Presented by

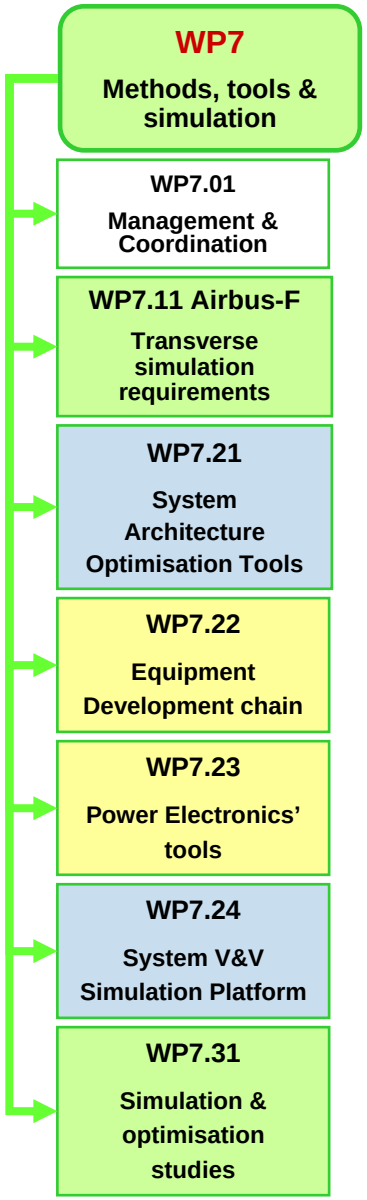
Johann BALS (D.L.R.)
MOET WP7 leader

Loïc RAULIN (AIRBUS-F)
MOET WP7 Focal Point

MOET PROJECT

WP7 – Methods, Tools & Simulation

WP7 - Methods, Tools & Simulation
WP BREAKDOWN DRAFT



Work package aim is to set up design environment based on simulations

Define V&V strategy for development & validation
Analyse modelling & simulation requirements / Develop road map for simulation/rigs

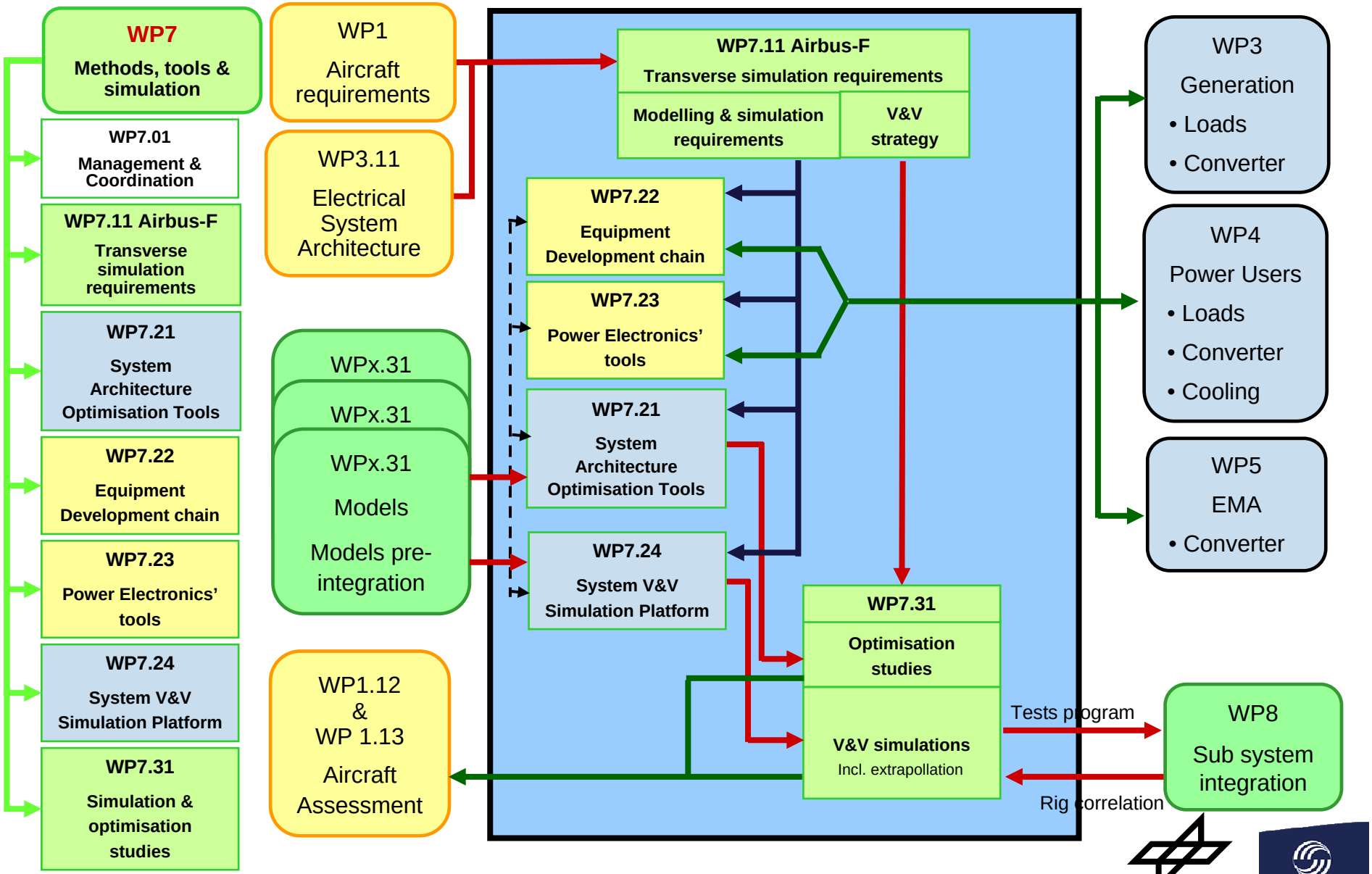
Evaluate new A/C concepts & innovative configurations
Establish & refine architectures & high level design objectives

Increase maturity of equipment at supplier level

Establish, refine and validate sub-system & equipment design requirements
Verify performances & electrical system integration.

Demonstrate effectiveness of developed methods & tools
Support the development of the new aircraft electrical standard
Support the development of new components / Integration and validation at A/C level

