Using FMI/SSP/SysML in an International Large-Scale Industrial Context

Novel Energy and propulsion systeMs for Air dominance (NEUMANN)

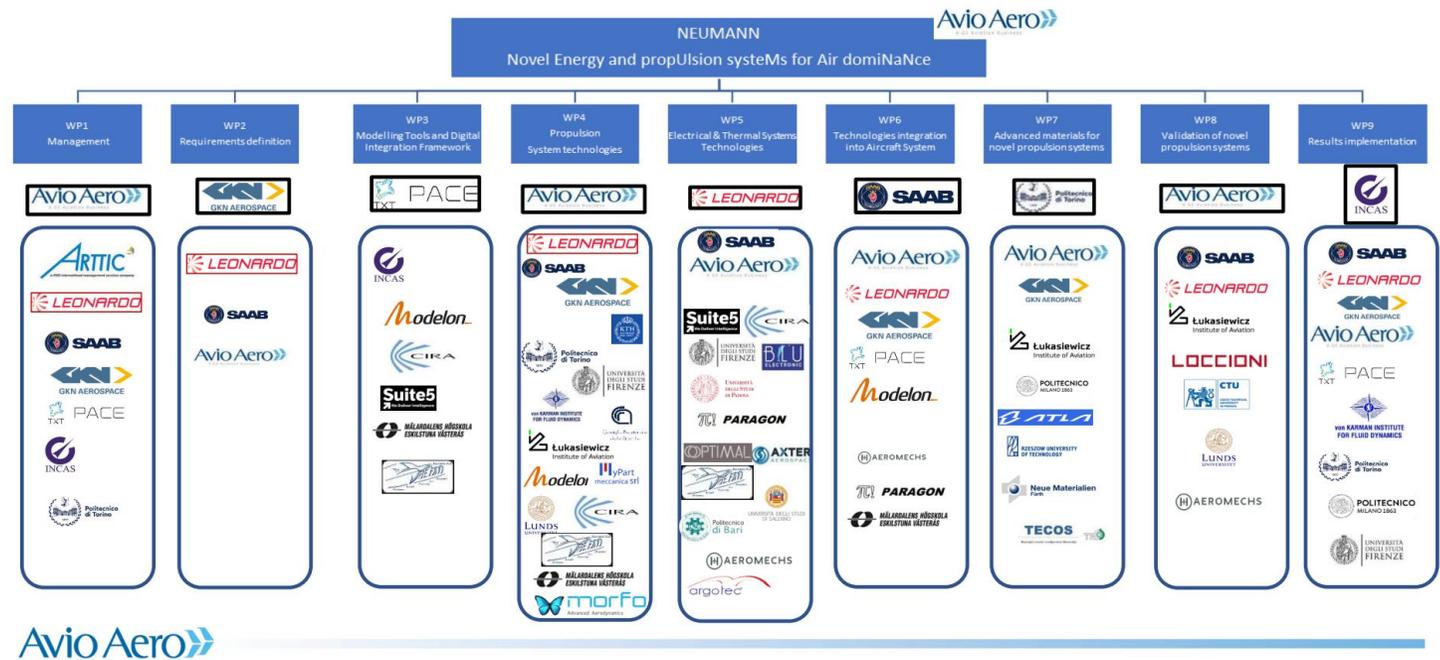Kristian Amadori, Robert Hällqvist

Agenda

- NEUMANN Overview
- What problem are we trying to solve
  - Modern model-based methodology in early phases
- Enablers
- Analysis focus
- Outcomes and status

NEUMANN Overview

- European Defense Fund
- EDF-NEUMANN
  - Lead: Avio Aero
  - Duration: 4 years

"The EDF supports companies across Member States develop competitive and collaborative defense projects that will deliver innovative and interoperable defense technologies and equipment"

"NEUMANN will study energy aircraft domains, with a focus on energy-efficient propulsion, electrical and thermal systems and management"

NEUMANN
Novel Energy and propUlsion systeMs for Air dominance

SELECTED PROJECTS EUROPEAN DEFENCE FUND (EDF) 2021

CALL TITLE:	Energy efficiency and energy management
TOPIC TITLE:	Alternative propulsion and energy systems for next generation air combat systems
DURATION OF THE PROJECT:	50 months
TYPE(S) OF ACTIVITIES:	Studies
ESTIMATED TOTAL COST:	€ 56,419,440.29
MAXIMUM EU CONTRIBUTION :	€ 48,919,439.88

EDF-NEUMANN

NEUMANN Overview

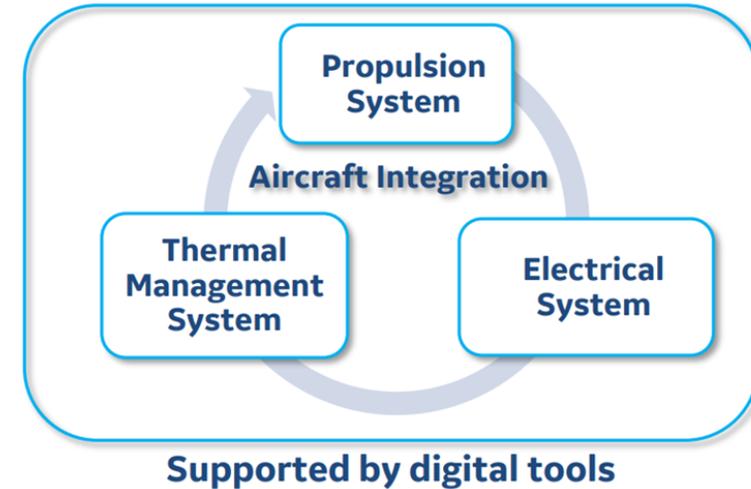**SAAB**

Main trends for next generation aircraft

Higher performance with unprecedented mission flexibility
- Thrust to weight ratio
- Efficiency for Endurance, Range, Fuel Consumption

