Model based Avionics roadmap and case studies

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A.Rossignol, S. Estables, A. Cortier, D. Thomas
Airbus Defence and Space – Space Systems
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Agenda

- Model-based Avionics motivation and needs
- E-Deorbit System MBSE approach & feedbacks
- Functional Avionics MBSE approach & feedbacks
  - FDIR & AOCS
  - Operations on Rover & JUICE
- Links with other SE & MBSE initiatives
- Model-based Avionics next steps

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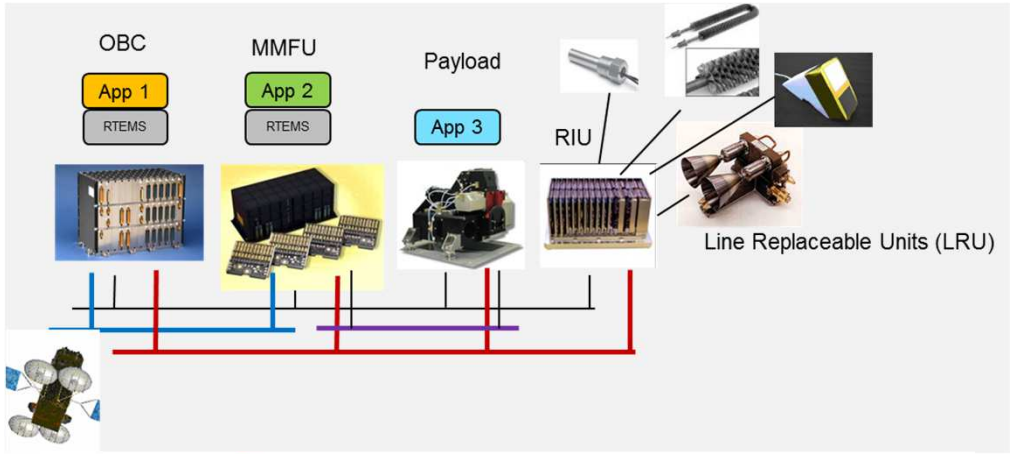
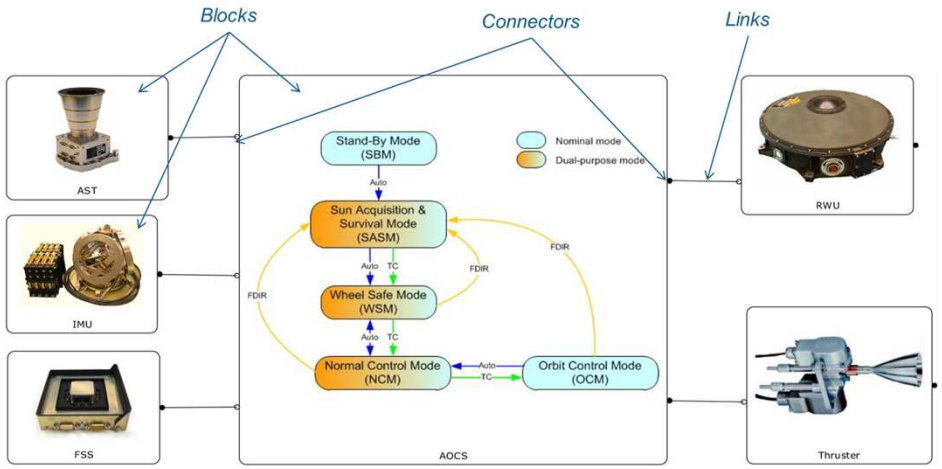
Model-based Avionics motivation





Functional avionics for a Satellite:

- Includes architecture and technologies
- Address definition, design, implementation and validation in Computers & SW intensive equipment of functions and algorithms
- Covers various system levels (complete system, sub-systems, platform, equipment, boards), from very different functional chains (Command & Control, mission management, GNC, Image processing, payload & instruments data processing…)
- With a large variety of criticality and safety levels.

On avionics architecture and computing domain, initial requirements and design engineering of new products with computers, on-board software, system functions and applications algorithms, sensors / actuators and payloads are key for mastering cost, schedule, quality and risks of the avionics development.

