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Property Model Methodology (PMM®):

A disruptive MBSE approach to digital continuity in systems development

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Property Model Methodology:

A disruptive approach to master system developments

1) Airbus Helicopters Stakes & Challenges
2) PMM overview
3) Early & robust specification validation
4) Collaborative System design architecture
5) Requirement refinement & validation
6) Detail design models
7) Verification process
8) Synthesis & perspectives

Property Model Methodology:

1) Airbus Helicopters main chalenges

- ✓ **Improve H/C development efficiency** (leadtime & NRC) to:
  - ➢ maintain its current **market share**
  - ➢ give freedom for developing **new concepts** (drones, SoS,…)

- ✓ …while managing **complexity**
  - ➢ **Various mission** to accommodate on same H/C platform
  - ➢ **High density** of functions to integrate
  - ➢ Stationary vs cruise phase permanent **compromise**
  - ➢ **4 degrees** of freedom (vs 3 on civil A/C)
  - ➢ **Critical parts** (rotor, gear boxes, ..)
  - ➢ **Unprepared** landing grounds
  - ➢ Strong militarisation **contraints**

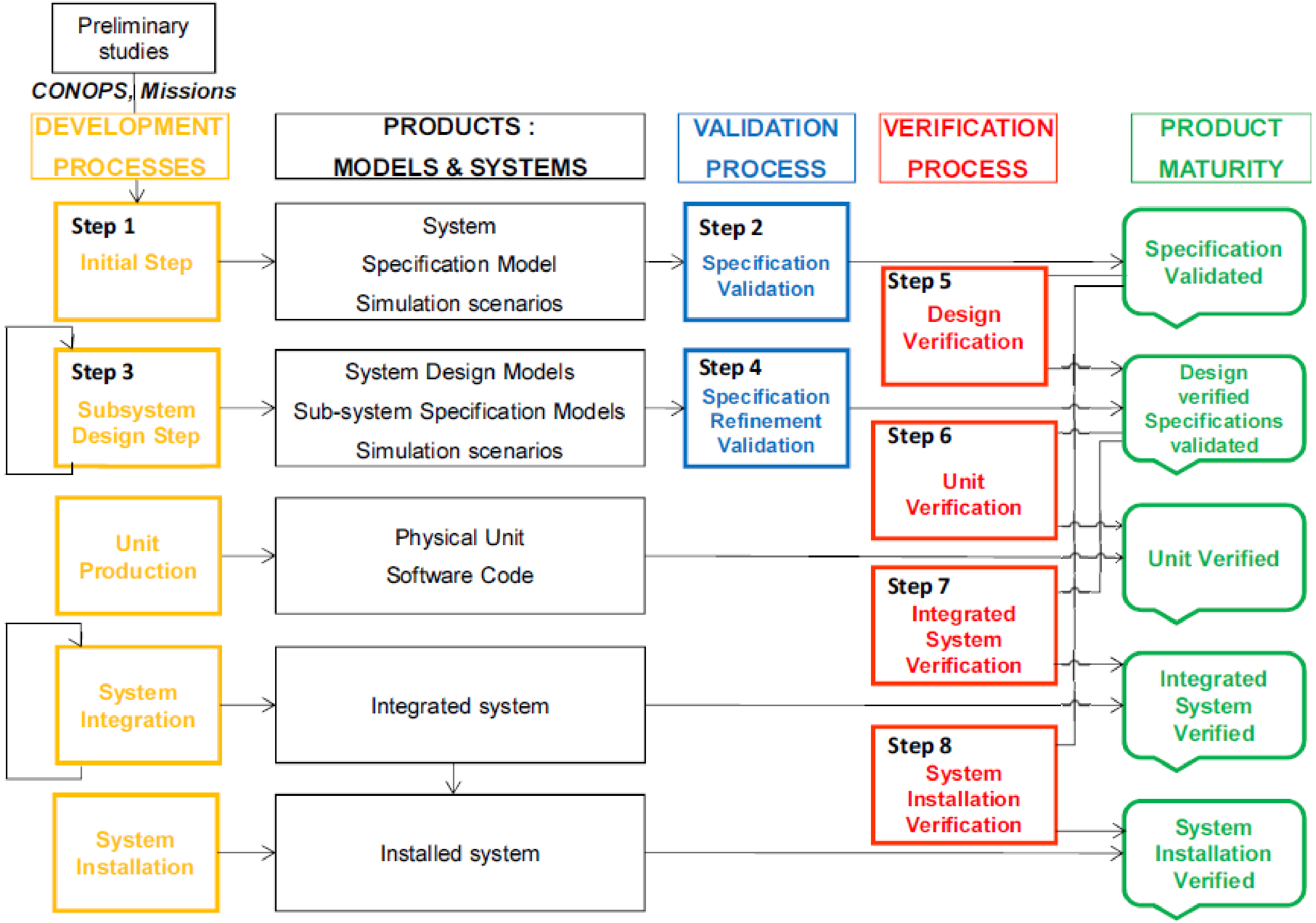
Property Model Methodology:

2) PMM overview (1/3)

Process architecture

Incremental process with definite stages

1. **Specifiying the right system**
    a) **Specification model elaboration**
    b) **Specification model validation**
        i. **Formal validation**
        ii. **Factual validation**
2. **Designing the system right**
    a) **Architectural design model**
        i. **Functional stage**
        ii. **Physical stage**
    b) **Requirement refinement and validation**
    c) **Physical design models**
    d) **Design verification**
3. **Verifying physical subsystems and integrated system**



Property Model Methodology:
2) PMM overview (2/3)
Process architecture & components

- **A VERY CLASSICAL PROCESS ARCHITECTURE CONSISTENT WITH ARP4754A**

- **PMM ENABLES A HIGH LEVEL DIGITAL CONTINUITY : HIGH VALUE ADDED DIGITAL ENGINEERING PRODUCTS EXCHANGED AMONG CONTRIBUTORS AND STAKEHOLDERS**

- **BASED ON FULLY INTEGRATED DISRUPTIVE PROCESS COMPONENTS**
  1. **MODEL BASED SPECIFICATION PROCESS → SPECIFICATION MODELS**
  2. **SIMULATION BASED VALIDATION PROCESS → VALIDATED SPECIFICATION MODELS**
  3. **MODEL BASED DESIGN PROCESS → DESIGN MODELS**
  4. **SIMULATION BASED DESIGN VERIFICATION → VERIFIED DESIGN MODELS**
  5. **TEST BASED IMPLEMENTATION VERIFICATION → VERIFIED PHYSICAL IMPLEMENTATION**

Property Model Methodology:
2) PMM overview (3/3)
PMM digital products

FOR PMM

➢ **A SYSTEM MODEL: CONFIGURATION OF 3 TYPES OF DIGITAL ENTITIES**

1. **SPECIFICATION MODELS**
2. **DESIGN MODELS**
3. **INTERFACE DICTIONARIES LINKED TO A FOURTH DIGITAL ENTITIY**
4. **V&V SCENARIOS**

➢ **PMM SYSTEM MODELS ARE COMPILED (STATIC COHERENCE) AND SIMULATED**

Property Model Methodology:

3) Early & robust specification validation (1/3)

1. **Benefits:**
   a) **Specification models are goal and user oriented**
   b) **Specification models are quickly available**
   c) **Specification models are unambiguous and not interpretable**
   d) **Simulation replaces tedious specification readings.**
   e) **Specification model simulation eases sharing with and commitment from acquirers, authorities, safety responsibles, ..**
   f) **Finally, specification models are error-free.**

2. **Way**
   a) **System specifications are modeled and simulated**
   b) **System specification models are formally validated**
   c) **System specification models are factually validated**

Property Model Methodology:

3) Early & robust specification validation (2/3)