More electrical power on-board

Reduced environmental footprint

Lifecyle costs

EU ambitions through EDF

Innovation, competitiveness of the European Defense Industry Technological Base

EU excellence and autonomy in key technologies

Collaboration across EU:
- cross-border cooperation
- innovative newcomers to enter defence sector

NEUMANN ambition

Provide Europe with an **advanced technologies suite** for Energy and Propulsion,

applicable in modular and flexible ways to different size and type of next generation systems,

to enable an optimised **global management of energy** on board, **propulsive and non-propulsive**

NEUMANN Overview

Main trends for next generation aircraft

Higher **performance** with unprecedented **mission flexibility**
- Thrust to weight ratio
- Efficiency for Endurance, Range, Fuel Consumption

More electrical power on-board

Reduced **environmental footprint**

Lifecyle costs

Propulsion System

Aircraft Integration

Thermal Management System

Electrical System

Supported by digital tools

An integrated approach is needed to address the challenges for Power and Propulsion

NEUMANN Overview Presentation Focus

Digital modeling and collaborative tools

- To support all other technology development sin need of M&S

	Propulsion efficiency and performance	Innovative energy management strategies	Advanced electric & control systems	Reduced environmental footprint
Flexible powerplant architecture – advanced cycles, electrification	●	●	●	●
Advanced cooling technologies	●		●	●
Advanced Aerodynamics for cooled turbines	●			
Advanced controls	●	●	●	
High temperature materials	●			
Novel Techs for Electrical generation/distribution/storage	●	●	●	●
Combustion technologies & advanced fuels	●			●
Additive Manufacturing Heat Exchangers	●	●		●
Digital modeling – collaborative tools	●	●	●	●
Integrated Thermal Management System	●	●	●	

What problem are we trying to solve

- Facilitate "Digital Modelling-collaborative tools" to enable the goals of NEUMANN
  - MBSE methodology
  - Tool interoperability
- Exercise methodology and tools in a set of realistic concept development scenarios
 - Ranging from system (aircraft), to sub-systems, to component
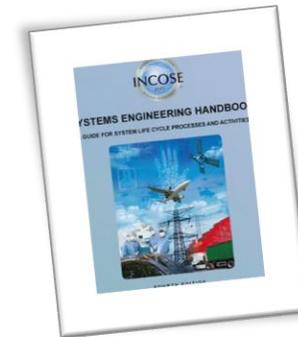
INCOSE. Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. Fourth Edition, Wiley

Why Model based analysis?

