28th Annual INCOSE international symposium
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AIRBUS HELICOPTERS

Property Modelling 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 specification elaboration & 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 challenges

- **Improve H/C development efficiency** (leadtime & NRC) to:
  - ✓ maintain its current **market share**
  - ✓ Make room for extending to **additional product** (drones, SoS,…)

- …while managing **complexity**
  - ✓ **Various missions** to accommodate on same H/C platform
  - ✓ **High density** of functions to integrate
  - ✓ Helicopter domain **specificities**
  - ✓ Unmanned flight **specificities**

Property Model Methodology:

*2) PMM overview (1/3): Process architecture **driven by ARP4754A goals***

➢ Modeling & Simulation method with coherent steps

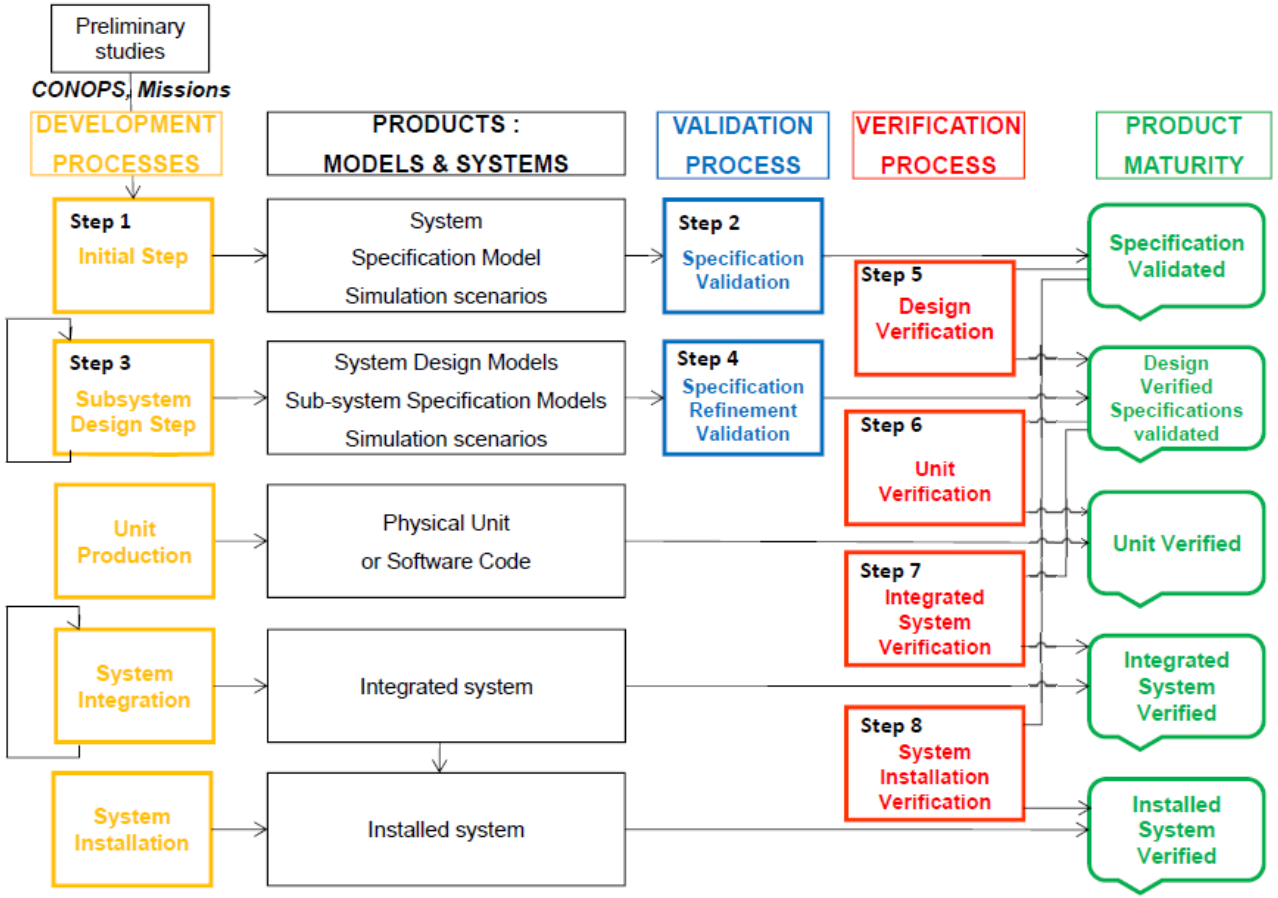
1. Specifying the right system:

a) Specification **model** production
b) Specification **model** validation:
   i. **Formal** validation
   ii. **Factual** validation

2. Designing the system right:

a) Architectural design **model**
b) Requirement refinement and validation
c) Physical design **models**
d) Design verification