***Formal** validation*

- **Goal:**

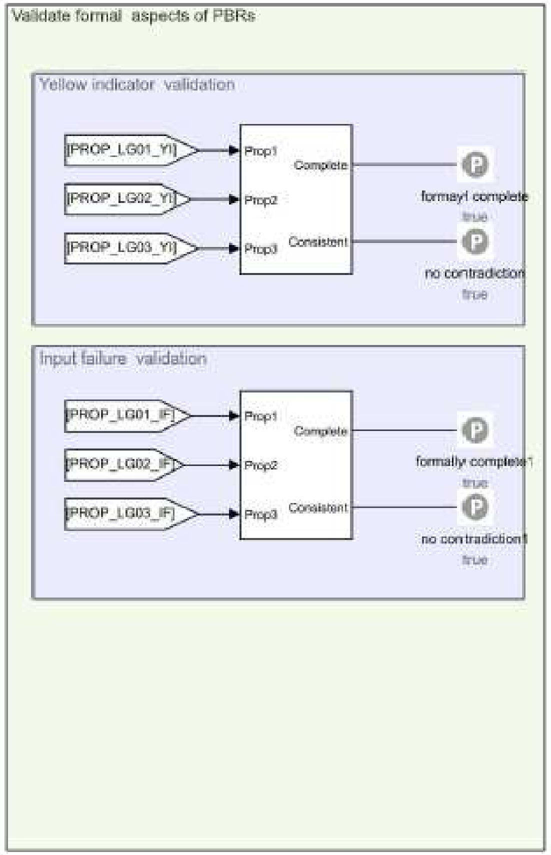
To remove from specification models

»Logical holes (logical completeness)

»Logical contradictions (logical correcteness)

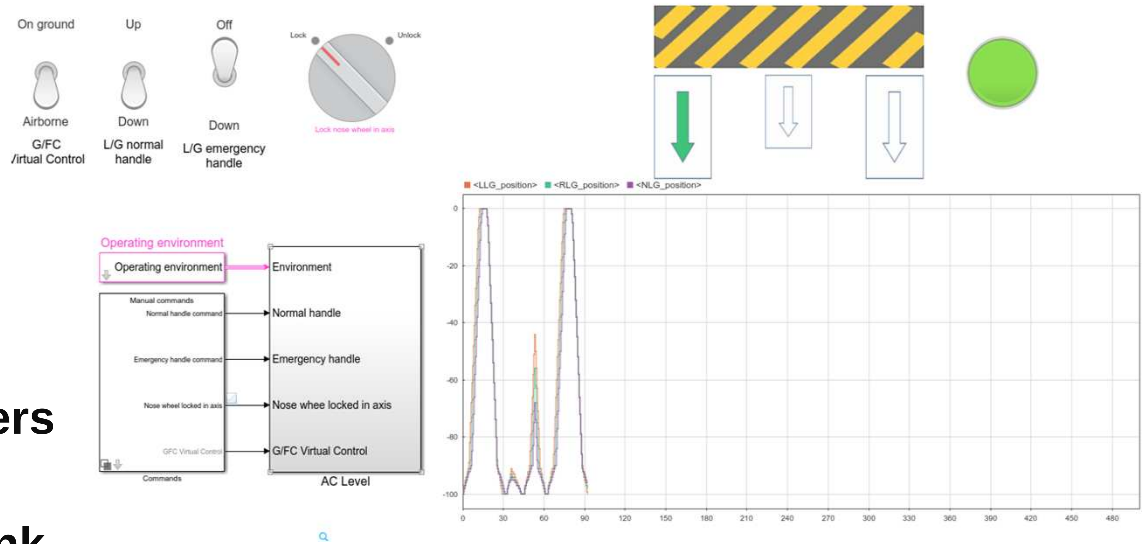
- **Means:**
  - **Intrumentation Resource : Proof & Test objectives**
  - **Human Ressource: Modeler**
  - **Computation Ressource:**
    SLDV prover

SLDV Test Generator



Property Model Methodology:
3) Early & robust specification validation (3/3)
***Factual** validation*

- **Goal: to reach an agreement among relevant stakeholders on**
  - **Factual completeness: the stakeholders consider that all the needs are covered.**
  - **Factual correctness: the stakeholders consider that the behaviors simulated are the right ones.**



- **Means**
  - **Intrumentation Resource :**
    - **Validation bench**
    - **Validation scenarios**
  - **Human Ressource: Relevant stakeholders (Client representatives, Pilots, ..)**
  - **Computation Ressource: Matlab/Simulink**
  - **Validation simulation reviews**

Property Model Methodology:

*4) **Collaborative** system design architecture (1/2)*

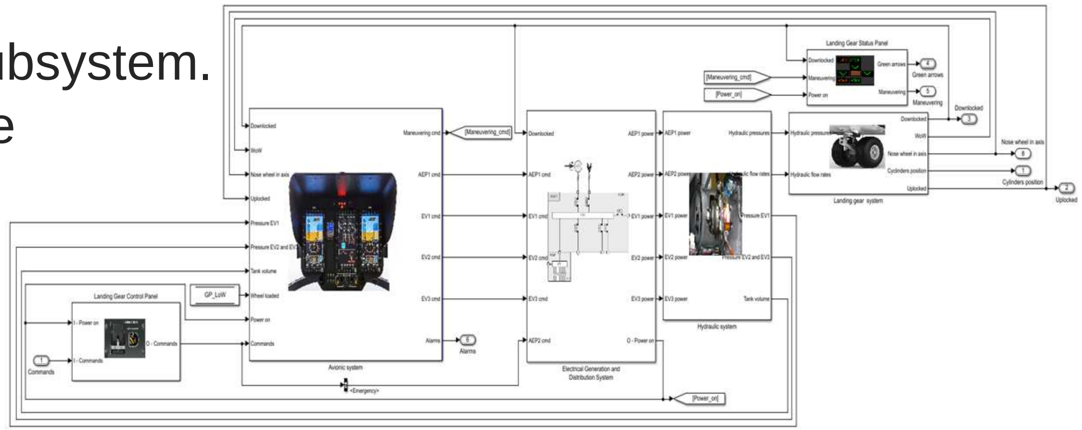
1. **Benefits:**
   a) **Functional chains are established in a collaborative way.**
   b) **Interfaces are strictly defined and fully coherent**
   c) **Roles and responsibilities of each contributor are committed**

2. **Way**
   a) **System architecture is modeled**
   b) **System internal interfaces are collected in a shared interface dictionary**
   c) **System specification model is refined in subsystem specification models**
   d) **Completness and correcteness of Subsystem specification models regarding to System specification model are established by simulation.**

Property Model Methodology:

*4) **Collaborative** system design architecture (2/2)*

- Goal to define candidate architectures for the system:
  - Selection of subsystems
  - Determination of interfaces among subsystems
  - System goals sharing
  - Roles and responsibilities for each subsystem.
  - Selection of the preferred architecture

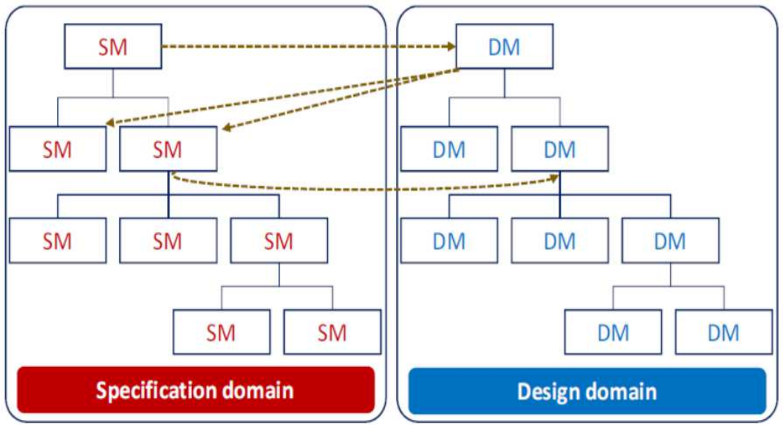


- Means
  - **Collaborative design**
  - Human Ressources: system or function responsible, architect, subsystem responsibles
  - Computation Ressource: Matlab/Simulink
  - Design Modeling reviews