WP7 - Methods, Tools & Simulation
WORK FLOW



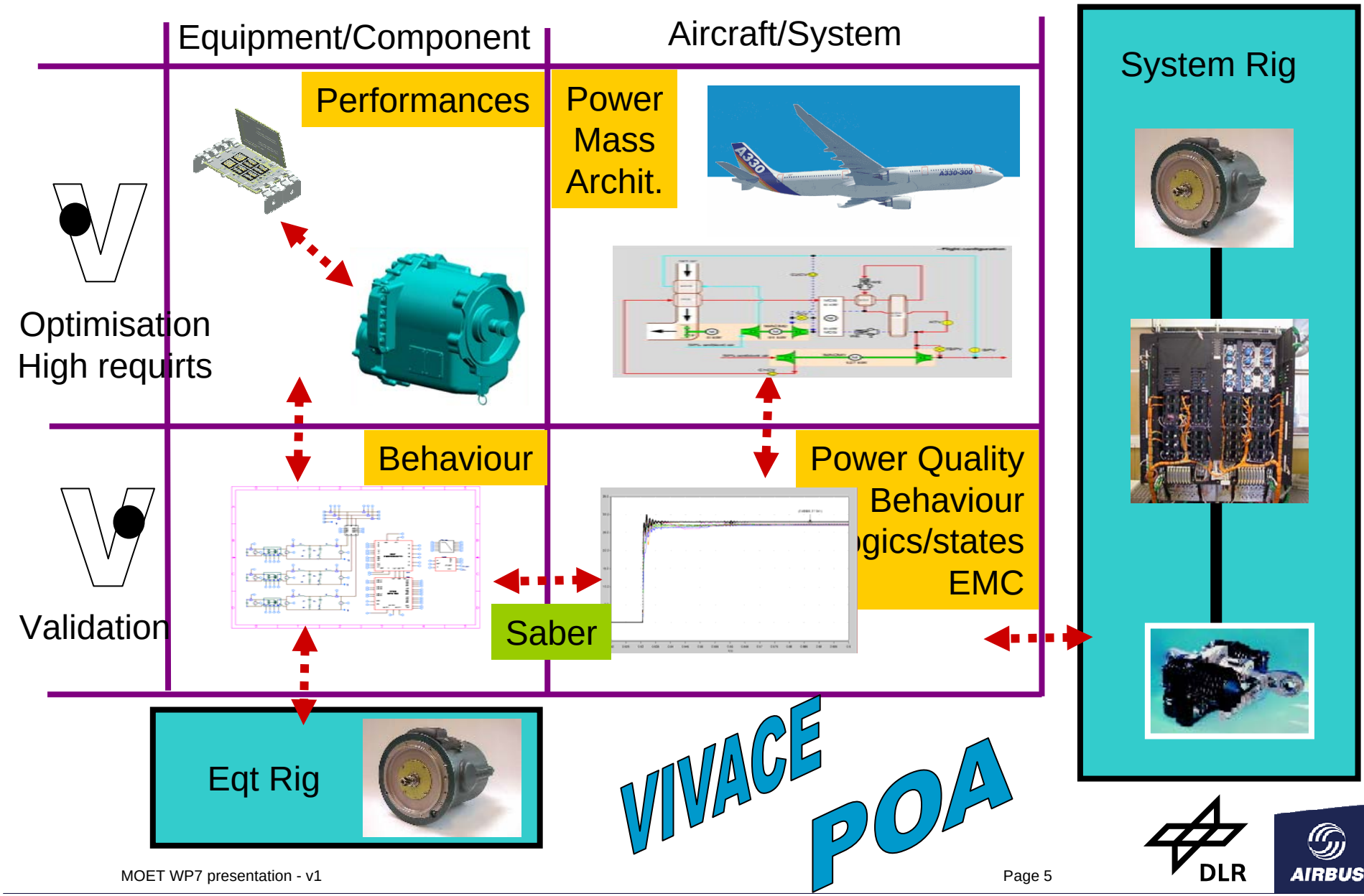
OBJECTIVES

MOET WP7 Objectives

- Simulation is part of **MOET design environment**
- Provision of supporting methods, tools, and supply chain relationships to enable the new A/C electrical standard to be implemented
- For architecture **optimization**, equipment **development** and system **verification and validation**
- Exploitation and demonstration of the design environment to **assess effectiveness**
- **Recommendations** and conclusions

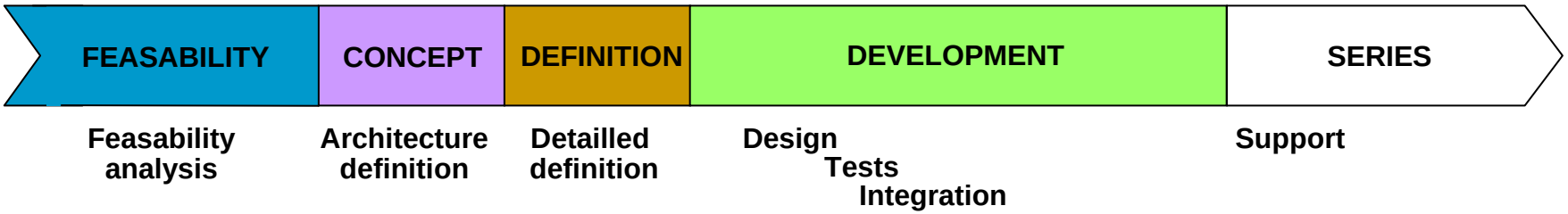
VISION OF THE FUTURE

Efficient & Effective Electrical Design Environment



SYSTEM ARCHITECTURE OPTIMIZATION
MOET - More Open Electrical Technologies

TYPICAL AIRCRAFT DEVELOPMENT CYCLE

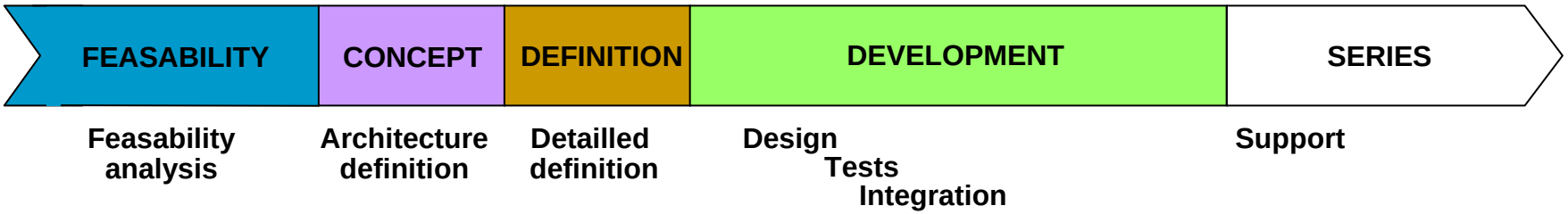


①

System architecture optimization

FUNCTION PROTOTYPING
MOET - More Open Electrical Technologies

TYPICAL AIRCRAFT DEVELOPMENT CYCLE

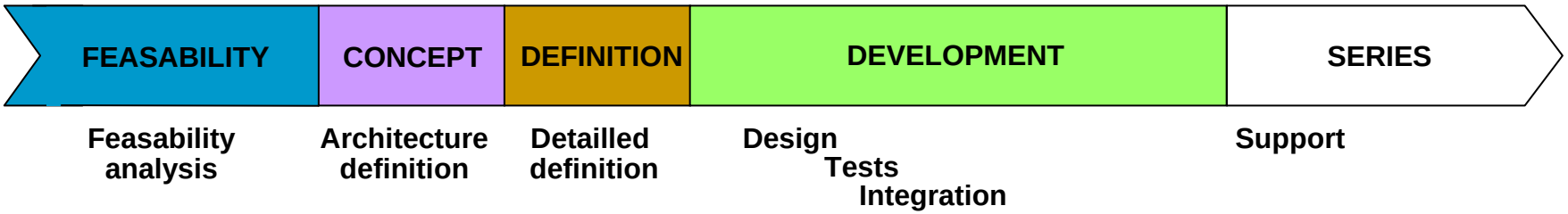


②

Virtual prototyping
HIL simulations

V&V SIMULATIONS
MOET - More Open Electrical Technologies

TYPICAL AIRCRAFT DEVELOPMENT CYCLE



③

Simulations for
Validation & Verification activities

DESIGN ENVIRONMENT
MOET - More Open Electrical Technologies

Other means (test benches…) **not mentionned**

SUPPLIERS

Development chain

- Dedicated design tools
- Function prototyping
- HIL simulations
- Software development process