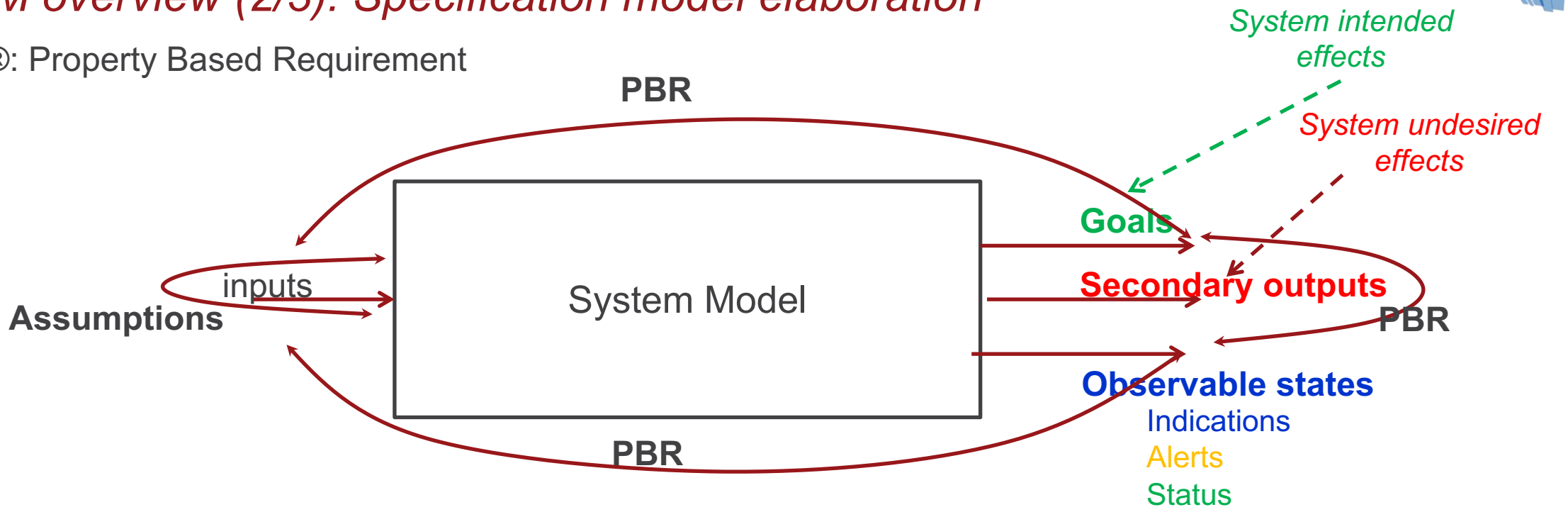
3. Verifying physical subsystems & integrated system



Property Model Methodology:

2) PMM overview (2/3): Specification model elaboration

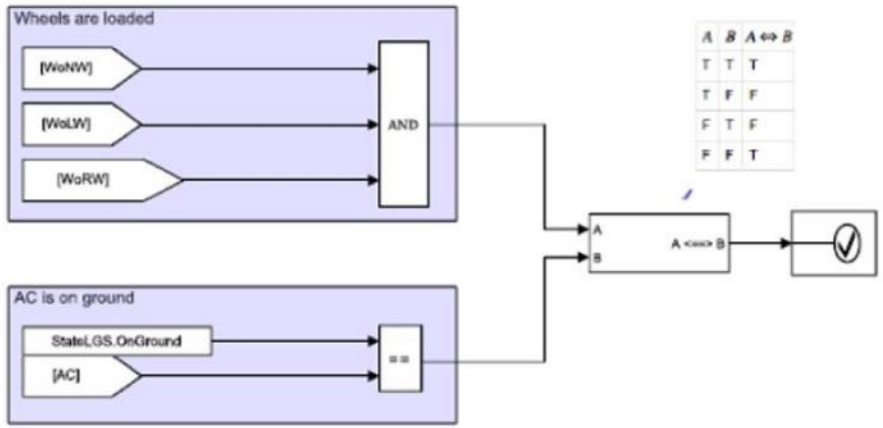
PBR®: Property Based Requirement



Specification modelling sequence **(PBR)** is a backward process from the effects to the causes:

When C → val(O.P) ∈ D

When **condition C** is true, **property P** of **object O** is actual and its value shall belong to **domain D**



Property Model Methodology:

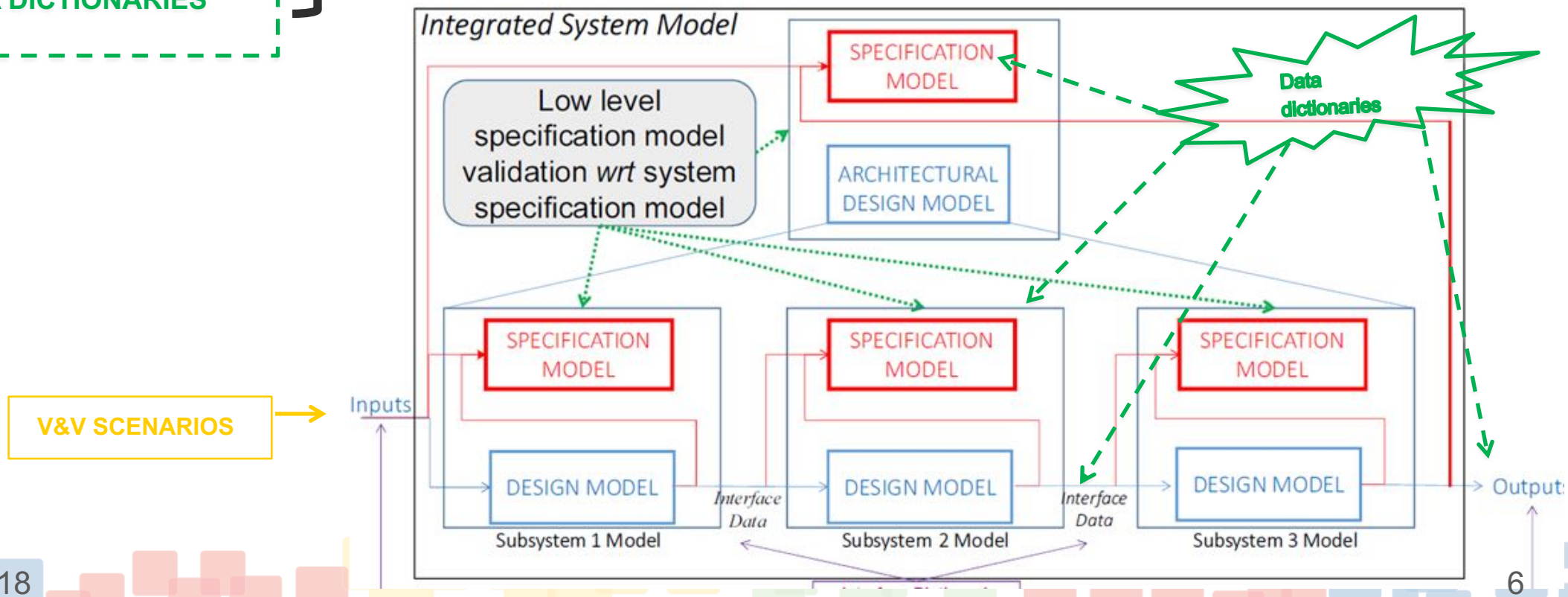
2) PMM overview (3/3): Digital product

➢ **A SYSTEM MODEL: CONFIGURATION OF 4 TYPES OF DIGITAL ENTITIES**

- ✓ **SPECIFICATION MODELS**
- ✓ **DESIGN MODELS**
- ✓ **V&V SCENARIOS MODELS**
- ✓ **DATA DICTIONARIES**

PMM SYSTEM MODELS are:

- ✓ **COMPILED (static coherence)**
- ✓ **SIMULATED (dynamic coherence)**

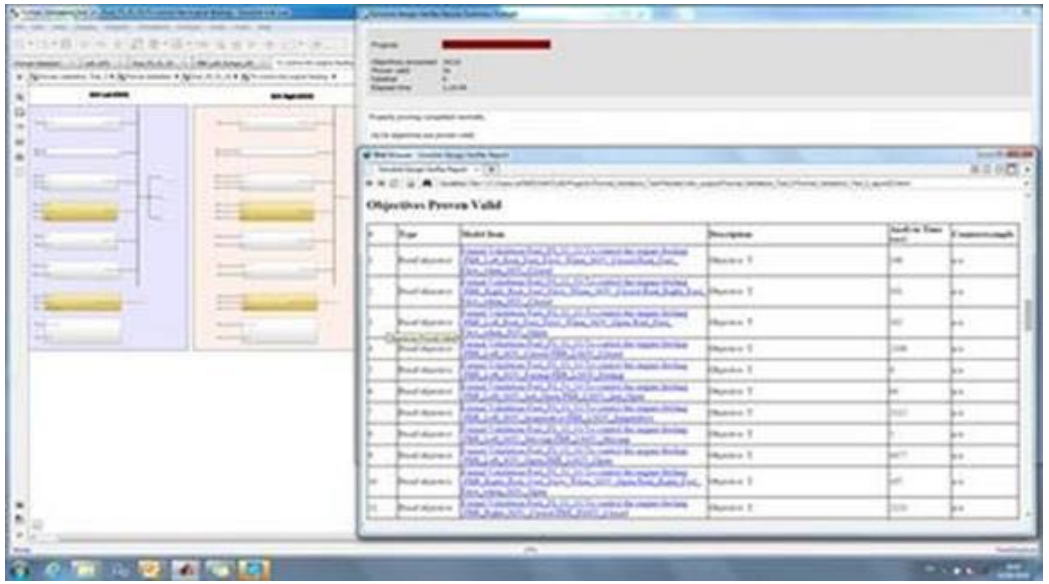


Property Model Methodology:

*3) Early specification validation(1/2): **Formal** validation*

- **Goal** is to remove from specification models:
  - ✓ **Logical holes** (logical completeness)
  - ✓ **Logical contradictions** (logical correctness)

- **Way**:
  - ✓ Instrumentation Resource : proof means
  - ✓ Human Ressource: **Modeler**
  - ✓ Computation Ressource: SLDV **prover**

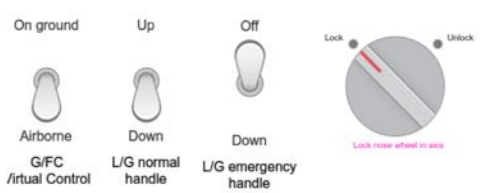


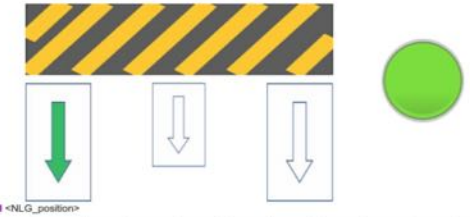
Property Model Methodology:

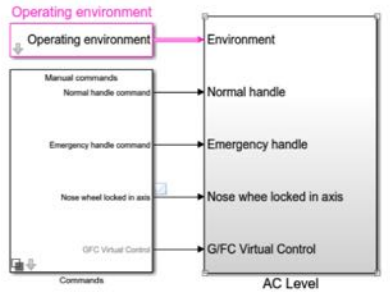
*3) Early specification validation(2/2): **Factual** validation*

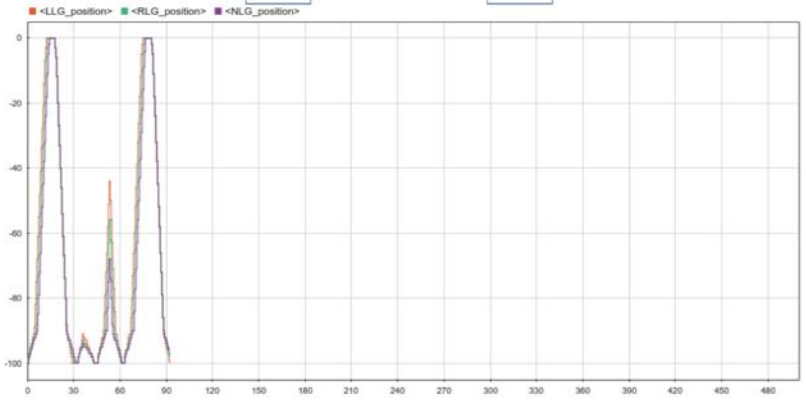
- **<u>Goal</u> is to reach an agreement among relevant stakeholders on**
  - ✓ Factual **completeness**: stakeholders **jointly** consider **all needs covered**
  - ✓ Factual **correctness;**→ stakeholders **jointly** consider **simulated behaviors** are the **right ones**

- **<u>Way</u>:**
  - ✓ Instrumentation Resource :
    - ✓ Validation **bench**
    - ✓ Validation **scenarios**
  - ✓ Human Ressource: **Relevant stakeholders**







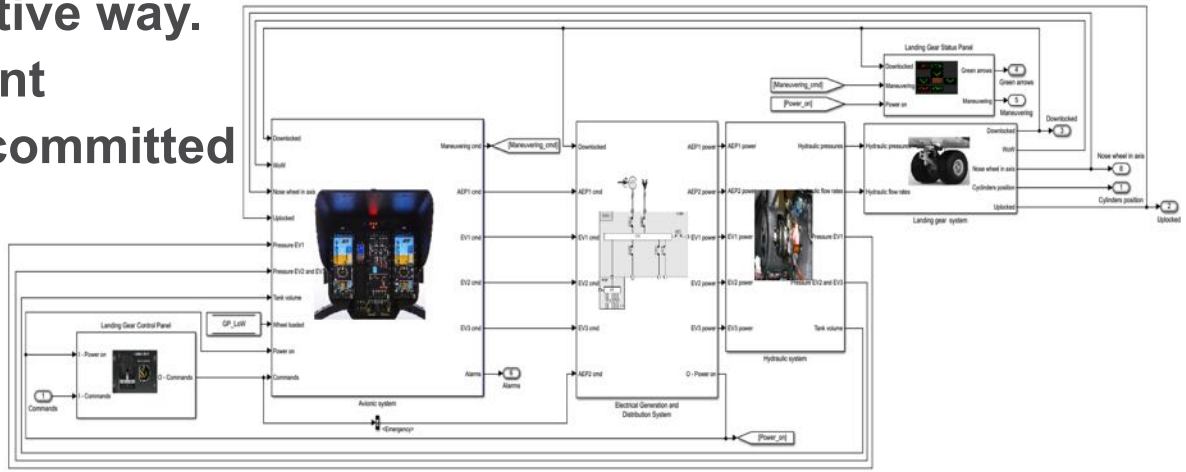


Property Model Methodology:

4) Collaborative system design architecture

➢ Goals

- ✓ **Functional chains** are established in a **collaborative way.**
- ✓ **Interfaces** are **strictely defined** and **fully coherent**
- ✓ **Roles & responsibilities** of each contributor are **committed**

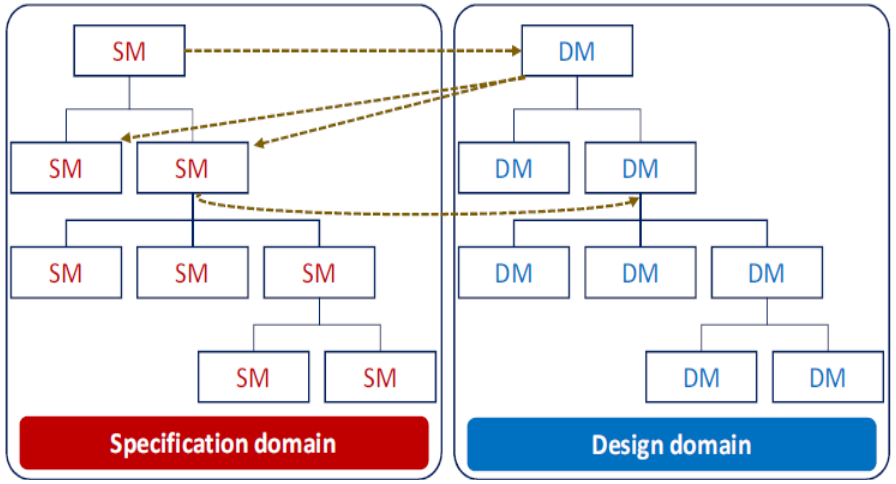


➢ Way:

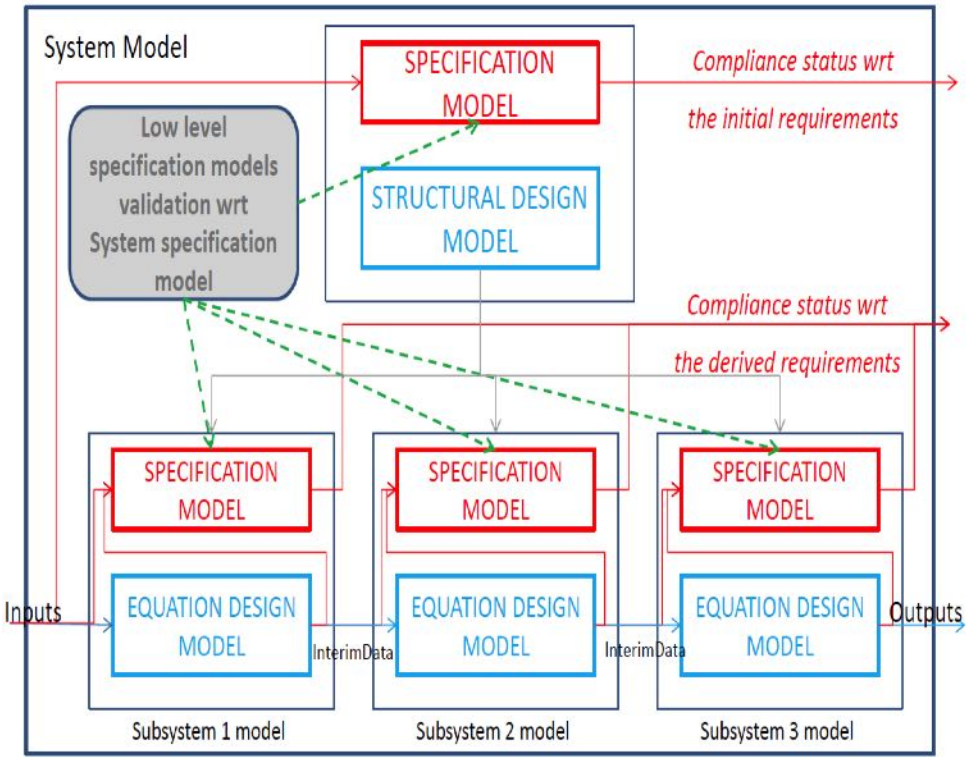
- ✓ System **architecture** is **modeled**
- ✓ System **internal interfaces** are collected in a **shared interface dictionary**
- ✓ System **specification** model is **refined in subsystem** specification models
- ✓ **Subsystem** vs **System** specification model **completness and correcteness** are established by **simulation.**

Property Model Methodology:
*5) Requirement **refinement** validation*

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



Zigzagging (Suh, 02)