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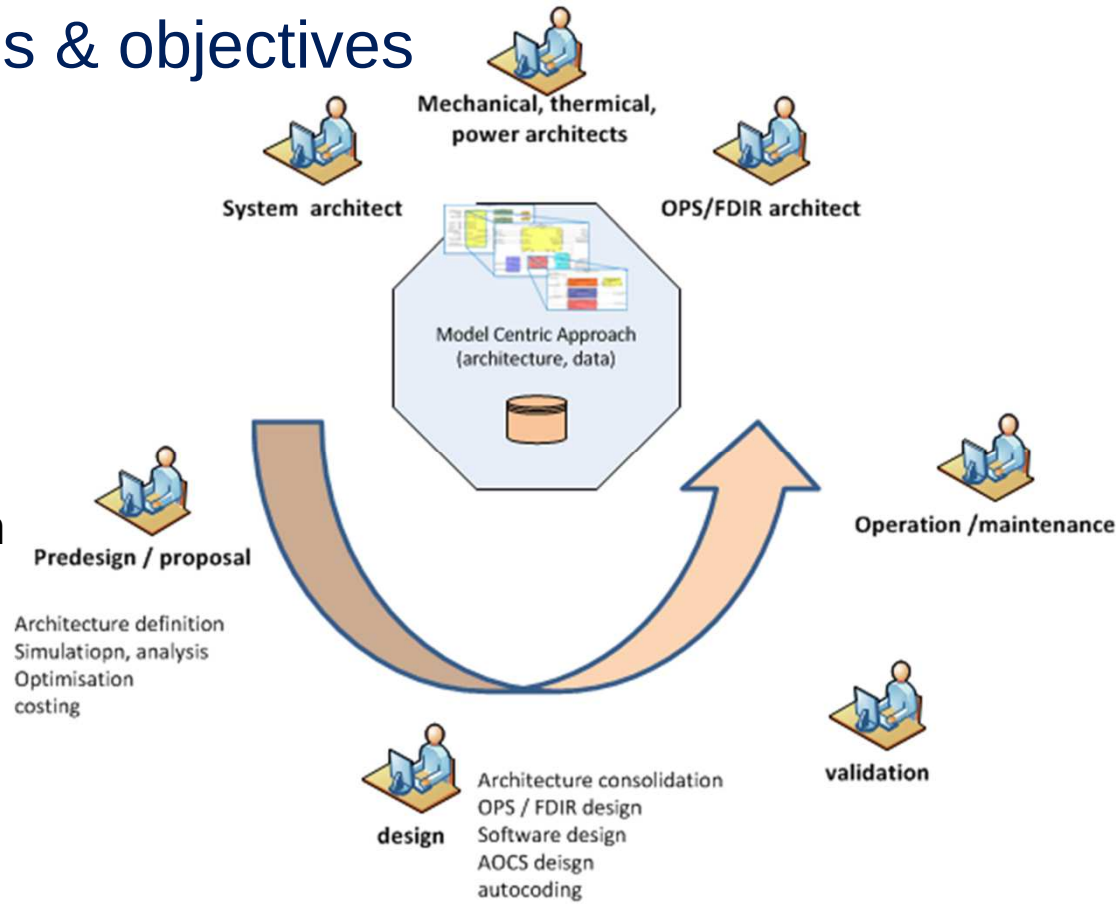
Model-based Avionics expectations & objectives

The main expectations out of a successful Avionics MBSE implementation are:

- Effective concurrent engineering and design
- Make the implicit explicit
- Consistency/completeness of the functional modelling (early validation)
- Formalisation of data needs & flows between disciplines (robust data model)
- Harmonised practices (disciplines / sites / projects) for establishing the functional requirements and architecture



The main Avionics MBSE objectives are:

- ***Reinforce System to SW engineering from documents-based only to model-based supporting engineering, capitalisation, documentation production, requirements Mgt***
- ***Cover models at system level (OPS, FDIR, Satellite, Avionics , HW) with better definition of modelling objectives (feasibility concept, requirement formalisation, properties verification)***
- ***Better support of Avionics & OBSW product lines development & building blocks reuse (Options / variants management, Robust and complete Data model full compatible with System Data Base, Product documentation generic / mission specific)***

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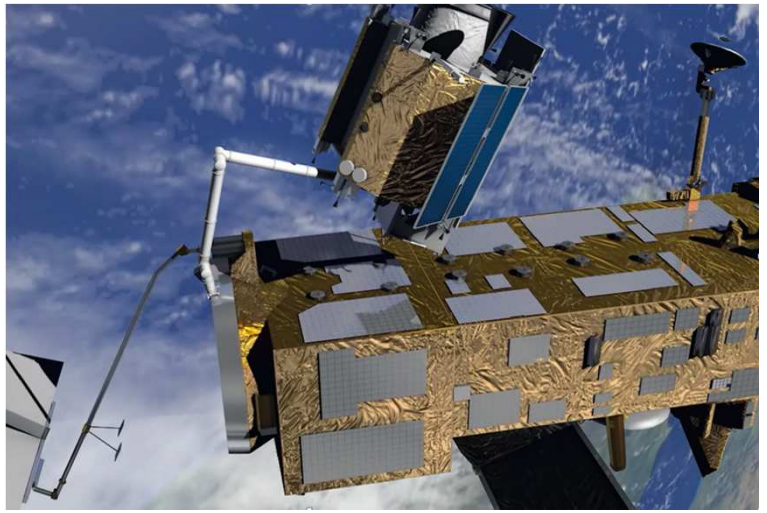
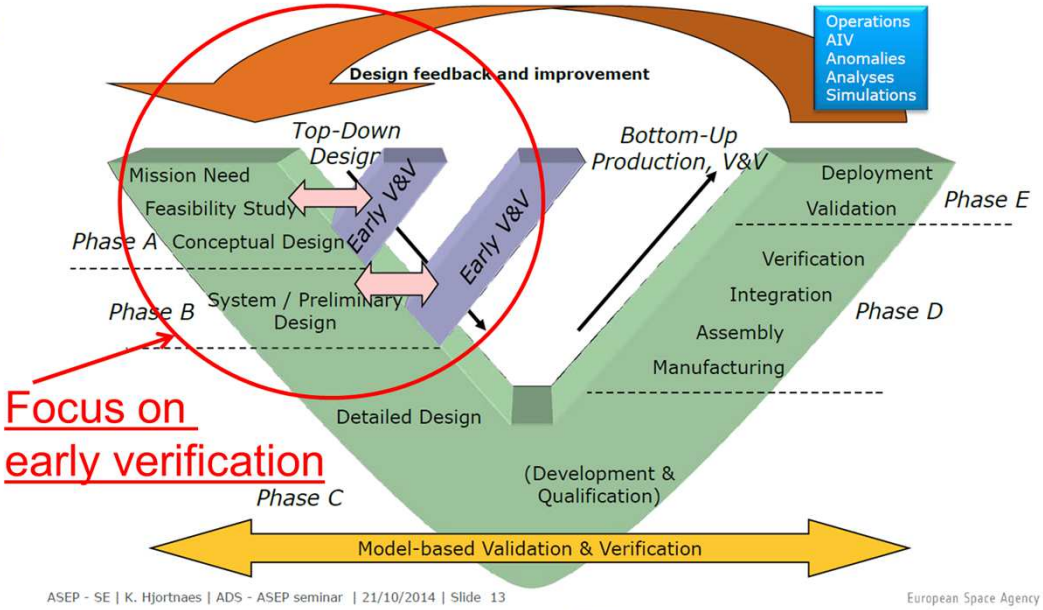
E-Deorbit System MBSE approach & feedbacks