- Communication interfaces
    - Multiple organizations in different countries
    - Cultural and linguistic differences
        - increasing the risk of miscommunication
        - Different ways of working
    - Different preferred tools
    - Different design perspectives
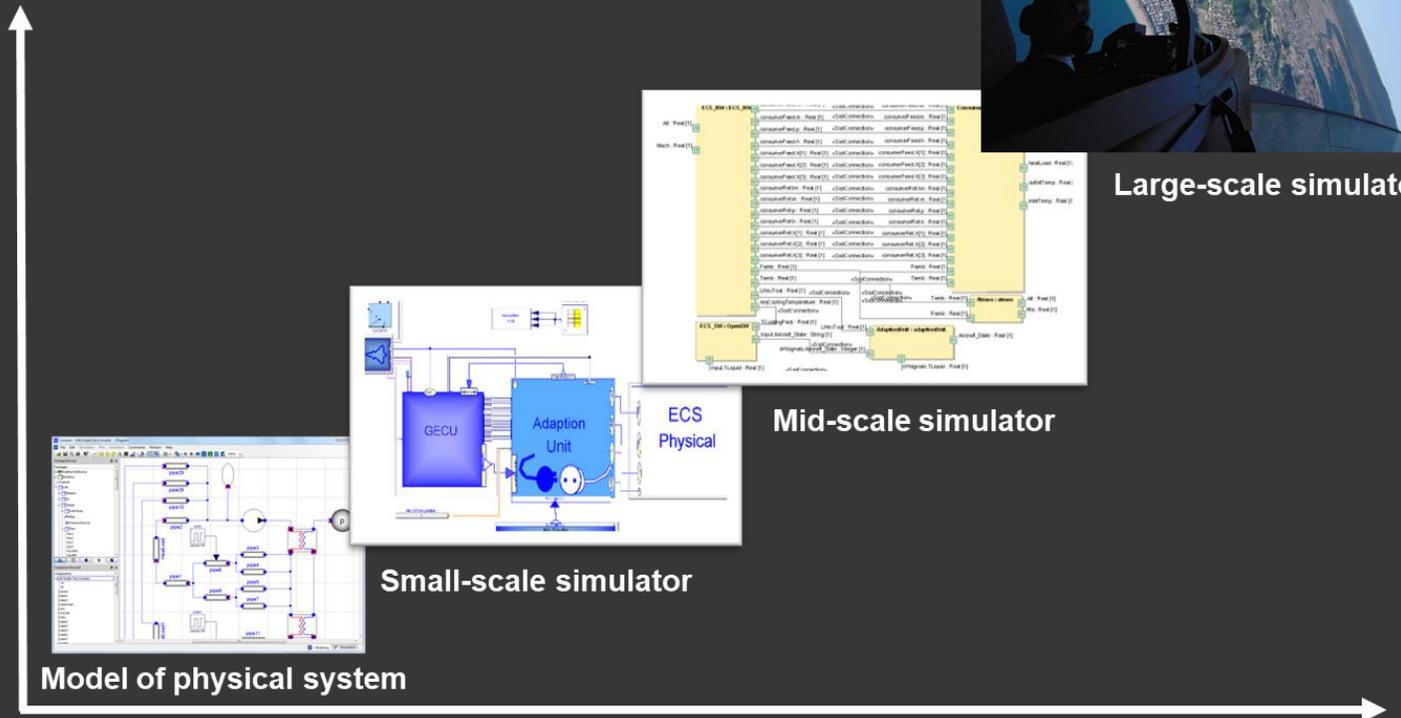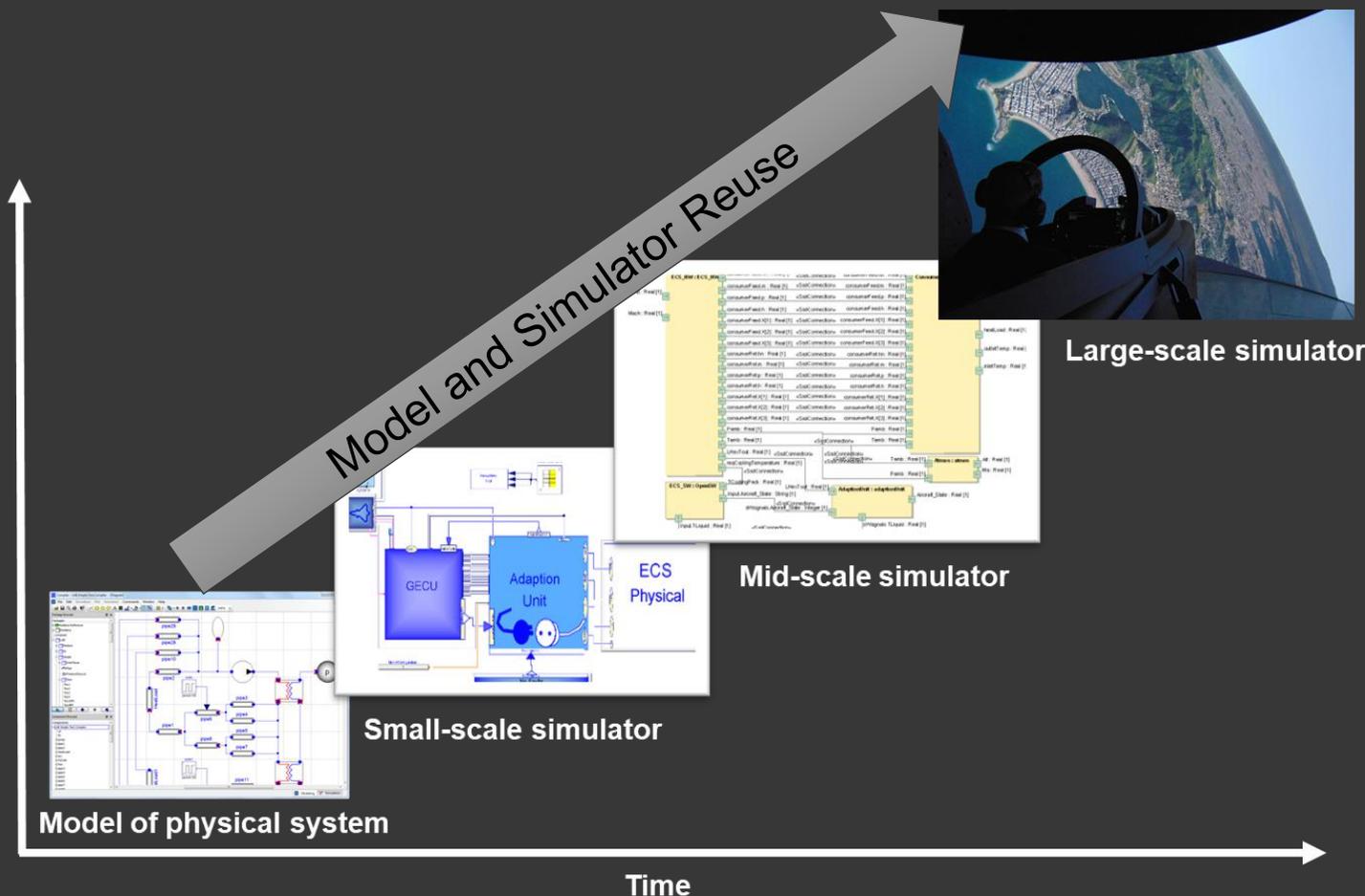   - What problem to solve at what system level?
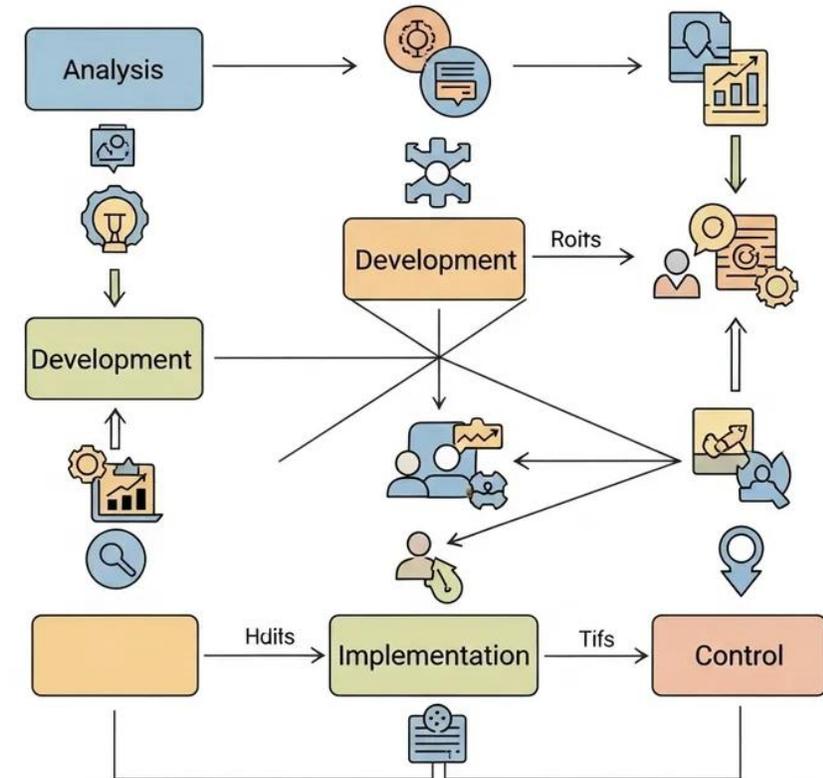
Approach to Modeling and Simulation (M&S) throughout the life-cycle phases of Aircraft