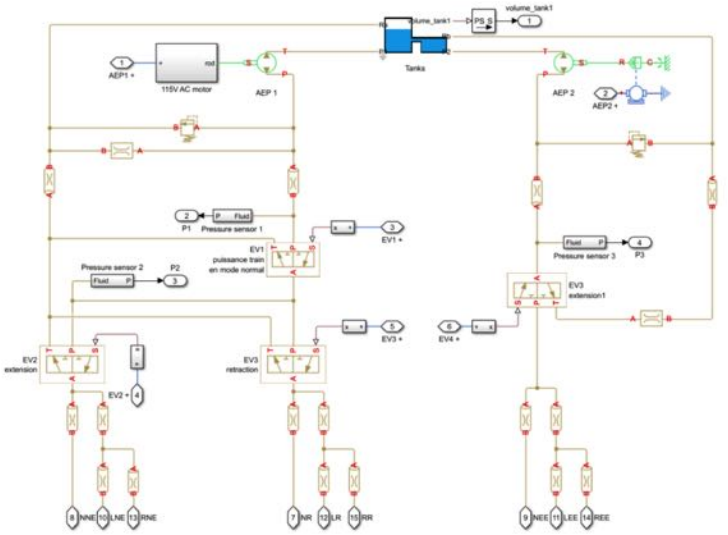


When DM → PBR ≤ $PBR_1 \wedge ... \wedge PBR_n$

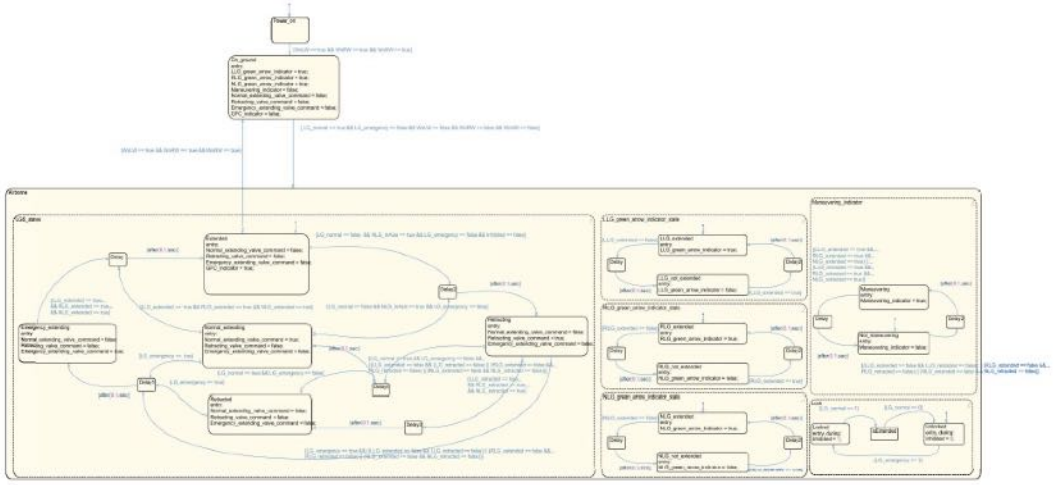
Property Model Methodology:

6) Detailed design models

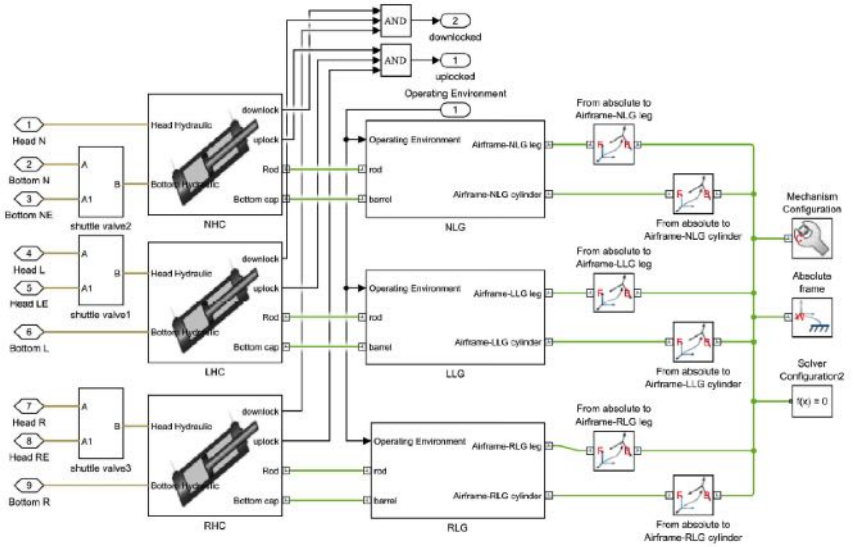
- **Goals:**
  - ✓ to define a detail design for the component subsystems
- **Means**
  - ✓ Language resources : Stateflow®, Simscape®, Scade®, Adams® ...
  - ✓ Relevant design specialists



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)

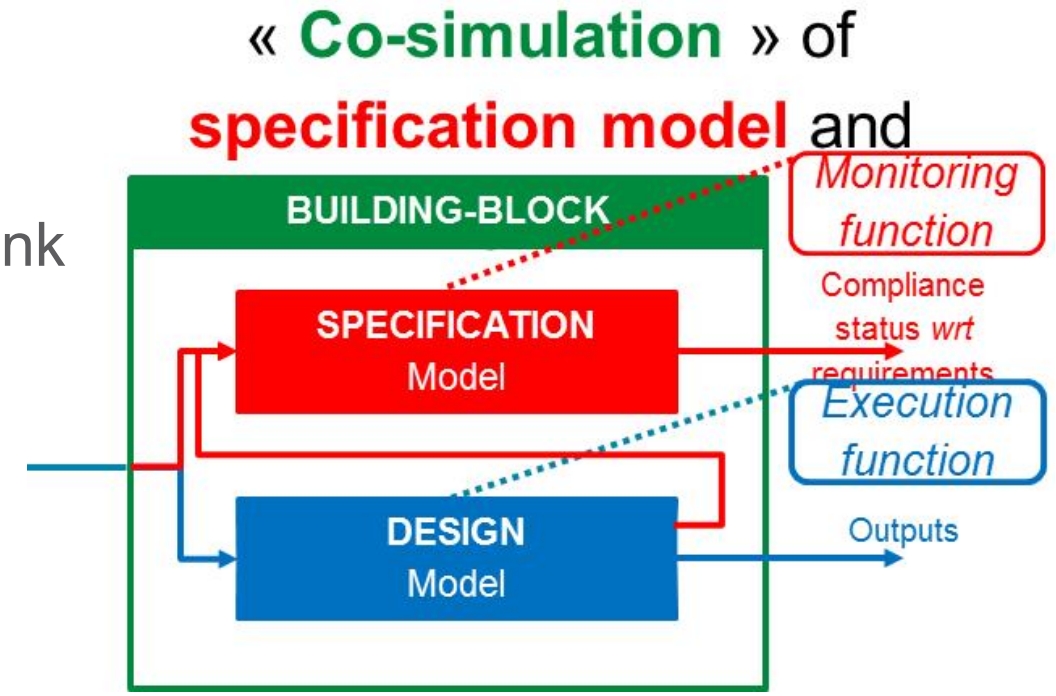
- **Goals:**
  - ✓ At any stage of the product, implementation is verified
  - ✓ Design is verified **before** production to remove design errors
  - ✓ Equipment, integration and installation is verified to equipment, integration and installation errors
- **Way**
  - ✓ Design models are verified by simulation regarding to their specification models .
  - ✓ 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 resp
  - ✓ Computation Ressource: Matlab/Simulink
  - ✓ test cases
    - from SLDV test generator
    - Flight test recorded data
  - ✓ Verification runs and results analysis