Mission needs = motivation for early system modeling and simulation

- Rendezvous and capture/docking missions are characterized by **complex sequence of operations in the vicinity of the client** where various mission domains like navigation, control, mechanics, communication, power, thermal, modes interact on each others.
- In the standard development approach the domains are covered individually **neglecting the potential interactions between the domains**. These interactions can be the source of problems discovered later in the engineering process if not considered right at the beginning leading to costly changes after the system design.
- Due to the important number of factors involved in rendezvous and capture phases, the **parameter space is huge and requests tool support to be properly and systematically explored**. Trade-offs and optimizations data shall be well documented and shared.





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E-Deorbit System MBSE approach & feedbacks

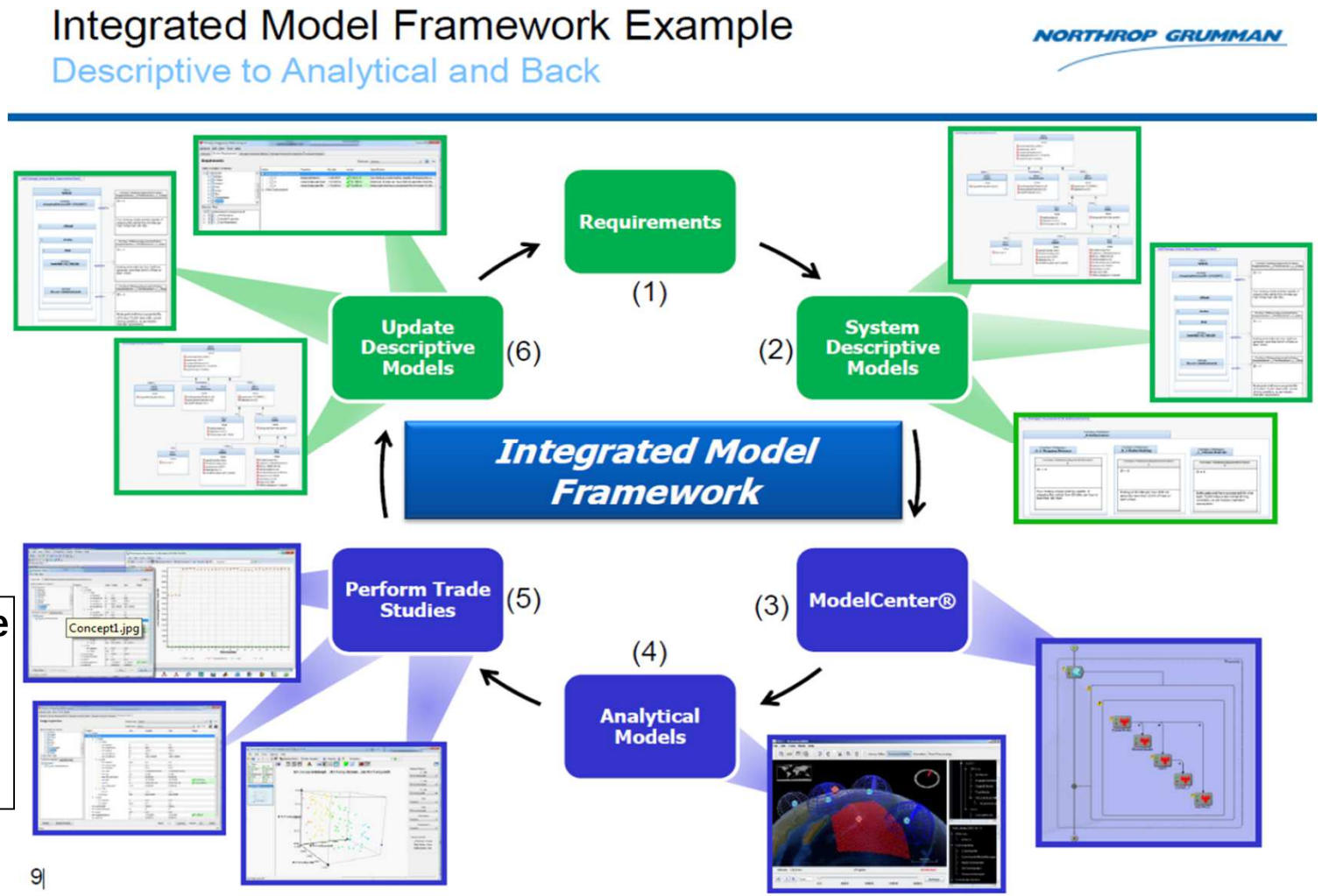
Environment for "Experiment and fail early"

