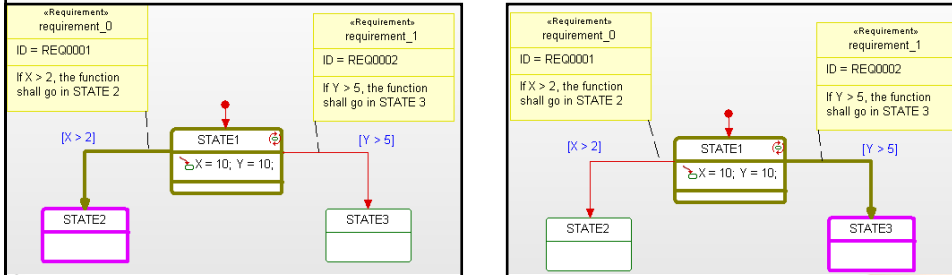
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SysML is adapted to system engineering

But the SysML semantics is not formal

Simulation with the Rhapsody tool



Two models graphically strictly equivalent
But with **different behaviours**

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The principles of Formal Model Driven Engineering

There are two ways of constructing a software design. One way is to make it so simple that there are **obviously** no deficiencies. And the other way is to make it so complicated that there are no **obvious** deficiencies.



Professor C. A. R. Hoare
The 1980 Turing award lecture

- ✓ Use of Model Driven Engineering
- ✓ Use of Formal Methods

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OMEGA SysML profile (1/2)

Objectives

- Definition of a **formal semantics** for SysML
 - OMEGA profile
- Validation of the SysML modelling
 - Static semantics checker
 - Simulator
 - Formal proof
- Implementation
 - Rhapsody tool
 - Papyrus tool foreseen

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OMEGA SysML profile (2/2)

A large subset of SysML

- Covering **discrete & timed** system specifications
- With **additional static coherence rules**
 - E.g., complex typing system for composite blocks & connectors
 - Formalized in OCL, enforced by tools
- With a **formal operational semantics**
 - No hidden choices
 - Captures voluntary non-determinism
 - Allow the designer to control the concurrency granularity
- With **few extensions**
 - E.g. for formalizing actions, properties, constraints

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Conclusion

- SysML in the space domain
 - Is **operationally** used
 - Improves the **system to software engineering**
 - Decreases the costs and the **delays**
- But needs
 - Clear **objectives**
 - Precise **guidelines** and processes
 - **Trained** teams
 - **Adapted** tools
- And will need to be in the future
 - More and more **formal**
 - With a **long term** availability

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