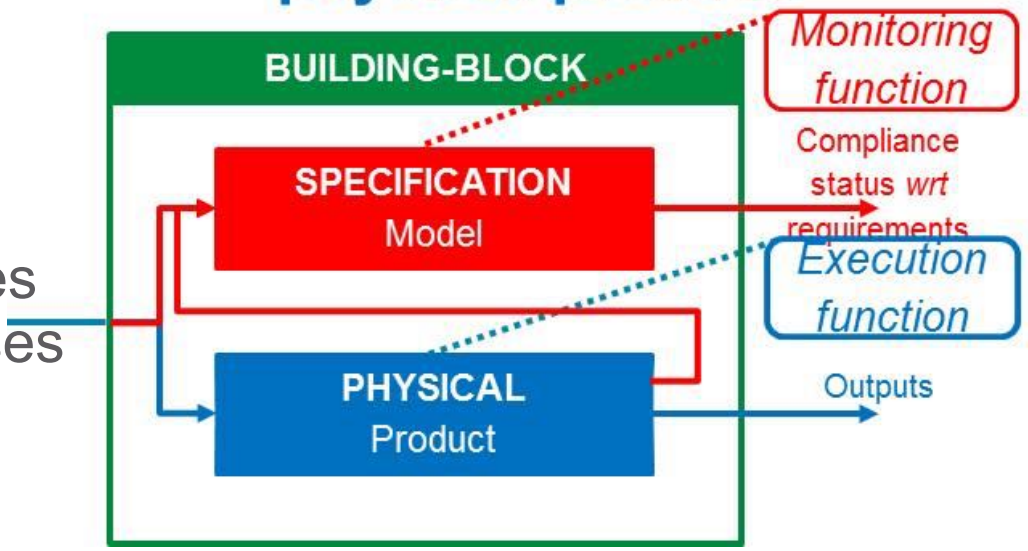
Property Model Methodology:

7) Verification process (3/3)

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

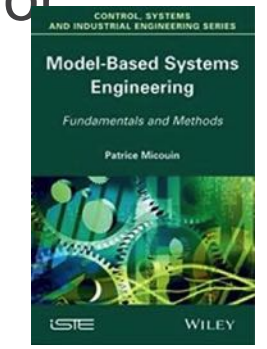
- **Means** *(Not yet experimented)*
  - ✓ Human Ressource: test responsibles
  - ✓ Test Resource: Test rigs
  - ✓ Computation Resource : Simulink
  - ✓ Validation and verification scenarios and cases collected during specification and design phases
  - ✓ Verification runs and results analysis

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



Property Model Methodology:
*8) **Synthesis** & perpectives (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** & perpectives (2/3)*