Experiment the system (Simulations, DMU, Analysis)

Optimize the system (Drivers, Performance/cost optimisation)

Link the data, search the data and get an overview on the data (Dashboard, System design synthesis)

Accumulate the knowledge and share the data (Basic models, System budgets)



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E-Deorbit System MBSE approach & feedbacks

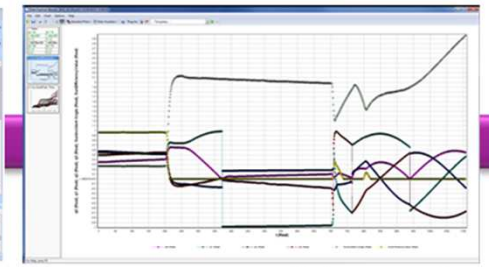
Link SysML / CDP / Matlab / ModelCenter in one process for implementing the Design – Analysis – Verification Workflow

ModelCenter

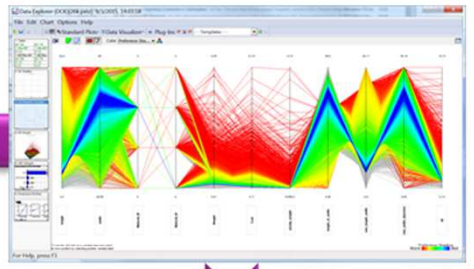
Analyse & Verify System

- Parameter trends
- Parameter coupling
- Optimisation
- Requirements verification

Simulation



Data generation

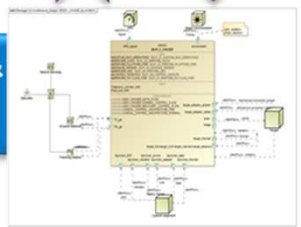


Data analysis

Exchange of model data

SysML

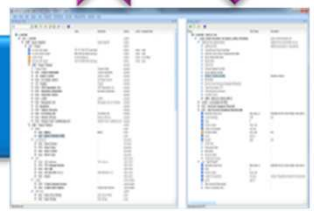
Develop Requirements & System Architectures



- Requirements definition
- Mission needs analysis
- Mission Modes and scenarios
- Functions and Safety
- Architectures
- Verification

CDP

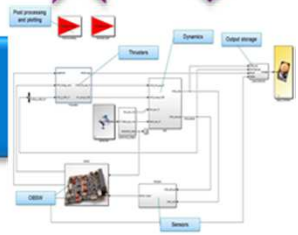
Develop Physical Architecture



- Product Tree
- System Budgets
- Physical architecture iterations

Matlab

Develop Dynamic Behaviour



- Trajectories
- Motion parameters
- Monte Carlo analysis
- Propellant consumption estimation

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Functional Avionics MBSE approach & feedbacks

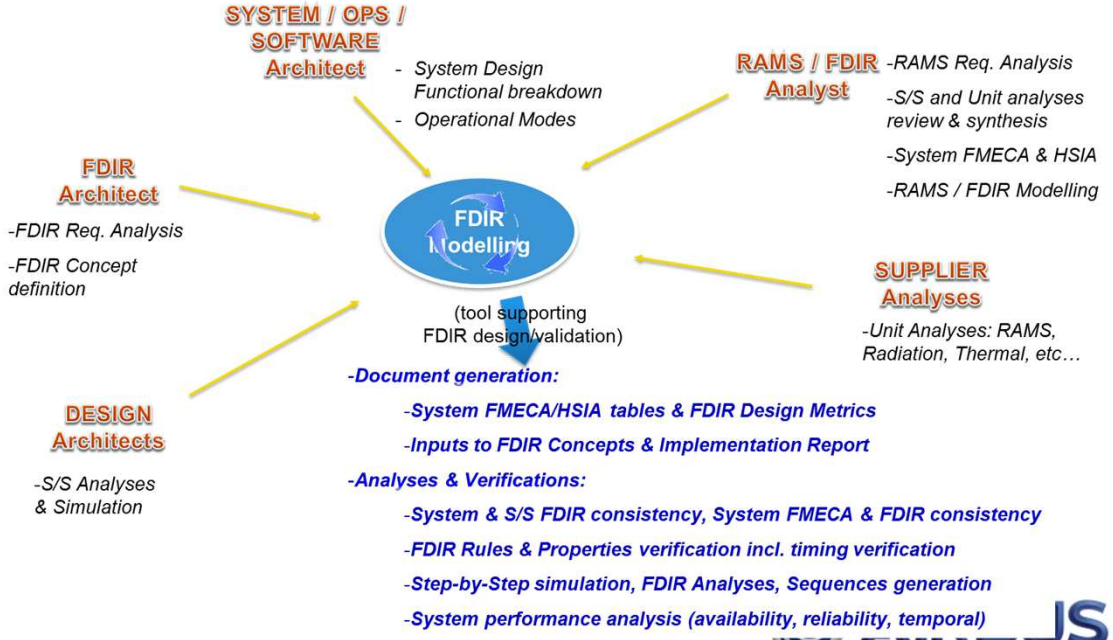
FDIR & AOCS modelling : objectives and expectations