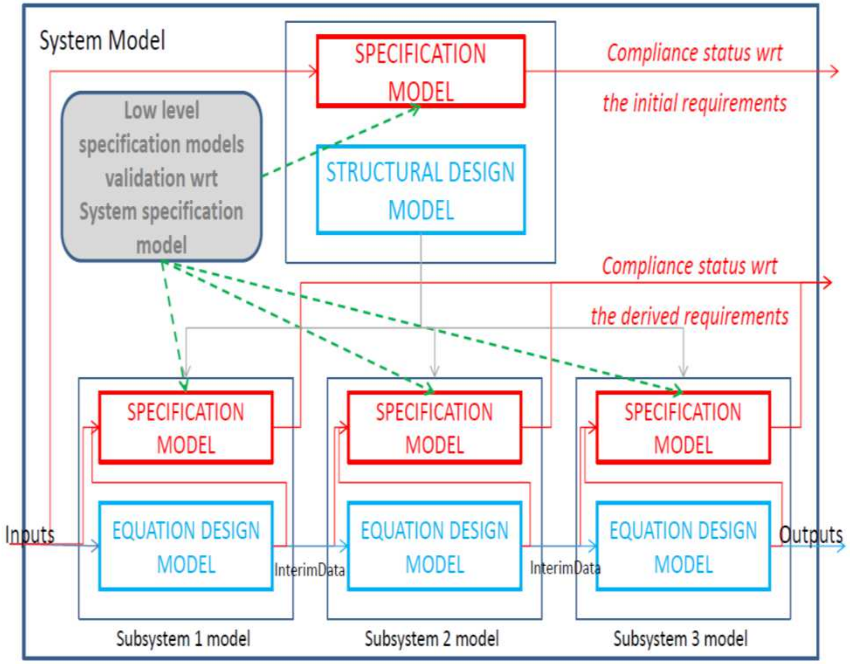
Property Model Methodology:

*5) **Requirement rafinement validation***

- **Goals** :
  - to refine system **requirements into** subsystem requirements
  - To **validate** the refinement (system req -> subsystem req)
- Means
  - Refinement based on Suh's zig zagging concept
  - Validation : SLDV prover & simulation



Zigzagging (Suh, 02)

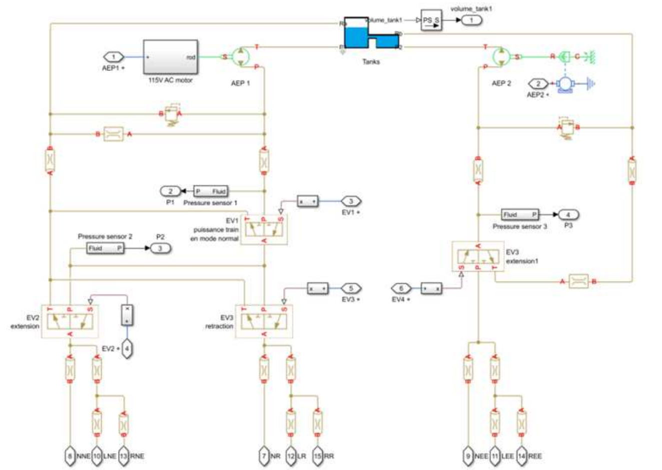


When DM → $PBR \leq PBR_1 \wedge ... \wedge PBR_n$

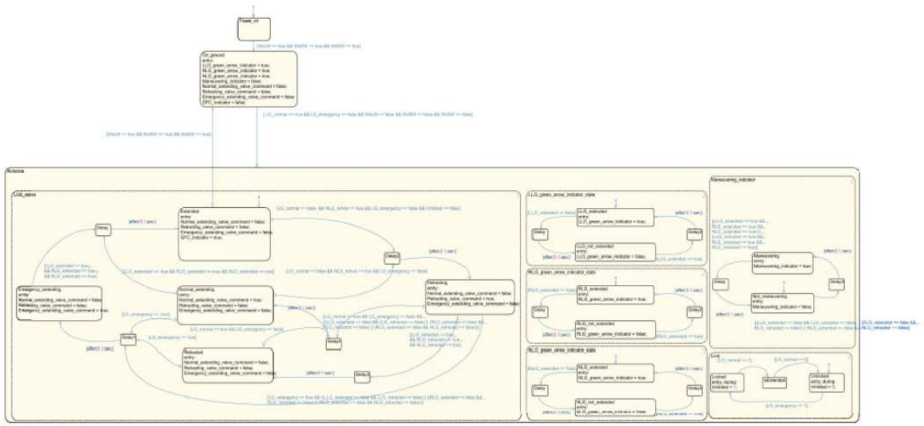
Property Model Methodology:

6) ***Detail design models***

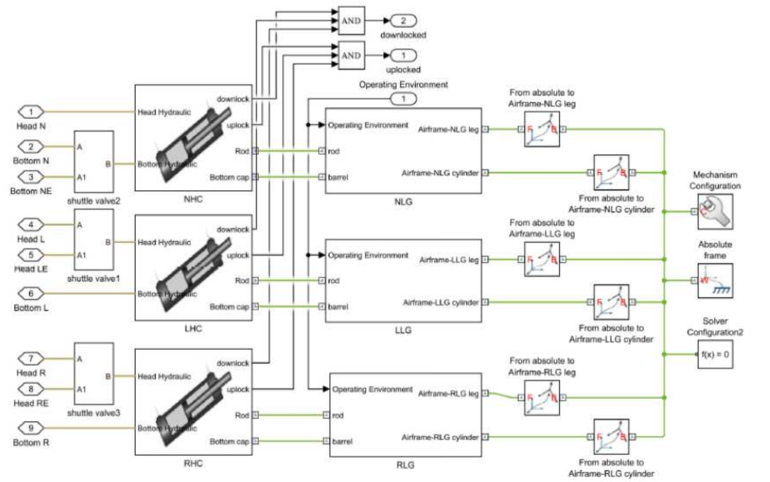
- **Goals :**
  - to define a detail design for the component subsystems
- **Means**
  - Language resources : Stateflow, Simscape, Scade, ..
  - Relevant design specialists



Simscape design of an hydraulic subfunction



Stateflow design of an avionic subfunction



Simscape design of an mechanical subfunction

Property Model Methodology:
*7) **Verification process (1/3)***

1. Benefits:

a) **At any stage of the product, implementation is verified**

b) **Design is verified before production to remove design errors**

c) **Equipment, integration and installation is verified to equipment, integration and installation errors**

2. Way

a) **Design models are verified by simulation regarding to their specification models .**

b) **equipment, integration and installation are verified by test regarding to the specification models**

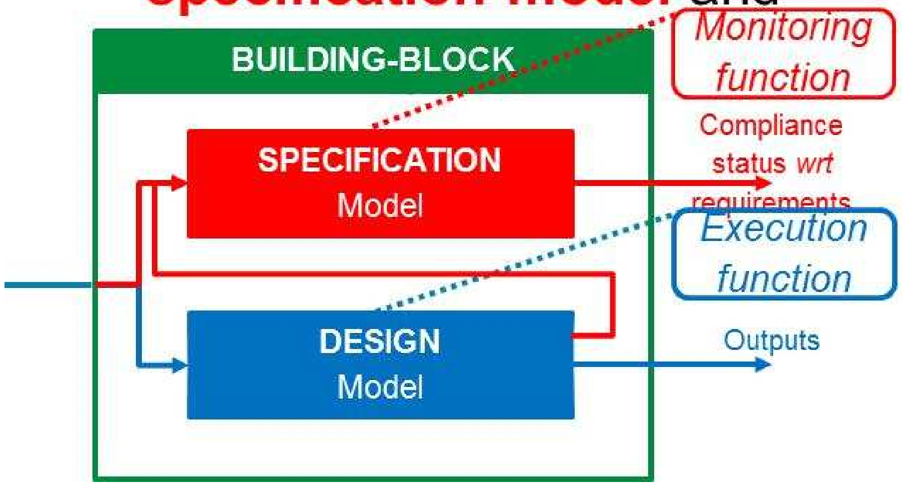
Property Model Methodology:

*7) **Verification process (2/3)***

- Goals :
  - to ensure that there is no **design error** at any level of the design hierarchy

- Means
  - Human Ressource: subsystem responsibles
  - Computation Ressource: Matlab/Simulink
  - test cases
    - from SLDV test generator
    - Flight test recorded data
  - Verification runs and results analysis