②

A/C MANUFACTURER

Optimization tools

- Architecture
- Load analysis
- Performances
- Weight

①

Simulation platform

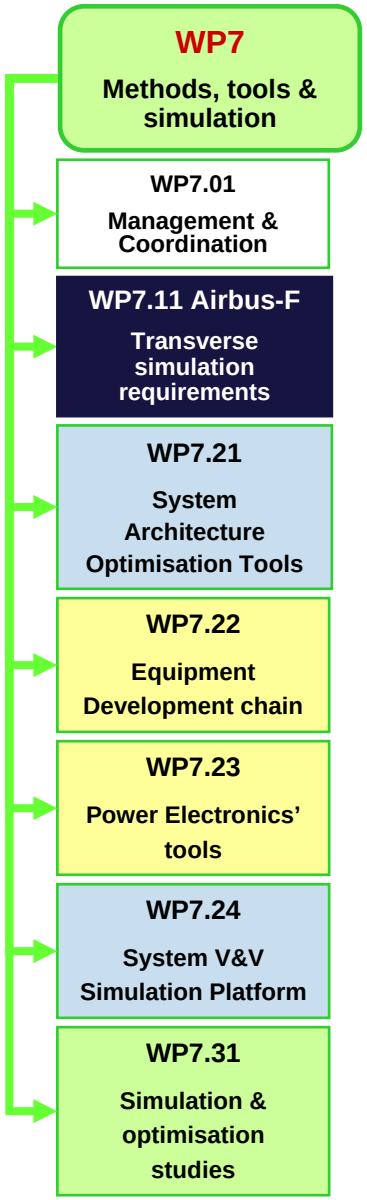
- Network power quality
- Network stability
- EMC
- Network configuration logics validation

③

DLR

AIRBUS

WP7.11
TRANSVERSE SIMULATION REQUIREMENTS



WP 7.11 Transverse Simulation Requirements

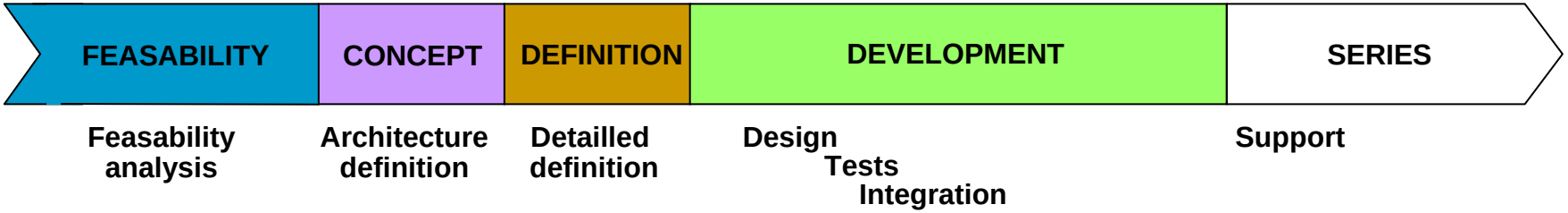
Define V&V strategy for development and validation in accordance with WP 1
- ➢ test rig and simulation strategy
- ➢ current status of the tools and the rigs

Analyse modelling and simulation requirements
- ➢ consider all MOET relevant design phases (architecture optimisation, equipment development, aircraft platform V&V)
- ➢ consider transverse aspects along different design phases: multi-level modelling, multi-domain aspects, offline and real-time simulation, model exchange between a/c and equipment manufacturers
- ➢ correlation between rigs and simulation to ensure coherency between the various V&V activities

Develop road map for simulation/rigs
- ➢ related to the electrical system design environment for an aircraft development

OUTPUT:
Transverse Simulation & Rig Requirements Roadmap

SYSTEM ARCHITECTURE OPTIMIZATION



①

System architecture optimization

MOPS TBD…

- **Evaluate:**
  - New A/C concepts led by technology evolutions
  - Innovative configurations
- **Establish and refine:**
  - Architectures
  - High level design objectives

OPTIMISING A/C ELECTRICAL SYSTEM

Criteria / Goals

- To achieve generator load profiles as constant as possible (= to minimise generator peak loads).
- To reduce generator and a/c wiring weights.
- To propose schemes for management / shedding of non-essential electrical loads.

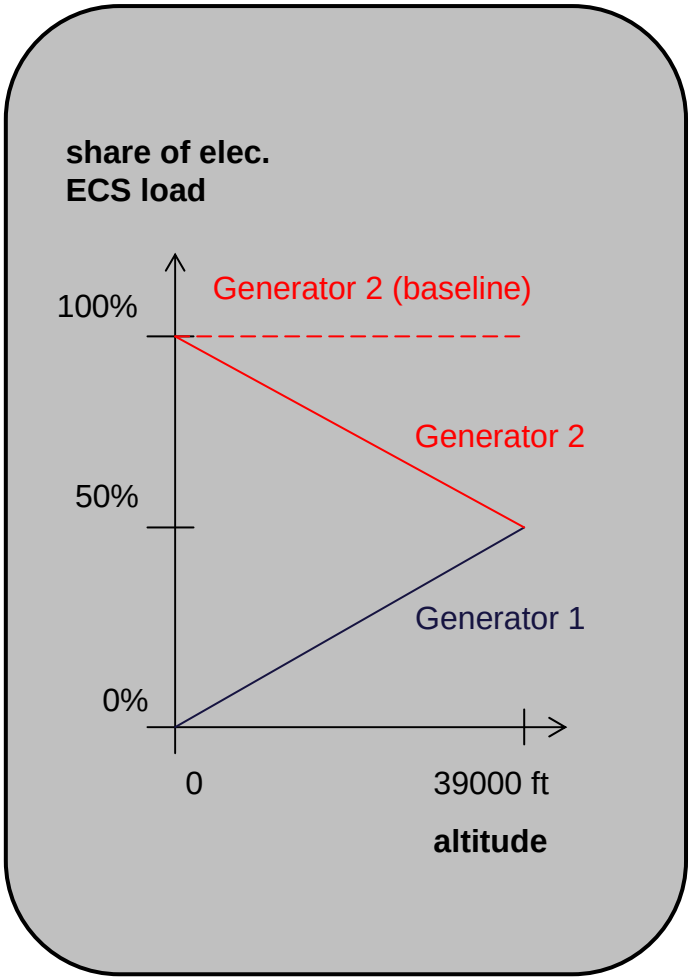
Constraints / Boundary Conditions

- Provide sufficiently redundant connections to separate power sources for critical a/c functions (e. g. thrust, flight control, decel on ground).
- Avoid accumulation of too many loads on a single source.
- Acceptable to partially or completely shed non-essential loads during abnormal or failure scenarios.

OPTIMISING A/C ELECTRICAL SYSTEM - Example

Environmental Control System – Electrically Powered

- Allocate the loads of the different ECS components in the best possible way to several generators.
- Definition by hypothesis of a flight altitude dependent share of the ECS loads between two separate generators.