Reduce the risks associated to the lack of FDIR maturity and inappropriate phasing ➔ ***reduce "non quality" cost***

- Reinforcing the Process application with a supporting tool.
- Correctness of the FDIR (scenarios and properties checking)
- Early FDIR concepts "validation" supporting FDIR engineering, fast iterations loop and changes "validation".
- Unique System/FDIR description to support communication between System and SW.
- Consistency of FDIR data all along the system life cycle (SM, FM, FIR) and for all related activities (FDIR report, FMECA, SW Spec, DB, …)

Support the ***industrialisation*** & cost reduction for Satellite products and ***reuse.***

At FDIR/System level
and at FDIR/SW level
mainly for PDR
with strong OPS / FDIR / SW / RAMS
co-engineering



Functional Avionics MBSE approach & feedbacks

FDIR & AOCS modelling : : two main approaches

Specific state-based dysfunctional model:

RAMS/FDIR Modelling with Simfia ➔ ADS Internal studies

- Languages / Tools
  - AltaRica
    - Formal allowing model-checking
    - Tools: Simfia (Apsys), Cecilia Ocas (Dassault Aviation), Safety Designer (Dassault Systems)
  - AADL + Error Model Annex
    - Formal allowing model-checking
    - Tools: Academic
  - ESA Compass
    - Formal allowing model-checking
    - Tools: Compass under development on ESA funding (low maturity)
  - SysML / UML
    - No model-checking but simulation
    - Tools: UML editors ….
  - UPPAAL, etc…

Fault injection in functional model

AOCS FDIR Modelling in Simulink ➔ ESA Study in progress

- Languages / Tools
  - ESA Compass
    - Formal allowing model-checking but performances are killer
    - Tools: Compass under development on ESA funding (low maturity)
    - Code generation: Ada
  - SCADE (control engineering)
    - Formal allowing model-checking
    - Tools: Compass under development on ESA funding (low maturity)
    - Code generation: C
  - Matlab/Simulink (control engineering)
    - Not formal but powerful simulations
    - Limited to control laws
    - Code generation
  - SysML / UML (software engineering)
    - Not formal but simulation supported
    - Code generation

Functional Avionics MBSE approach & feedbacks

FDIR/RAMS modelling with Altarica : main benefits & drawbacks

Main benefits for RAMS

- Failure Modes and Effects Analysis helped through modelling
  - Modelling of propagation avoids thinking again / repeating system effects in bottom-up approach
  - Consistent FMEA where each effect is presented the same way
- HSIA (referencing of SW FDIR requirements) is push button provided FDIR information is modelled
- Provides indicators to track FMEA progress / maturity: source of failure modes

Main benefits for FDIR

- Formal, modelled FMEA: clear links between failures, observables, propagation
- Support the simulation and verification of monitoring validity logic
- Provides indicators to track FDIR design progress: failure coverage, monitoring definition

Main benefits for Project

- FMEA / FDIR consistency

But some drawbacks

- *Relativity expensive without existing architecture functional model with import / transformation*
- *Could be deployed only on projects with complex & new FDIR, and potentially only on some specific part of the functional architecture*