M&S on increasing level throughout the life-cycle phases

- Component to Sub-system to Aircraft

Level of Integration

Time

Large-scale simulator

Mid-scale simulator

Small-scale simulator

Model of physical system

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Approach to Modeling and Simulation (M&S) throughout the life-cycle phases of Aircraft

M&S on increasing level throughout the life-cycle phases

- Component to Sub-system to Aircraft

- Model/Simulator Reuse is essential
  - Model capabilities/limitations
  - Sustainable tool Interoperability via standards
  - Credibility

Level of Integration

Model and Simulator Reuse

Large-scale simulator

Mid-scale simulator

Small-scale simulator

Model of physical system

Time

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Round-trip Engineering for the Development of cOmplex systems (REDO)

Information exchanged through portable packages (models, architecture, meta-data)

Characterized by: **parallel activities** and **frequent points of synchronization**

Highlights separation between system and analysis architectures
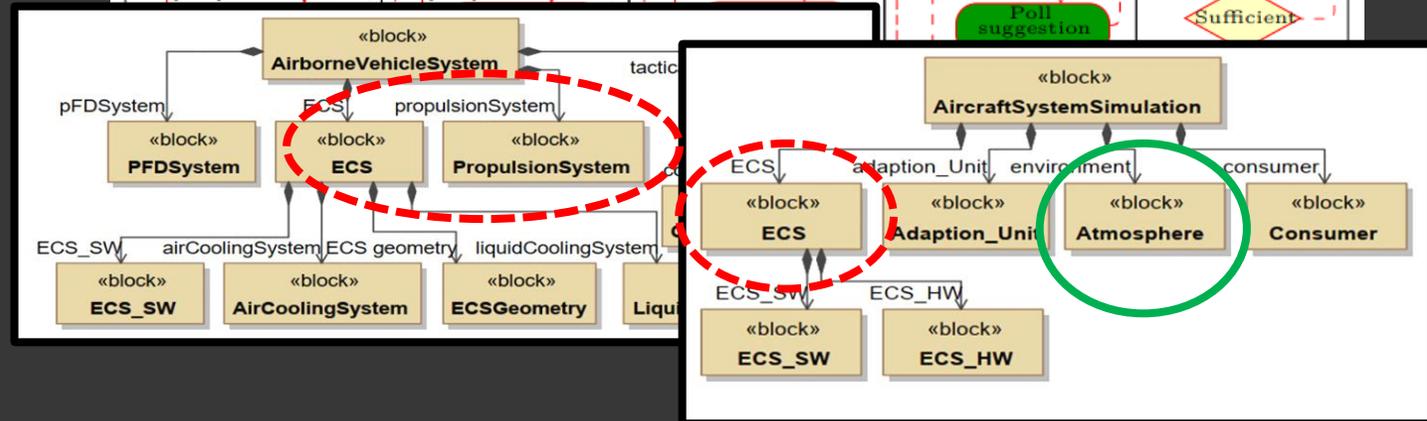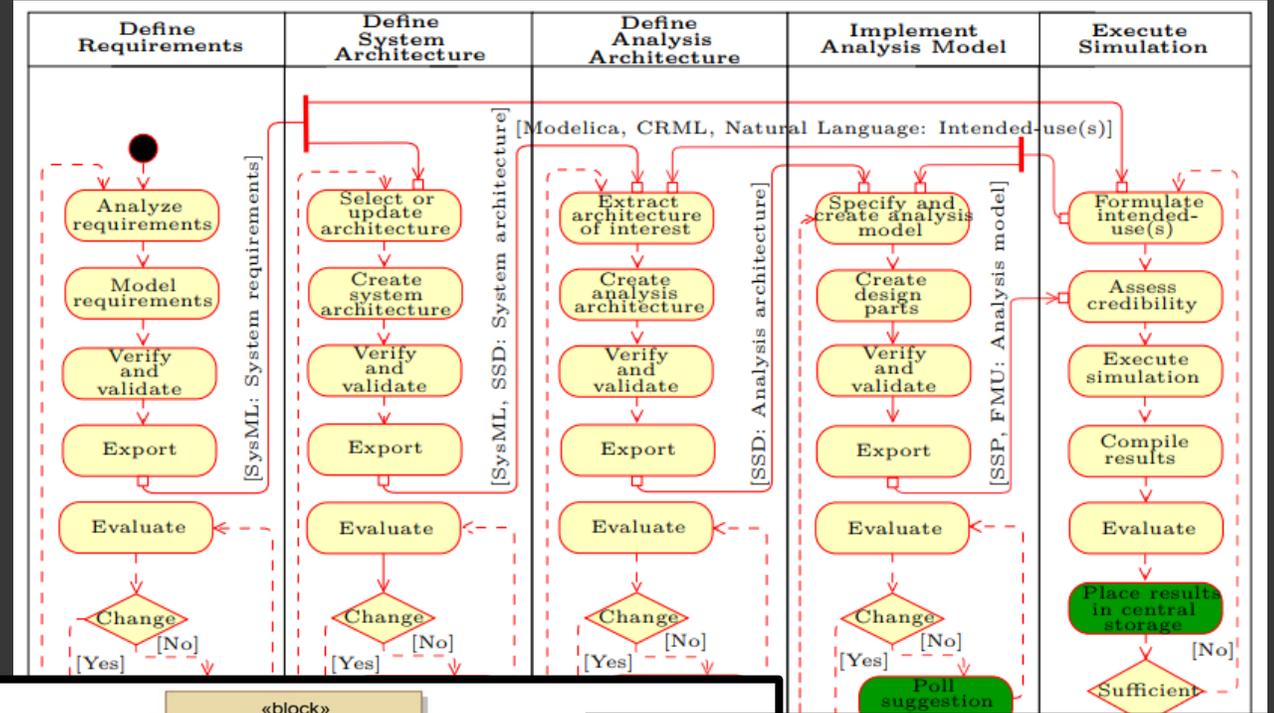
Round-trip Engineering for the Development of cOmplex systems (REDO)