« **Co-simulation** » of **specification model** and

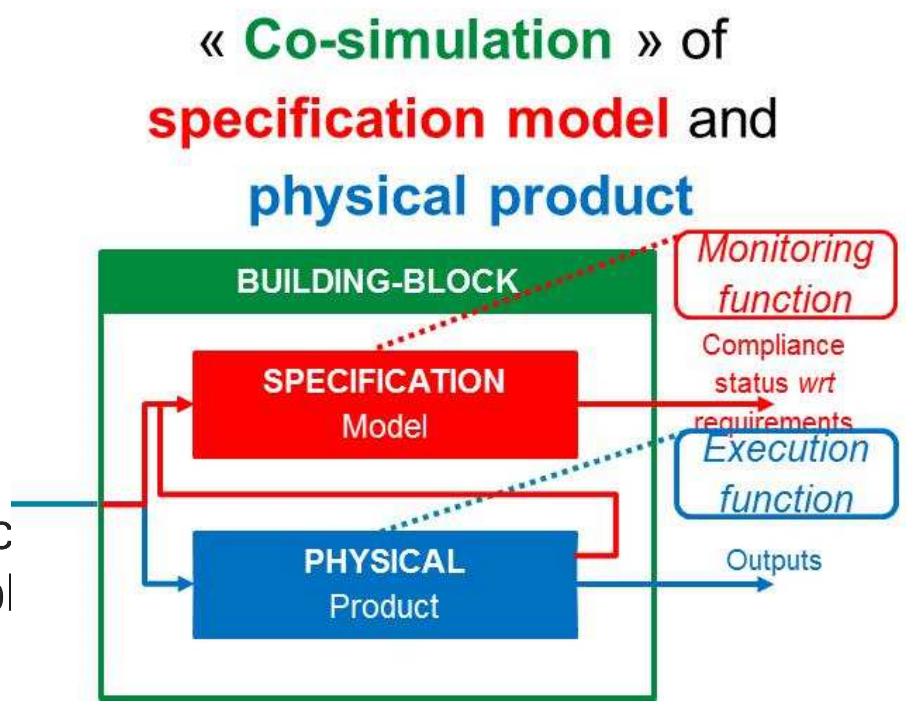


Property Model Methodology:

*7) **Verification process (3/3)***

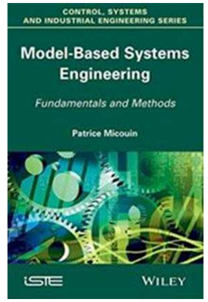
- Goals :
  - to ensure that there is no production or physical integration errors at any level of the product hierachy

- Means *(Not yet experimented)*
  - Human Ressource: test responsibles
  - Test Resource: Test rigs
  - Computation Resource : Simulink
  - Validation and verification scenarios and c collected during specification and design pl
  - Verification runs and results analysis



Property Model Methodology:

8) ***Synthesis &*** *perspectives* ***(1/3)***



- ✓ A method (i.e. concepts + strictely defined development process for continuous, discrete and hybrid systems)
- ✓ Follows the **ARP 4754A** recommendation for A/C development
- ✓ Follows Systems Engineering and Parsimony Principles
- ✓ User and Goals Oriented
- ✓ Centered on Engineering Disciplines
- ✓ Model and simulation based approach
- ✓ **Framework for Digital Continuity of Development Products**
- ✓ An approach language- and tool- agnostic
  - ➢ Currently implemented in several simulation languages

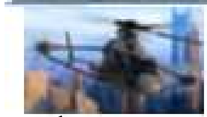
MATLAB SIMULINK — MODELICA — VHDL

Property Model Methodology:

8) **Synthesis &** perspectives **(2/3)**

-50% reduction of functional requirement

End2end Function chain maturation → Early maturity of I/F

Systems / Programs	LGS	Hydro	VMS	EGDS	Fuel
	Spec Design	Spec Design	Spec Design	Spec	N/A
	Spec Design	N/A	N/A	N/A	N/A
	N/A	N/A	Spec	Spec Design	N/A
	N/A	N/A	Spec	Spec Design	Spec Design

Unambiguous, complete & correct requirements

Design loop improved thanks to common key data dico

Property Model Methodology:

*8) Synthesis **& perspectives (3/3)***

- ✓ **Extend** pilot to others **representative systems** & down to **component** levels
- ✓ **Improve** PMM **digital environment** securing & easing:
  - ✓ PMM application (patterns, automate automatisable tasks,…)
  - ✓ Reusability of PMM artefacts (PBR, design rules,…)
- ✓ **Launch** evaluation with some **key suppliers**
- ✓ **Define** simple & robust PMM model **configuration management**
- ✓ **Demonstrate** benefits in **testing verification product**
- ✓ Build & validate **PMM referential**
- ✓ **Demonstrate** PMM added value for **leaner certification process**
- ✓ …and once PMM globally applied in a program **proves significant TCQP benefits**

Thank you for your attention

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