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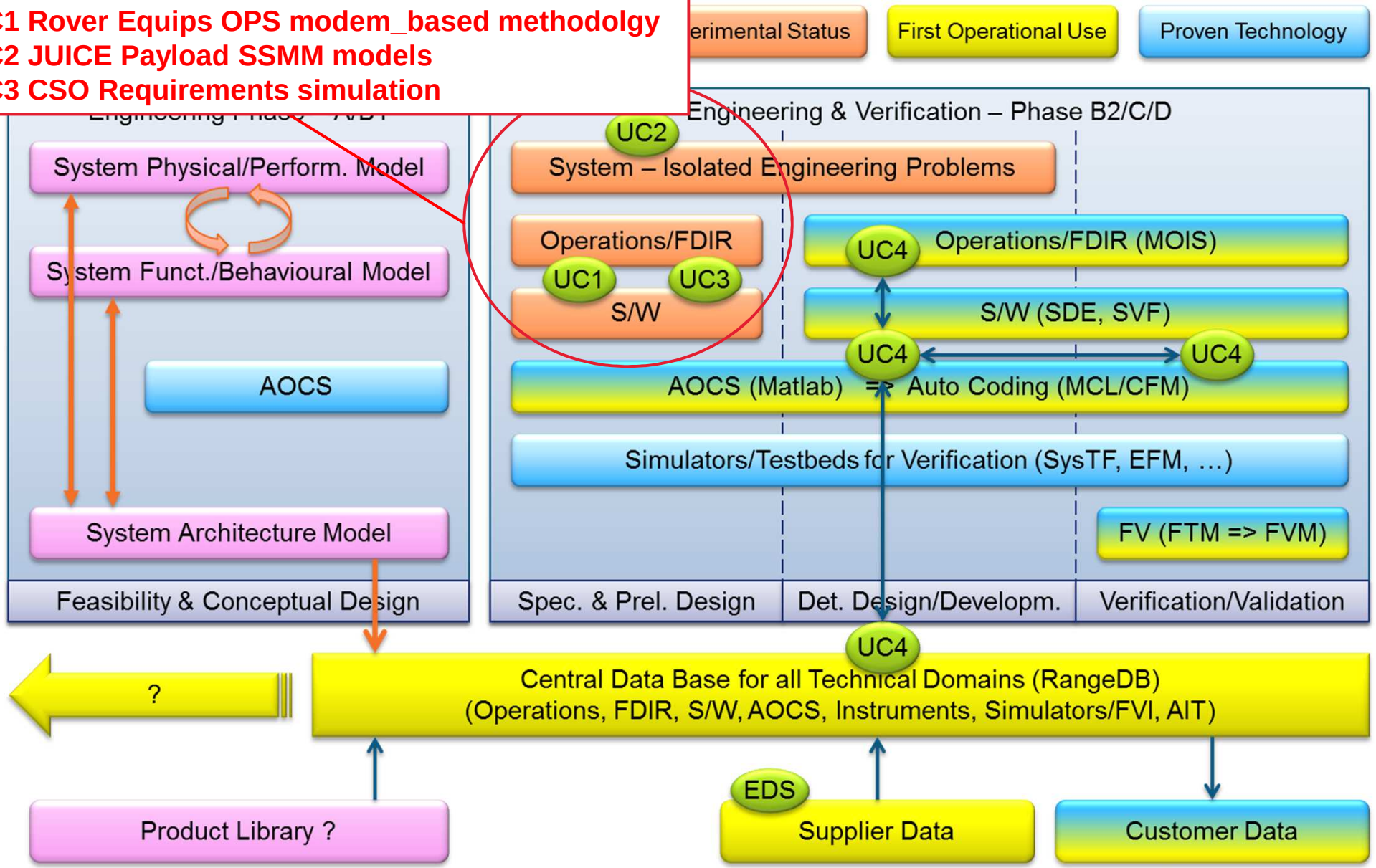
FAMOUS
Functional Avionic Model Oriented USage

FAMOUS - Functional Avionics Model Oriented Usage

Use cases : general introduction

First Focus & Use cases
UC1 Rover Equips OPS modem_based methodolgy
UC2 JUICE Payload SSMM models
UC3 CSO Requirements simulation



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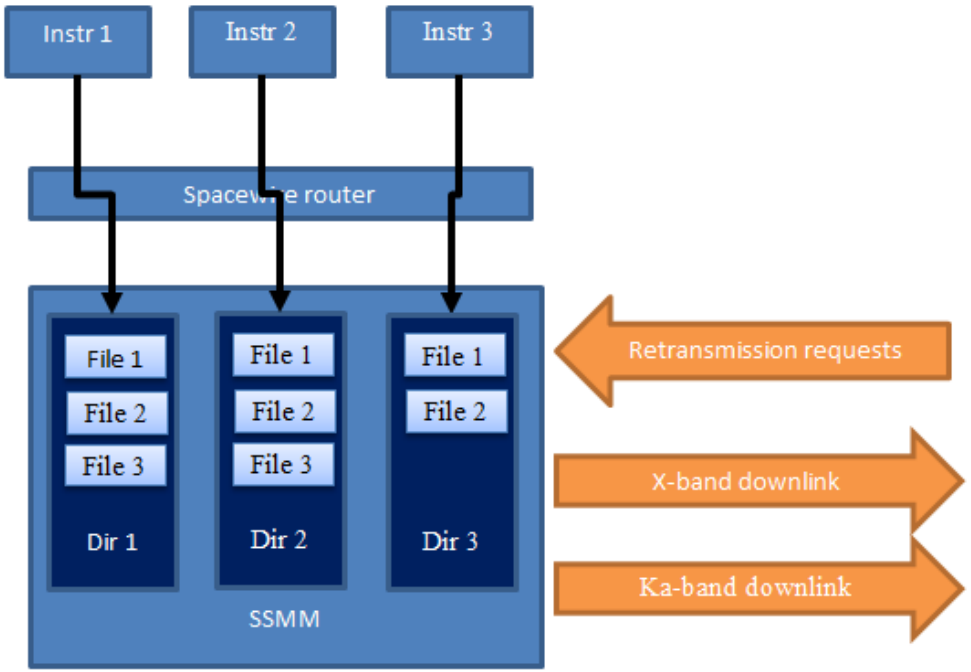
FAMOUS - Functional Avionics Model Oriented Usage

UC2 : JUICE Payload SSMM

JUICE Use Case

- **Mission characteristics and constraints :**
  - Deep space mission
  - Low TM rate
  - 2 downlink bands (X & Ka-Band)
  - Spacewire router
  - Up to 10 equipments
  - Solid state mass memory
  - FBO : File Based Operation (CFDP protocol)
  - Capability of retransmission