In NEUMANN

Developing virtual realizations and simulations iteratively, going forward
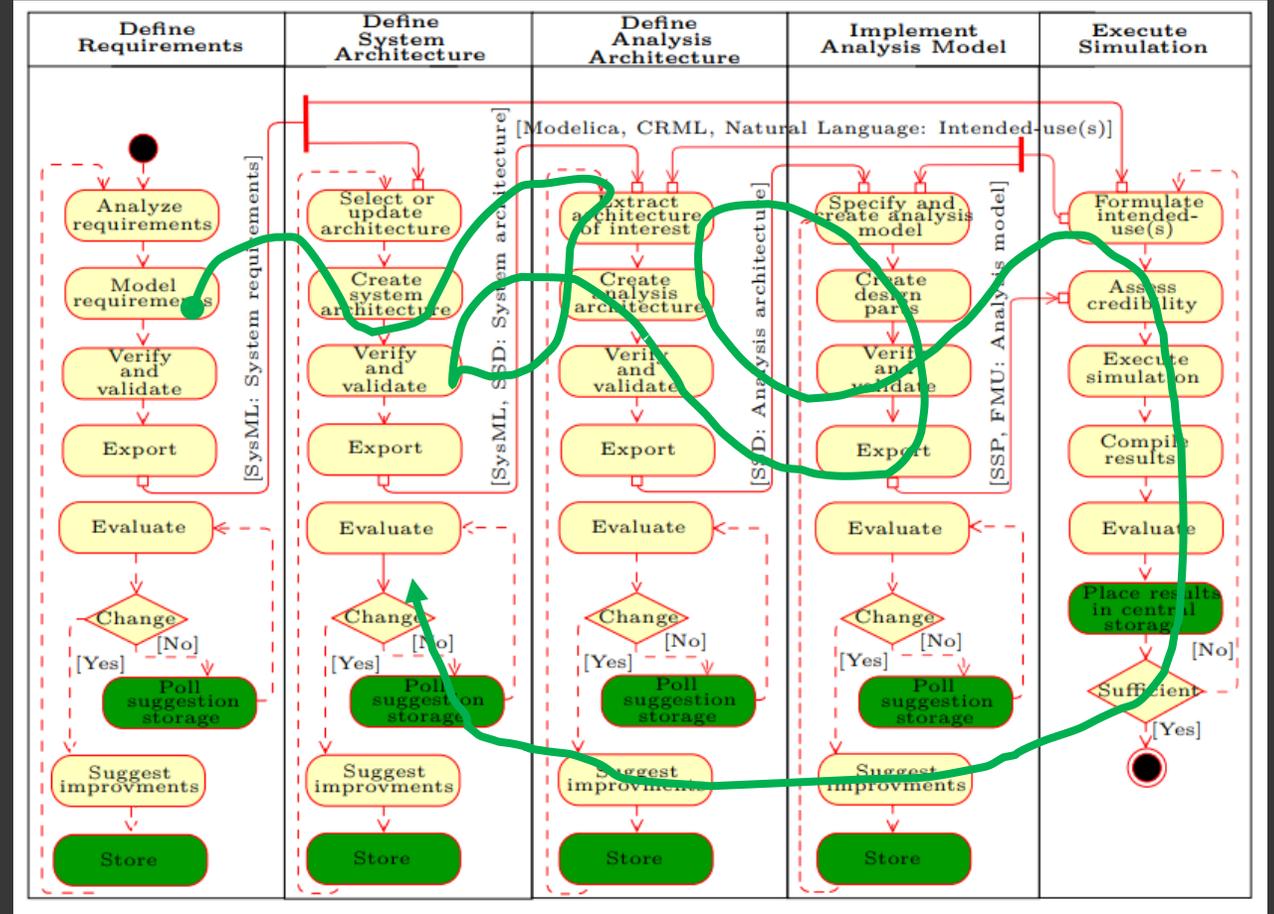
Round-trip Engineering for the Development of cOmplex systems (REDO)