OPTIMISING A/C ELECTRICAL SYSTEM - Example

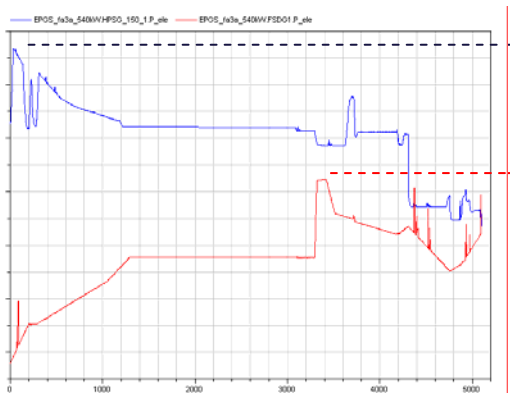
Electrical Loads per Generator during Standard Flight Profile

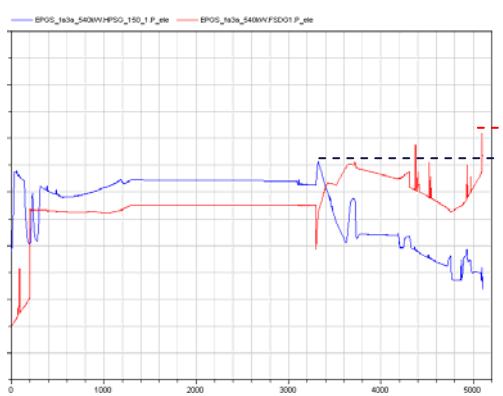
Baseline

Optimised

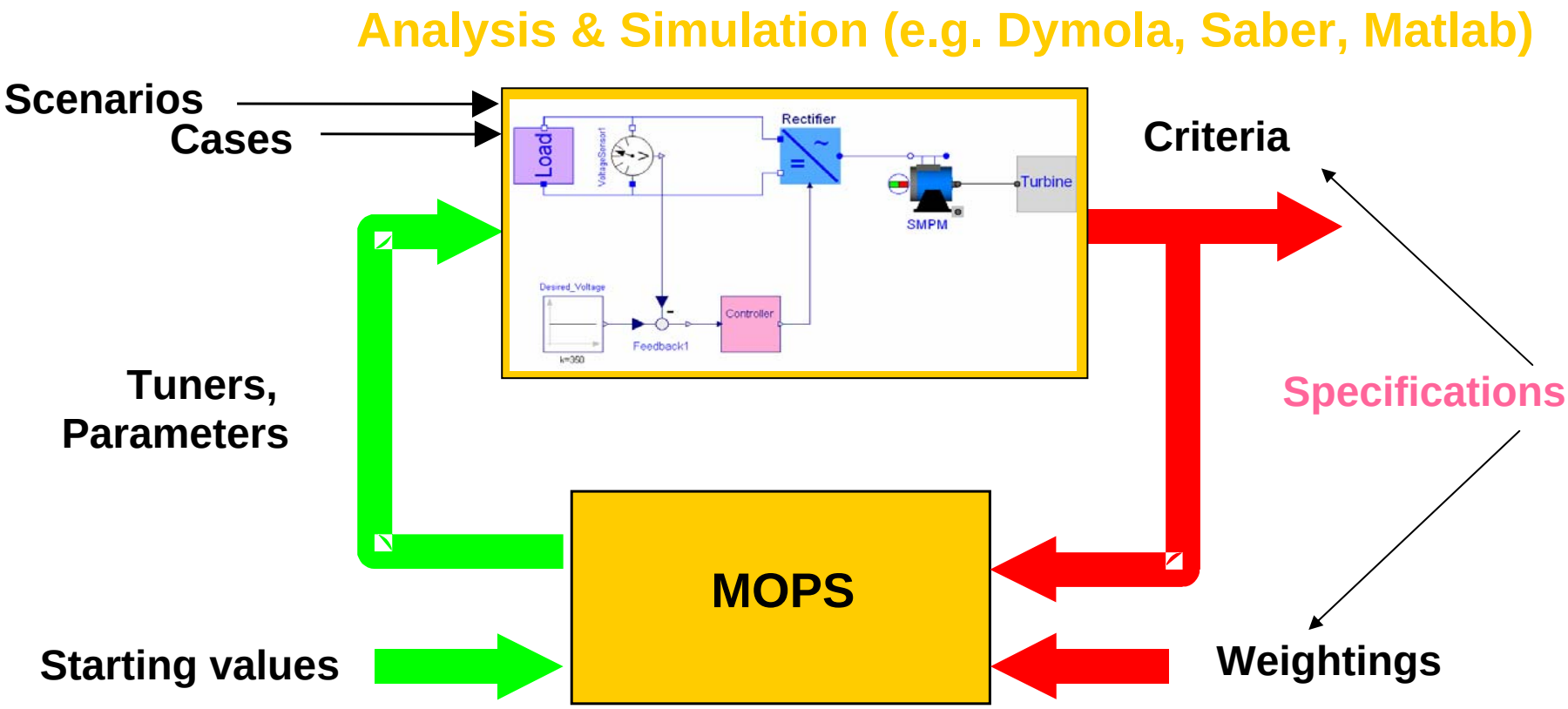
altitude [ft]

Gen. 1
Gen. 2
elec.
power
[W]



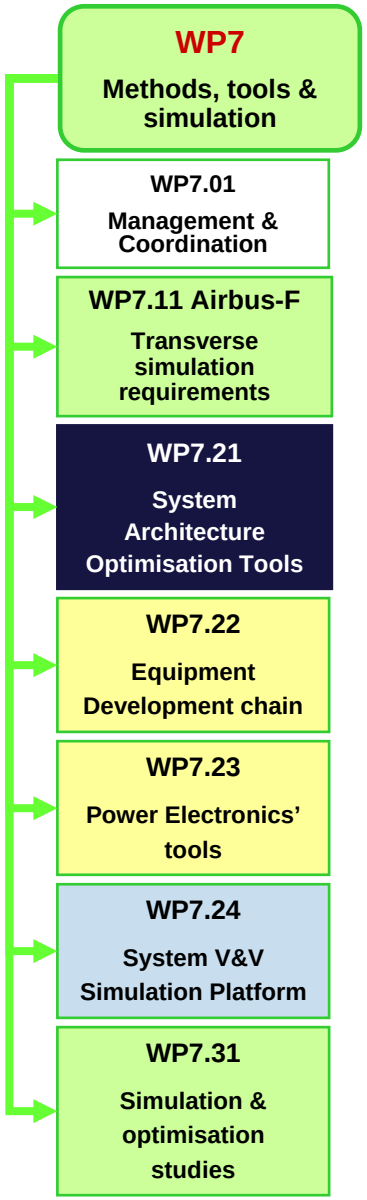


MOPS - Multi-Objective Parameter Synthesis



- Robust multi-criteria optimisation
- Multi-domain (pre-) design optimisation
- Worst-case search based robustness analysis (anti-optimisation)
- Monte Carlo simulation for robustness & uncertainty analysis

WP7.21
SYSTEM ARCHITECTURE OPTIMISATION TOOLS



WP 7.21 System Architecture Optimisation Tools

Define optimisation tool requirements for power system and for electrical network

- define computational design criteria from high level design drivers, performances, and specifications (WP 1): power, weight, …
- specify simulation and analysis tools necessary to evaluate defined computational design criteria
- set up requirements for an electrical system architecture optimisation environment starting from POA-VIB and VIVACE outcomes

Develop and validate

- parametric design object models for scalable generic components and equipments describing the dependencies between free design parameters and equipment performances (based on validated data provided by other WP's)
- design object models for a number of representative samples using test rig results
- aircraft extrapolation capacities and rig correlation / validation