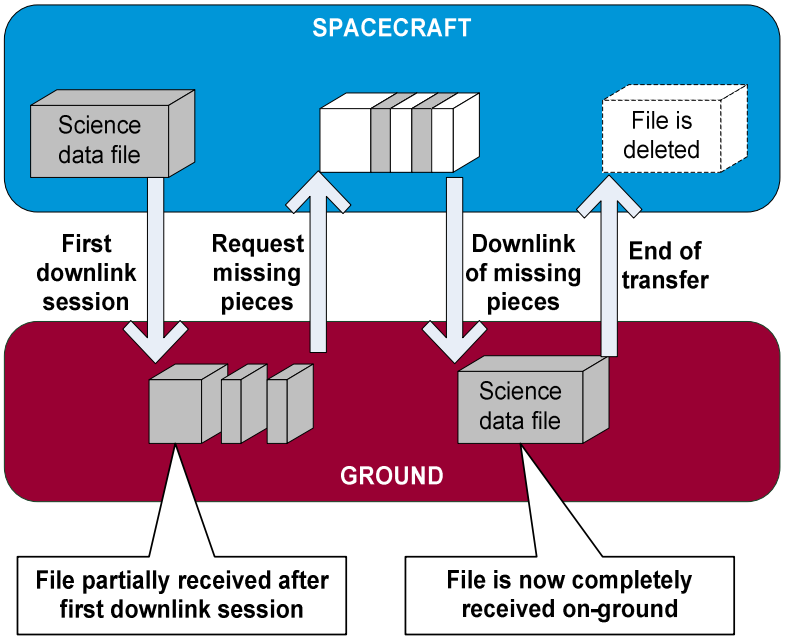


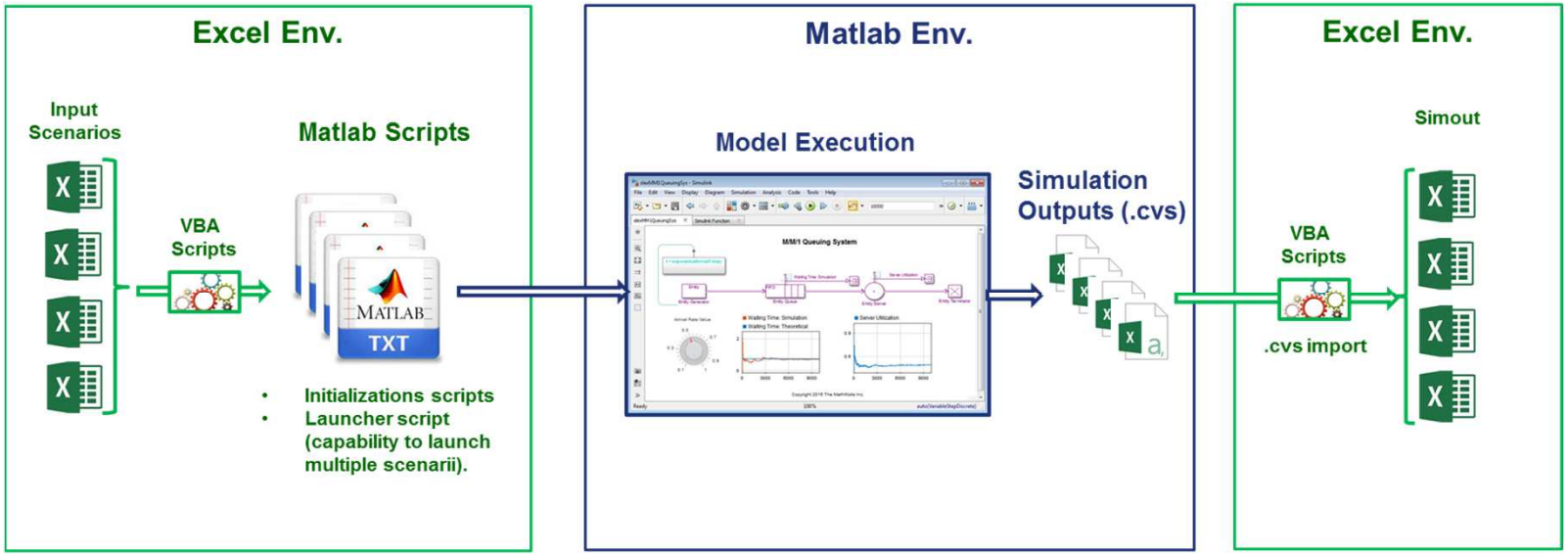
- **Objectives : How to operate the satellite to maximize the amount of transmitted data with respect to the scientific requests ?**
  - Model the science data flow from instrument production to downlink to :
    - Assess data latency on-board
    - Amount of segment retransmission
    - Help PIs in understanding the system and designing the data storage (file size, number of files, criteria for file Switching, selective downlink usage)
    - Assess Memory occupation
- **Simulation objectives :**
  - Simulation up to 7 mission days
  - Performance : 1 simulation scenario played in less than 2h