In NEUMANN

Developing virtual realizations and simulations iteratively, going forward

Current research on

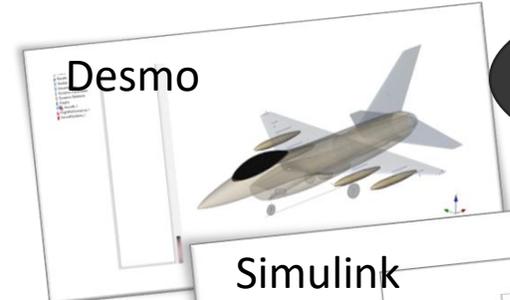With the option to **re-do** (go back) only based on the information contained in **exchange packages**
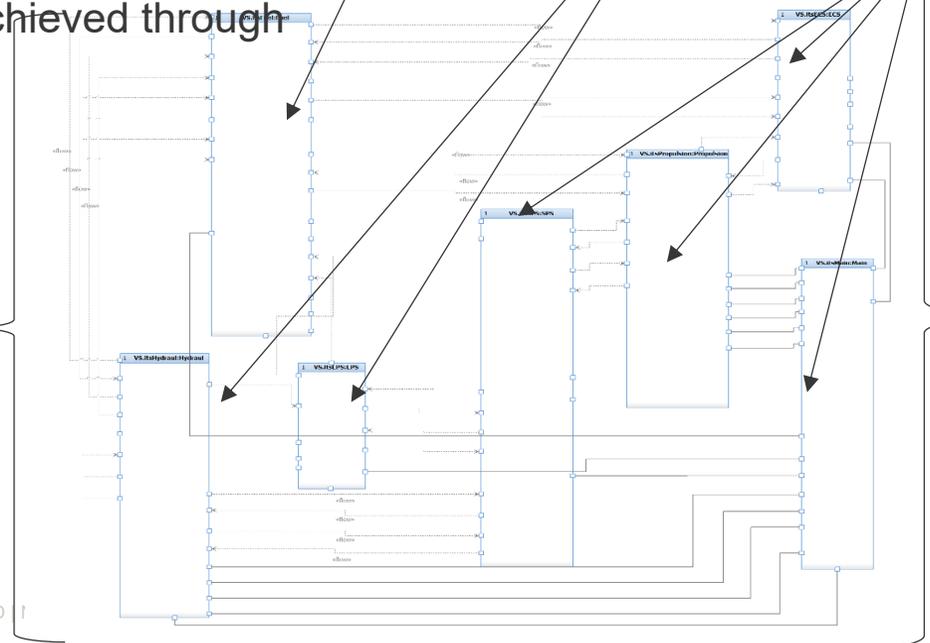
REDO in NEUMANN

SAAB

Models developed in the tools/languages where engineers are most comfortable.

- Integrate in one place, develop in any tool
- Portable models and simulators, founded on a centralized architecture
- Portable parameter sets
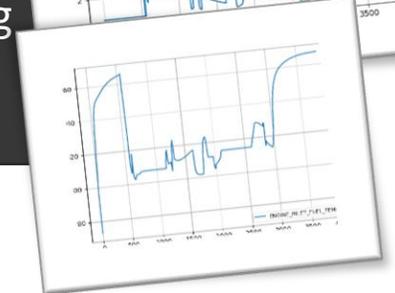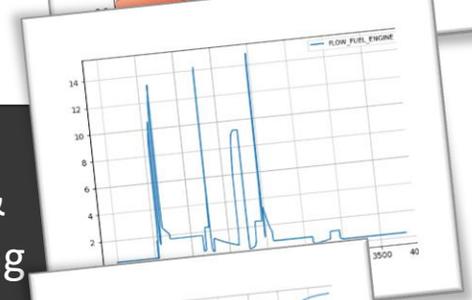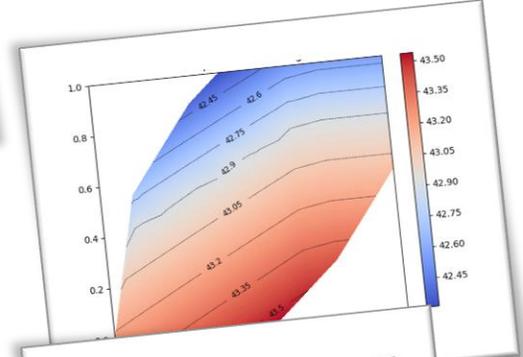- Interoperability achieved through standards