-50% reduction of functional requirement

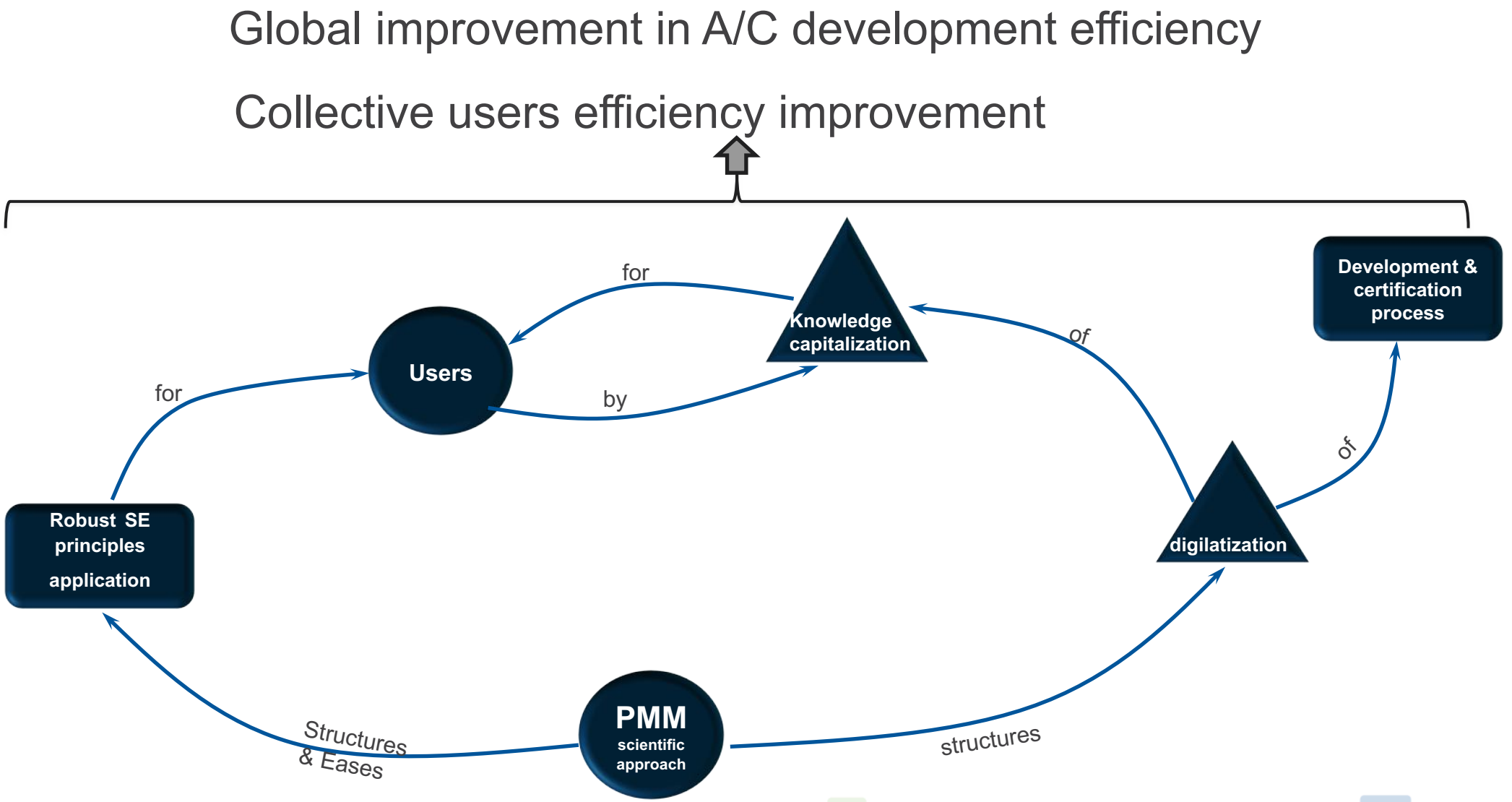
End2end Function chain maturation → Early maturity of I/F

Programs \ Systems	LGS	Hydro	VMS	EGDS	Fuel
	Spec Design	Spec Design	Spec Design	Spec	
	Spec Design				
			Spec Design		
			Spec Design		Spec Design

Unambiguous, complete & correct requirements

Design loop improved thanks to common key data dico

Property Model Methodology:
*8) Synthesis & **perpectives** (3/3)*



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- Mission breakdown
  - Commercial
    - EMS
      - Commercial Primary EMS / MEDEVAC
      - Commercial Secondary EMS / ITC Intensive Care
    - Commercial Transport
      - Commercial Passenger transport (Comfort)
      - Commercial Passenger / Cargo transport
    - Sightseeing
    - Harbour pilot / Windmill
    - Commercial Survey and surveillance
    - Aerial work
      - Aerial work Cargo Internal/External
      - Agricultural work
    - Commercial Training
      - Ab initio training commercial
      - Advanced training commercial
    - Electronic News gathering / Film
  - Public services
    - EMS
      - Public Primary EMS / MEDEVAC
      - Public Secondary EMS / ITC Intensive Care
    - Police / Airborne Law Enforcement (ALE)
      - ALE Observation & command
      - ALE Surveillance
      - Intervention / Special operations (SWAT / RABIT)
      - Public services Passenger/ teams / Cargo transport
    - Transport
      - Public services Passenger/ teams / Cargo transport
      - Fire fighting
    - Land & Maritime border security
      - EEZ Surveillance & Control, Fisheries / Pollution surv & control
      - EEZ Drug smuggling & Control
      - EEZ Boarder Patrols / Customs
    - Search and Rescue
      - Specialized all weather civil SAR
      - ONshore / Maritime civil SAR
      - ONshore / Mountain civil SAR
  - Oil & gaz
    - Offshore Crew change
    - Offshore quick role change SAR
    - Onshore Crew change
    - Onshore quick role change SAR
    - Pipeline survey
  - Corporate
    - Private (Privately owned)
    - Private (Company owned) (JAR-OPS 3)
    - Executive aviation
  - VIP
    - VVIP (State owned)
  - Utility
    - Special ops
      - Special forces
      - Personnel recovery / CSAR
    - Transport internal/external cargo
    - Command and Control
    - Casevac / Medevac / SAR
    - Tactical transport
    - Air interception (MASA)
  - Armed scout
    - ISTAR
    - Command and control C2
    - Fire support
  - Attack
    - Attack
  - Training
    - Ab initio training
    - Advanced training
    - Conversion to role training
  - Maritime missions
    - Amphibious
      - VERTREP
      - CASEVAC / MEDEVAC / SAR
    - Maritime security
      - EEZ Surveillance & Control, Fisheries / Pollution surv & control
      - Anti-Smuggling & Control
      - Maritime counter-terrorism (MCT)
  - Naval operations
    - Air surface warfare
    - Anti submarine warfare
    - Anti-Air-Warefare, Airborne early warneing (AAW-AEW)
    - Signal & Electronic Intelligence (SIGINT-ELINT)
    - Mining & Mine Countermeasures
    - Training
      - Conversion to role

Civil ← → **Military**