FAMOUS - Functional Avionics Model Oriented Usage

UC2 : JUICE Payload SSMM

- **Activities:**
  - **Simulink/SimEvent** model of the SSMM ➔ **Main model for the Use case**
    - First model Matlab/Simevent R2015b
    - Second model : Matlab/Simevent R2016a
  - **Pragmadev model** ➔ Alternative model to compare
- **Outcomes :**
  - **Understand/agree the requirement related to science data flow management**
  - **Define & evaluate traffic scenario and optimal refrence test case for system validation**
  - Could help better scope the CFDP sub-contractor work

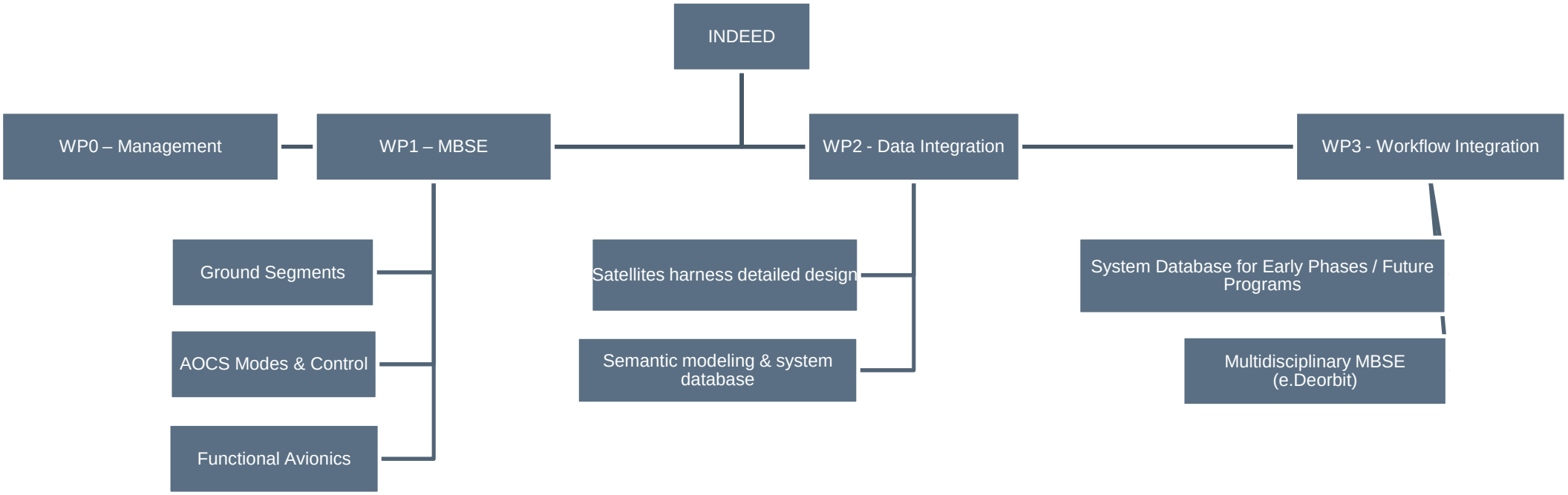




Links with other MBSE initiatives

With ADS & Space Systems INDEED project (INtegrateD Engeering Enhancement Delivery)

The global objective of the INDEED project is to ***propose a System Engineering architecture, enabling effective interdisciplinary integration***, notably through improved **interdisciplinary sharing of data and models** and enabling **re-use of models from program to program.**



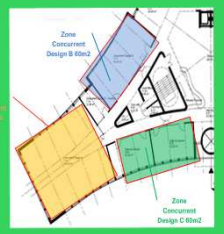
Links with other MBSE initiatives

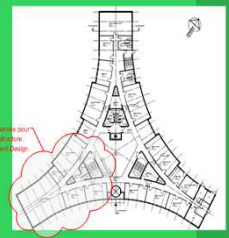
With ADS Space Systems "Conceptual Design Support" typical elements

1) Multidisciplinary Team

2) Process, Methods & Facilitation

6) Facilities





3) Toolbox

CATIA

C€F

5) Data Integration

4) Collaborative Environment

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Model-based Avionics next steps

➔ ***MBSE for functional avionics***

- Expectations are on short term results, based on identified needs for improvements.
- Main focus & priority : OPS/FDIR/OBSW architects on early phasis B/C from Needs capture to CONOPS definition / FDIR & FMEA definition /OBSW SSS & requirements..
- Focusing on MBSE techniques implementation and support but more on methodology and use of existing tools (COTS, OSS, internal) with limited customisation.
- Done through experimentations & use cases with direct involvement of key stakeholders mainly architects with support of Models specialists & Process owners
- Current Toolbox : RQA/RQS with Doors, SysML/Cameo/Papyrus/A, Mathworks, Capella, ModelCenter, SIMFIA/OpenAltarica

➔ ***Integrated in System engineering and Entreprise Information System***

- With Engineering Data integration & Exchanges with PLM
- In a collaborative environment and a integrated workflow
- Current Toolbox : Mega, Doors, Range-DB, SpaceCode/CDP, PLM-TBD

➔ ***Covering Extended Enterprise***

- With customers
- With suppliers

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Thank you for your attention !

Questions ?