Desmo

Simulink

Modelica
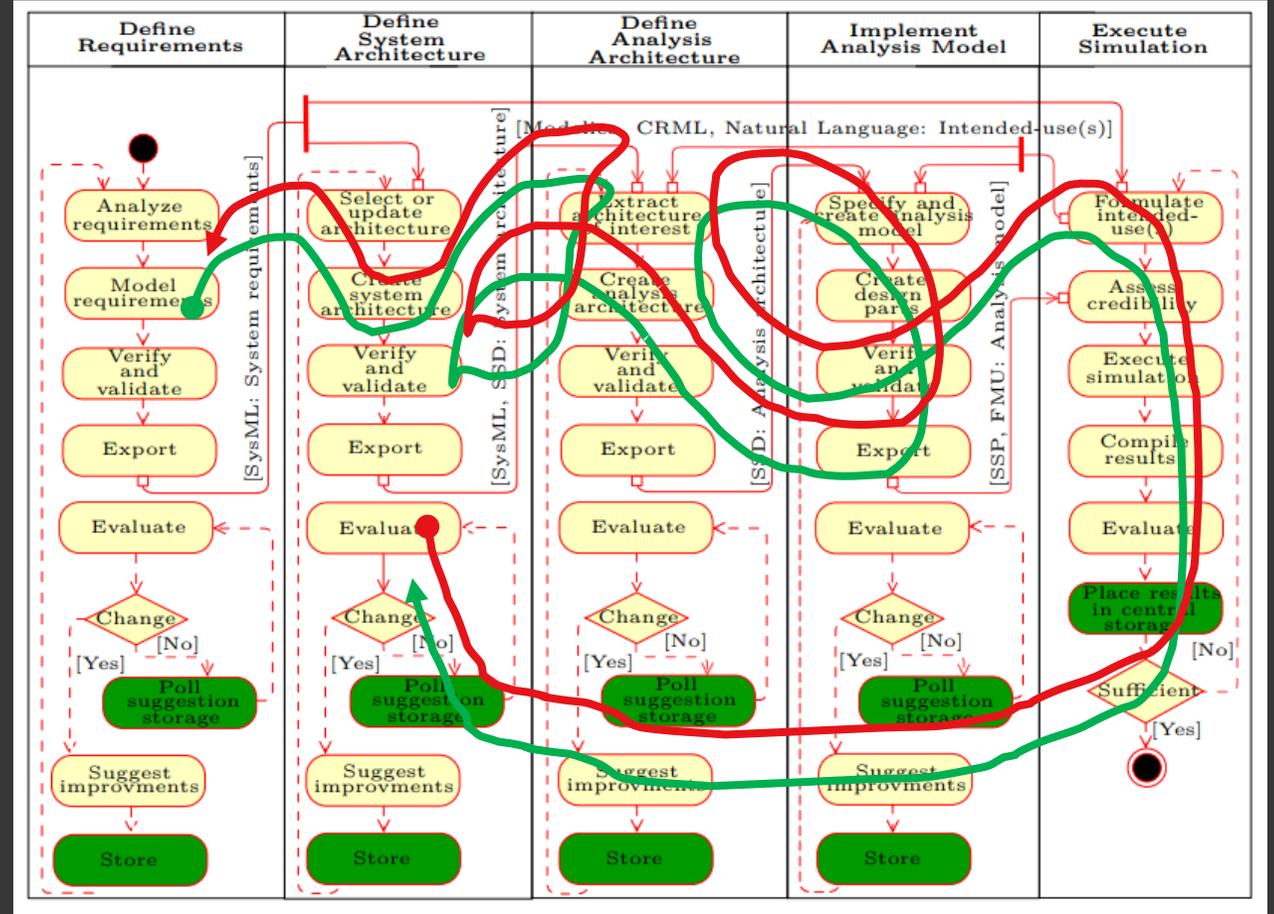
Model development tools

fmi

ssp

SysML tools

Requirements and architecture

Simulation & Postprocessing tools

Composite modeling for aircraft level analysis: with variable focus

- Studies with three primary focus areas. All three focus areas encompass novel propulsion solutions (heat dissipation, installation, etc.)

- Common system architecture (More Electric Aircraft)
  - **Overarching aircraft**
  - **Thermal Management System (TMS) accounting for first order feedback loops in aircraft**
  - Electrical Power System (EPS) accounting for first order feedback loops in aircraft
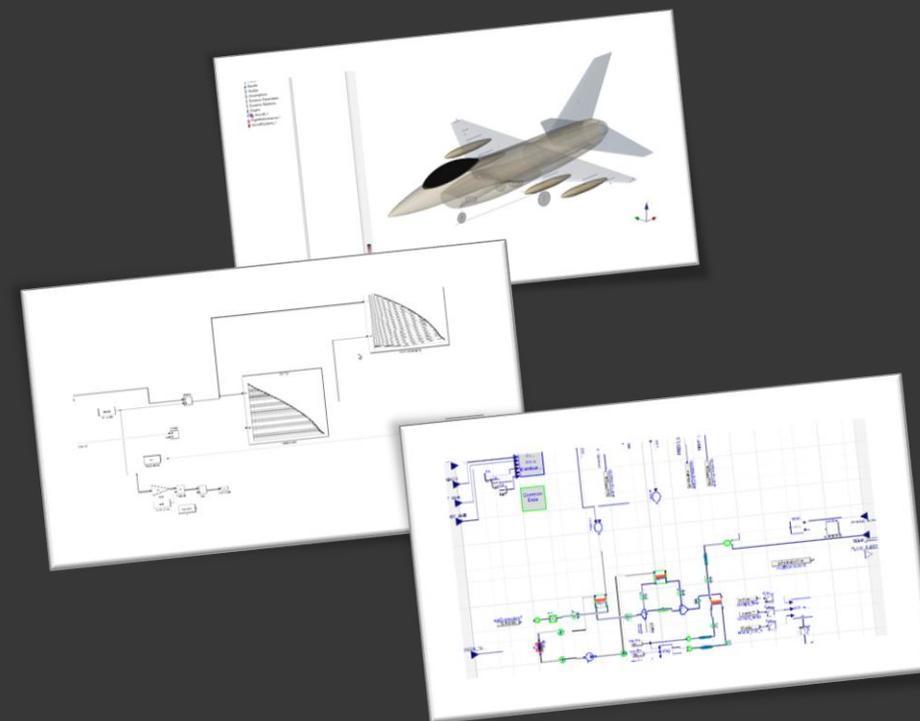
Aircraft Level
Overarching aircraft designed in Desmo*

Analysis Architecture based on:

- Assumptions on mission capabilities

- Rough assumptions about aircraft configuration and architecture

- Further NEUMANN study needs and requirements

*PACE Aerospace Engineering and Information Technology GmbH. Desmo
– A Preliminary Design Platform for Aircraft and On-Board Systems. Version
9.1. url: https://pace.txtgroup.com/products/preliminary-design/desmo-for-engineers-by-engineers.