Assess the capacities

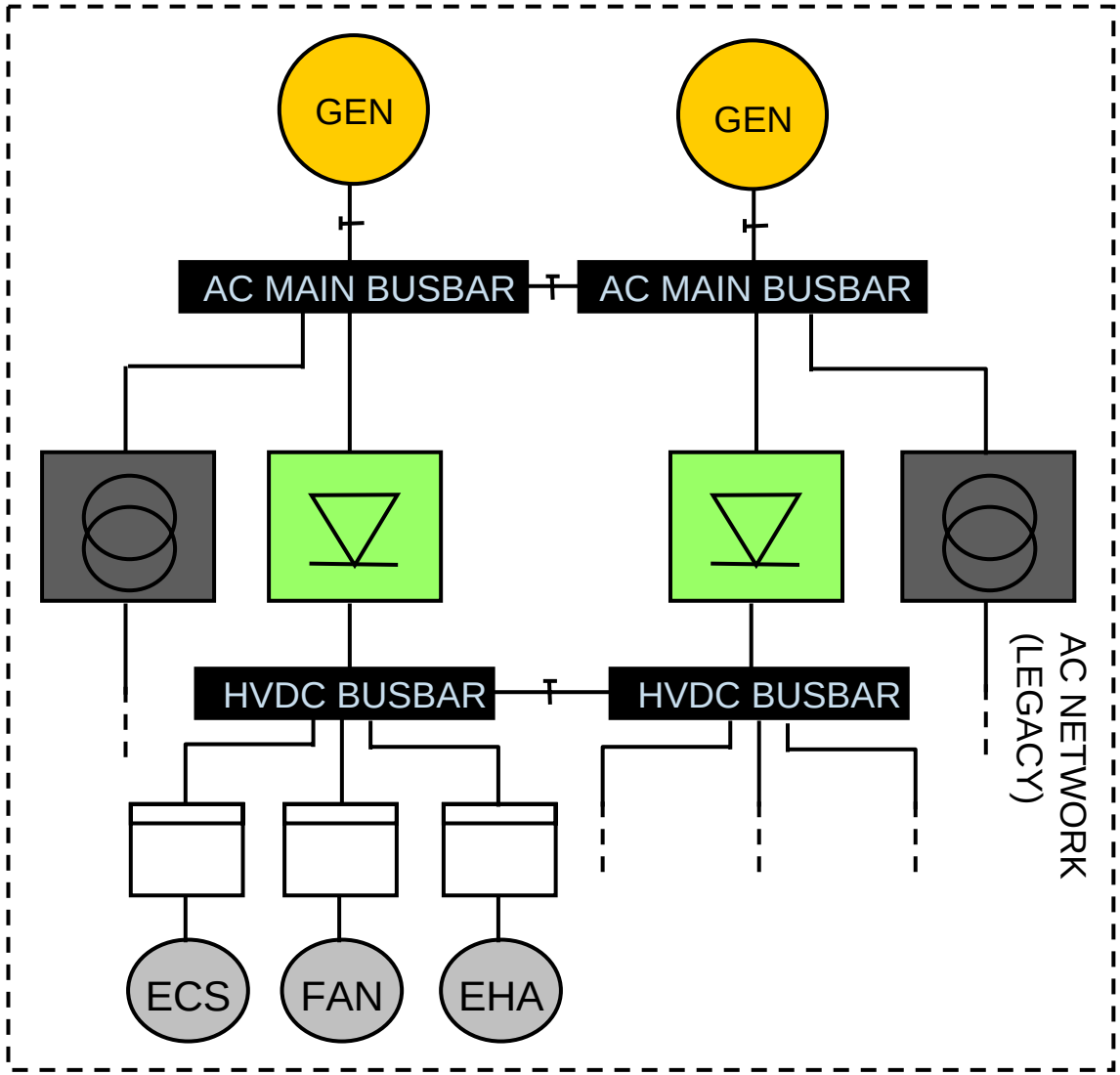
- for variable system architecture modelling, which allows automatic architecture optimisation; e.g. network topology, distribution of loads

OUTPUT:
Enhanced System Architecture Optimisation Environment (model library, design criteria, analysis methods, adapted MOPS)

WP7.21

SYSTEM ARCHITECTURE OPTIMISATION TOOLS

SCALABLE & GENERIC MODELS

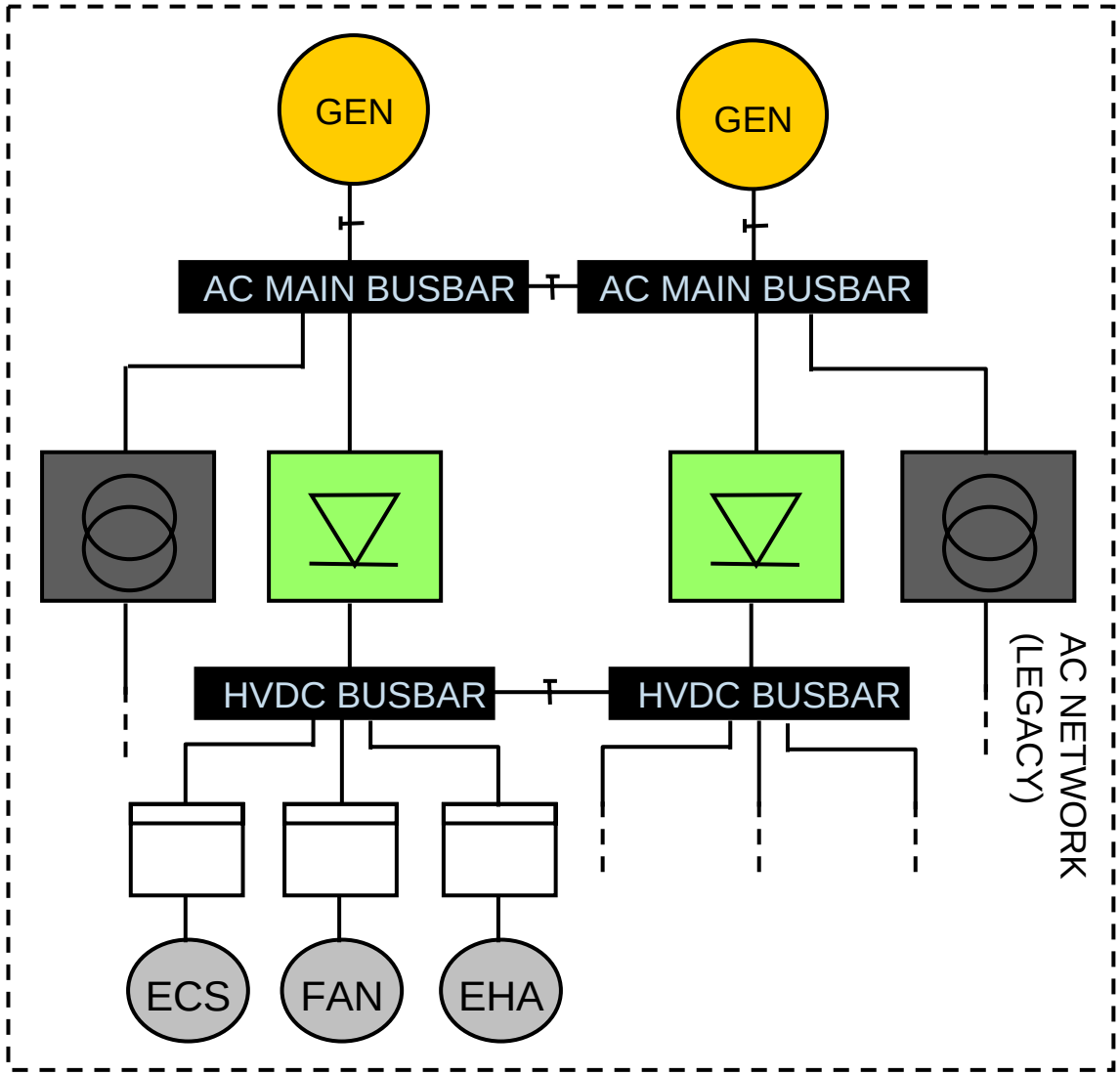


Optimisation of the:

- Electrical performances and characteristics
  - -HVDC voltage level
  - -Power quality performances (filters…)
- Network topology and management
  - -Distribution network architecture
  - -Loads allocation
  - -Load management

SYSTEM ARCHITECTURE OPTIMISATION TOOLS

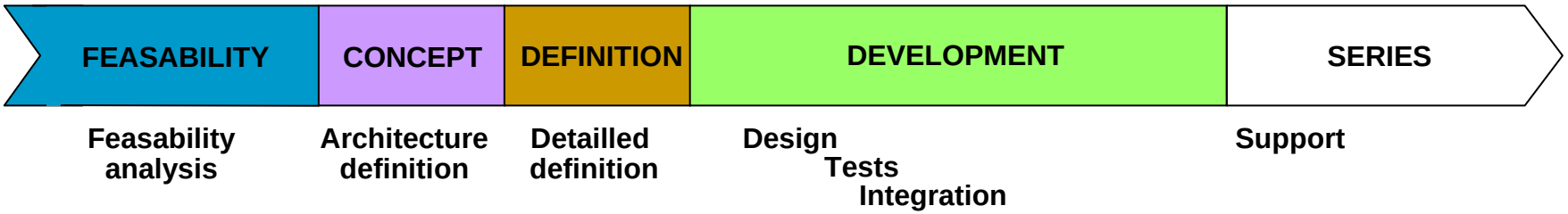
SCALABLE & GENERIC MODELS



Minimal set of models needed in the frame of MOET (optimisation studies):

- Generation
- Main power users (ECS, FAN…)
- Electrical power center
- Active filter for harmonic currents
- Etc…

FUNCTION PROTOTYPING



②

Virtual prototyping
HIL simulations

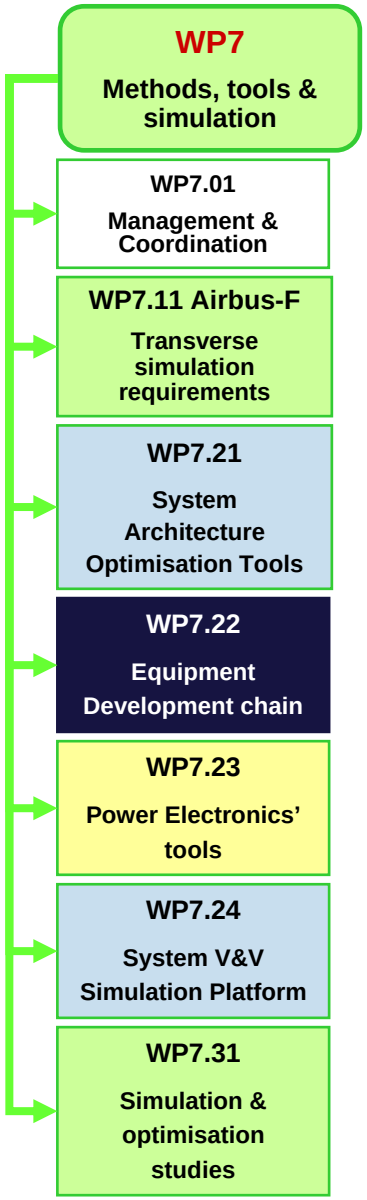
Equipment level

dSPACE
MATLAB
SIMULINK

On the basis of a standard tool chain, **virtual prototyping and HIL simulations** enable to:

- Validate concept feasability as soon as possible
- Enable high flexibility in design phase
- Optimize development time, quality and maturity
- Reduce costs factors

WP7.22
EQUIPMENT DEVELOPMENT CHAIN



WP 7.22 Equipment Development Chain

Questionnaire for suppliers about current situation:
used simulation tools, details of models, design process, improvement proposals, ...

Define equipment development chain
- equipment specifications: interfaces, performance measures, specs in executable form
- virtual design / prototyping (modelling, algorithm and software, automatic tuning)
- HiL-Simulations
- validation model export
- automatic code-generation for a/c V&V and target h/w download
- select, test and adapt tools for equipment development chain

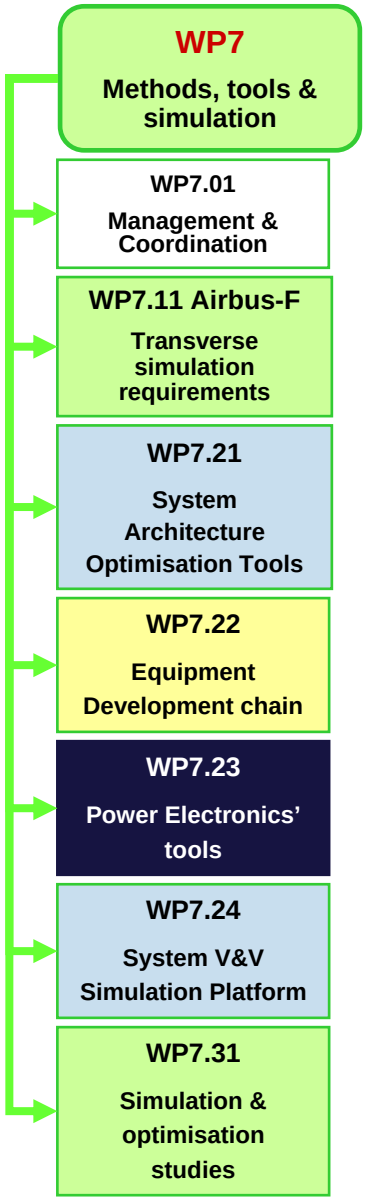
Improve simulation tools at supplier side
- rotating machines: improve tools accuracy from electromagnetic simulation (flux 2D, …) up to network quality studies (Saber, …)

Demonstration, workshop, conclusions
- test and demonstrate equipment development chain at selected equipment (e.g. from test rig).
- workshop with other work package partners
- conclusions and recommendations

OUTPUT:
- **equipment development chain definition document**
- **development guidelines and standards**
- **adapted tool set**
- **benchmark demonstration**
- **workshop proceedings**

See WP leader
Link with aircraft needs

WP7.23
TOOLS FOR POWER ELECTRONICS DEVELOPMENT



WP 7.23 Tools for power electronics' development

Tools for electronics development
- Thermal
- EMC
- Mechanical
- Electronic
- Control

Improve simulation tools at supplier side
- power converters: improve tools for EMC studies related to power converter & loads behaviour and interactions

Tool links

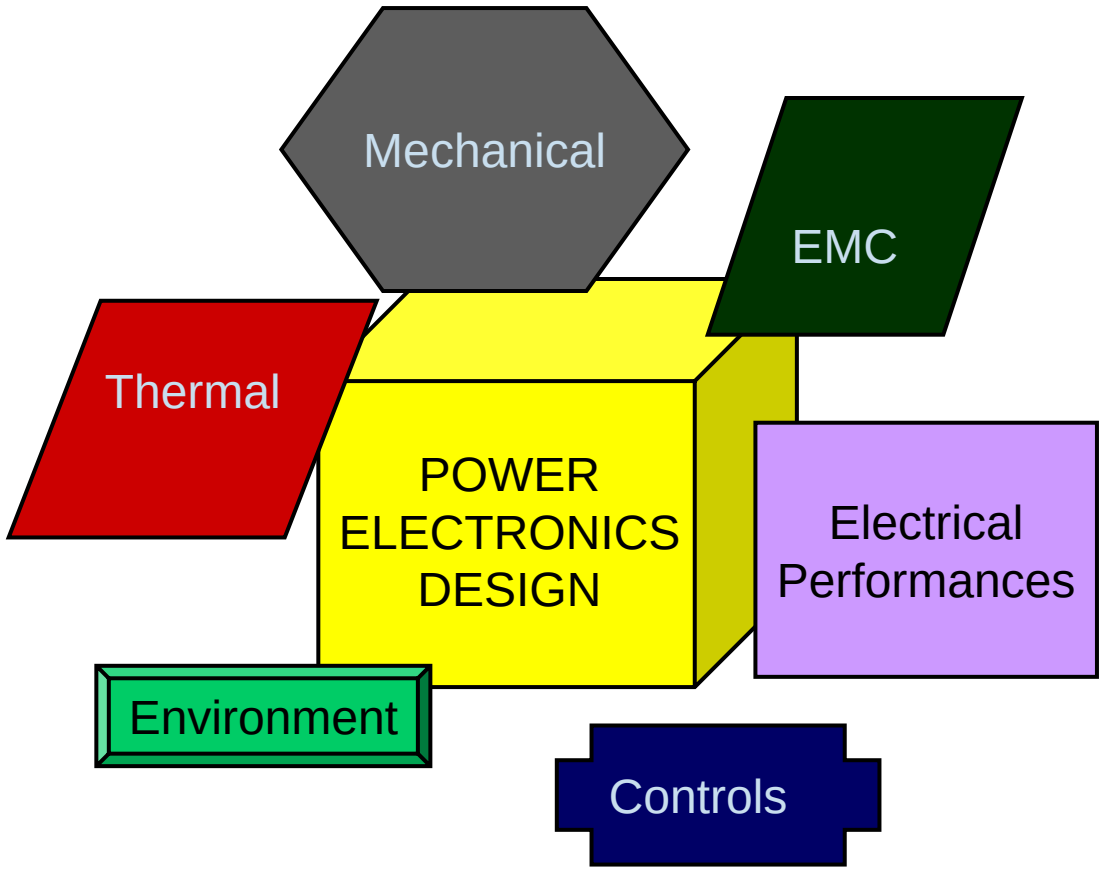
OUTPUT:
- **Set of tools**

Link with Power electronics' theme

WP7 Methods, Tools & Simulation – WP content

WP7
Methods, tools & simulation

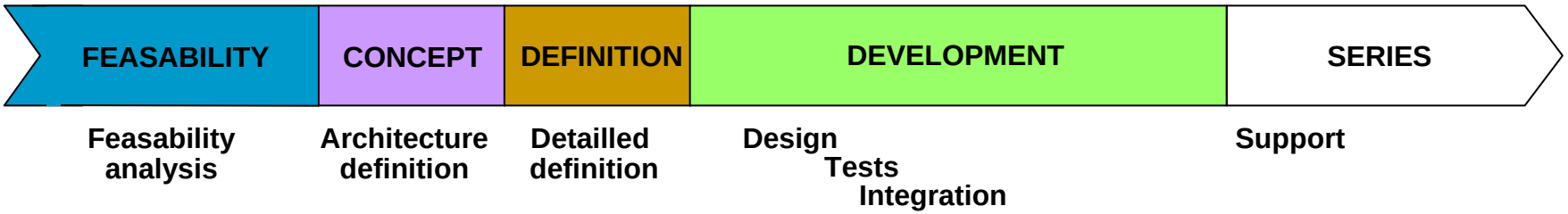
- **WP7.01** Management & Coordination
- **WP7.11 Airbus-F** Transverse simulation requirements
- **WP7.21** System Architecture Optimisation Tools
- **WP7.22** Equipment Development chain
- **WP7.23** Power Electronics' tools
- **WP7.24** System V&V Simulation Platform
- **WP7.31** Simulation & optimisation studies



One design
And
Several constraints

Link with Power electronics theme

V&V SIMULATIONS



③

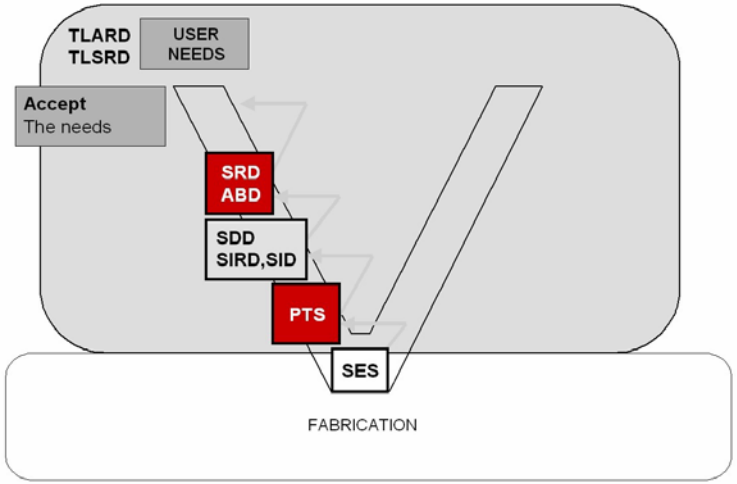
Simulations for
Validation & Verification activities

SABER
VHDL tools…

- **Establish, refine and validate:**
  - Sub-system and equipment design requirements
- **Verify by integration of suppliers models:**
  - Performances at system and equipment levels
  - Electrical System integration

V&V SIMULATIONS

Validation



Before design phase, use of simulation to determine and **validate**:

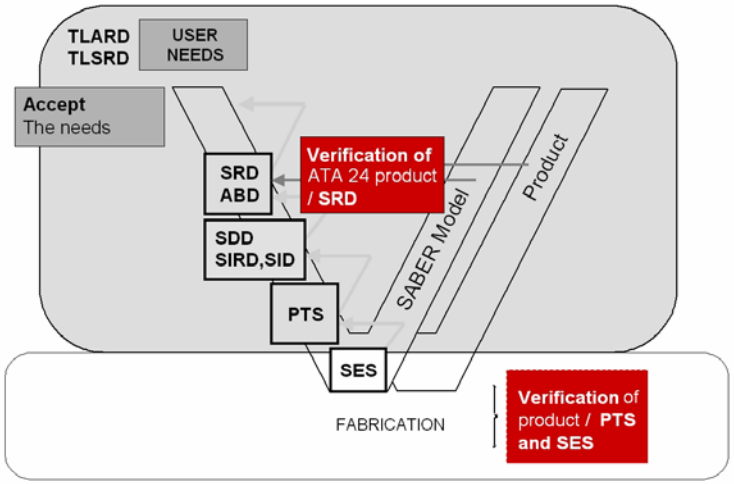
- System requirements

e.g.: power quality requirements at network level

- Equipment requirements

e.g.: power source transient power capability and steady-state sizing

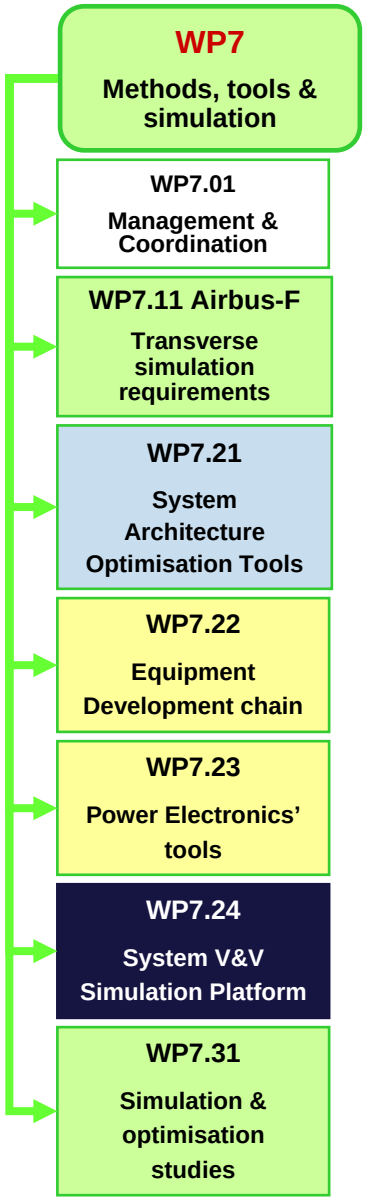
Verification



Preliminary **verification** of the electrical system performances:

- Verification of network quality and stability with regard to system requirements
- Verification of network configuration logics performances

WP7.24
SYSTEM V&V SIMULATION PLATFORM



WP 7.24 System Validation and Verification Simulation Platform

Define verification and validation of systems and equipments by simulations
- system simulation models and tools
- analysis tools (network power quality, stability, configuration logics and EMC)
- parametric assessment tools (parameter variation, DoE, Monte Carlo simulations, worst case optimisation, ...)
- distributed simulation to reduce simulation time

Tool selection and tool adaptation
- generic model library for selected components / equipment (e.g., generation, distribution, conversion, loads)
- validation of models from library with test rig
- improve version handling of models and of simulation results (cvs system, automatic report generation, ...)
- assembly of system level models for extrapolation
- analysis and parametric assessment tools

Improve equipment and system requirement standards using simulations
- network power quality, stability, EMC
- configuration logics (executable specifications), code generation
- test and demonstration of developed process with equipment and subsystems from test rig
- conclusions and recommendations

OUTPUT:
- **requirements specification document**
- **A/C platform methods & adapted tool set**
- **benchmark demonstration**

WP7.24
SYSTEM V&V SIMULATION PLATFORM

Models to be developed and validated by suppliers involved in WP2,3…6

- **V&V studies: top-priorities**

▸ Power quality – Steady-state voltage levels – Transient voltage levels – Harmonic distortion (AC network) – Voltage ripple (DC network or sub-network)	**« BEHAVIORAL »** ELECTRICAL MODELS (detailed)
▸ Network stability ▸ Network configuration logics – Compatibility in terms of logics and states – Network management rules and algorithms	**« FUNCTIONAL »** ELECTRICAL MODELS (linearized, embeded software)
▸ EMC	**TBD**

- **Tool: SABER simulator**, except if not appropriate

WP7.24
SYSTEM V&V SIMULATION PLATFORM

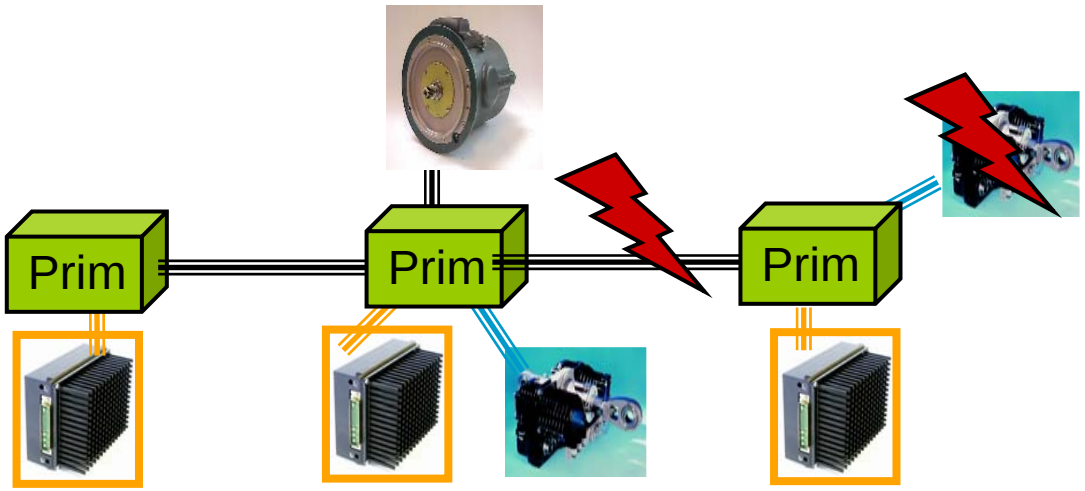
WP7
Methods, tools & simulation

- **WP7.01** Management & Coordination
- **WP7.11 Airbus-F** Transverse simulation requirements
- **WP7.21** System Architecture Optimisation Tools
- **WP7.22** Equipment Development chain
- **WP7.23** Power Electronics' tools
- **WP7.24** System V&V Simulation Platform
- **WP7.31** Simulation & optimisation studies

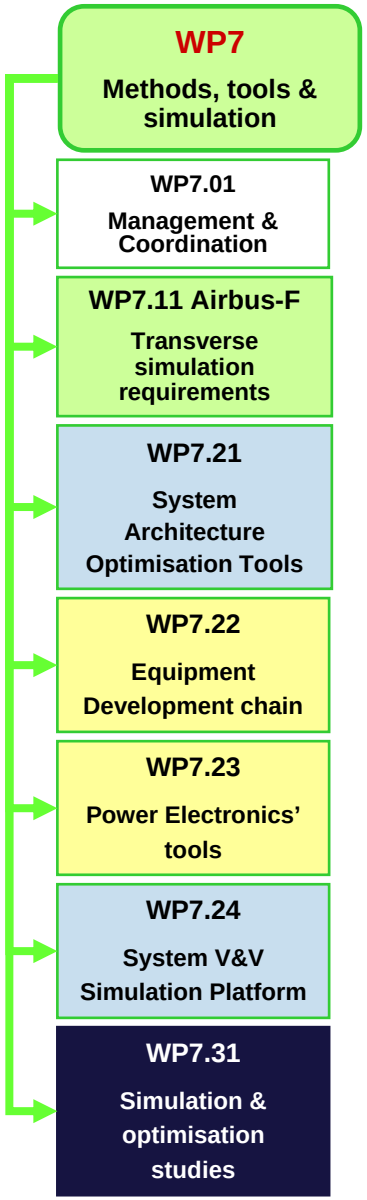
Those new functions aim to integrate more skills

- Utilities, Protections, Health Monitoring, Efficient communication
- Permanent load management

How to identify faulty equipment, inducing a network misbehaviour?



WP 7.31
SIMULATION AND OPTIMISATION STUDIES



WP 7.31 Simulation and Optimisation Studies

Definition of simulation and optimisation studies according V&V plan
- architecture optimisation,
- component/equipment development
- system validation & verification

Tool application (from 7.21, 7.22 … 7.24)
- optimise defined architecture (WP1)
- harmonise / follow up simulation based component optimisation and validation
- A/C platform simulation
- Rig correlation
- Electrical system extrapolation

Methods & tools conclusions and recommendations

Test program writing for WP8.xx

OUTPUT:
- **optimized architecture**
- **recommendations document**
- **Aircraft platform simulation results**

This document and all information contained herein is the sole property of AIRBUS S.A.S. No intellectual property rights are granted by the delivery of this document or the disclosure of its content. This document shall not be reproduced or disclosed to a third party without the express written consent of AIRBUS S.A.S. This document and its content shall not be used for any purpose other than that for which it is supplied.

The statements made herein do not constitute an offer. They are based on the mentioned assumptions and are expressed in good faith. Where the supporting grounds for these statements are not shown, AIRBUS S.A.S. will be pleased to explain the basis thereof.