Aircraft Level
Thermal Management System (TMS)

Analysis Architecture Realized Based on

- Aircraft architecture and requirements

- Study analysis needs
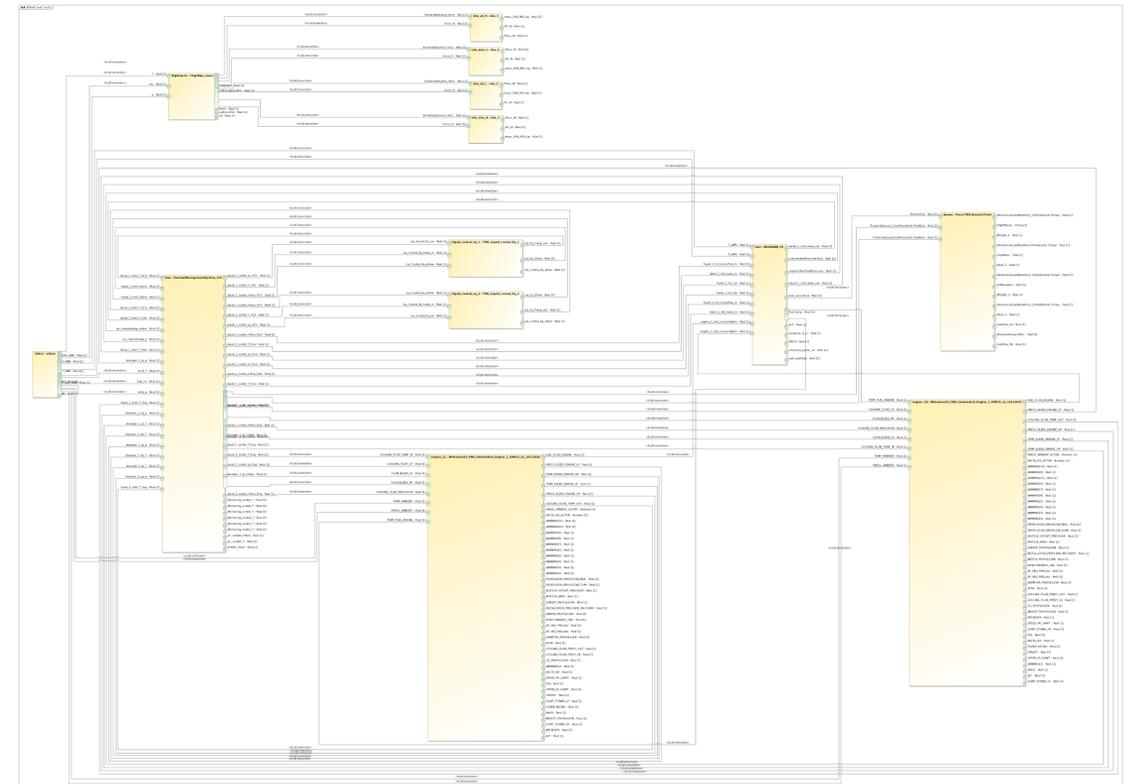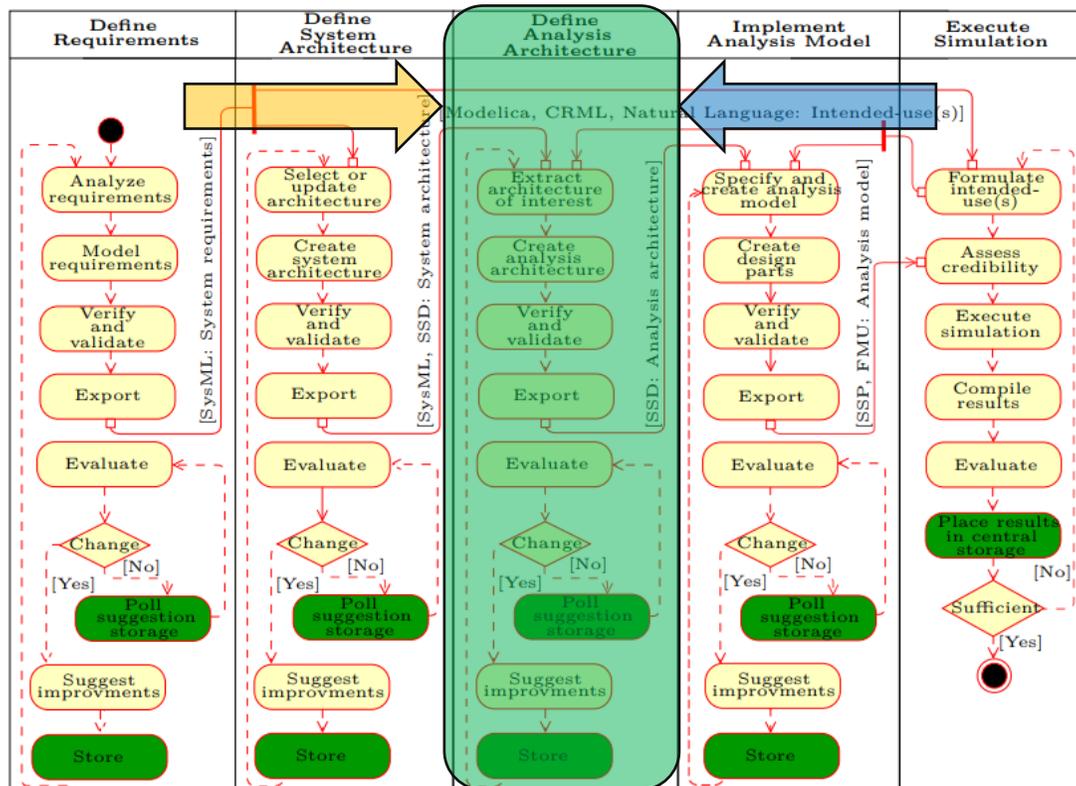
Aircraft Level Thermal Management System (TMS)

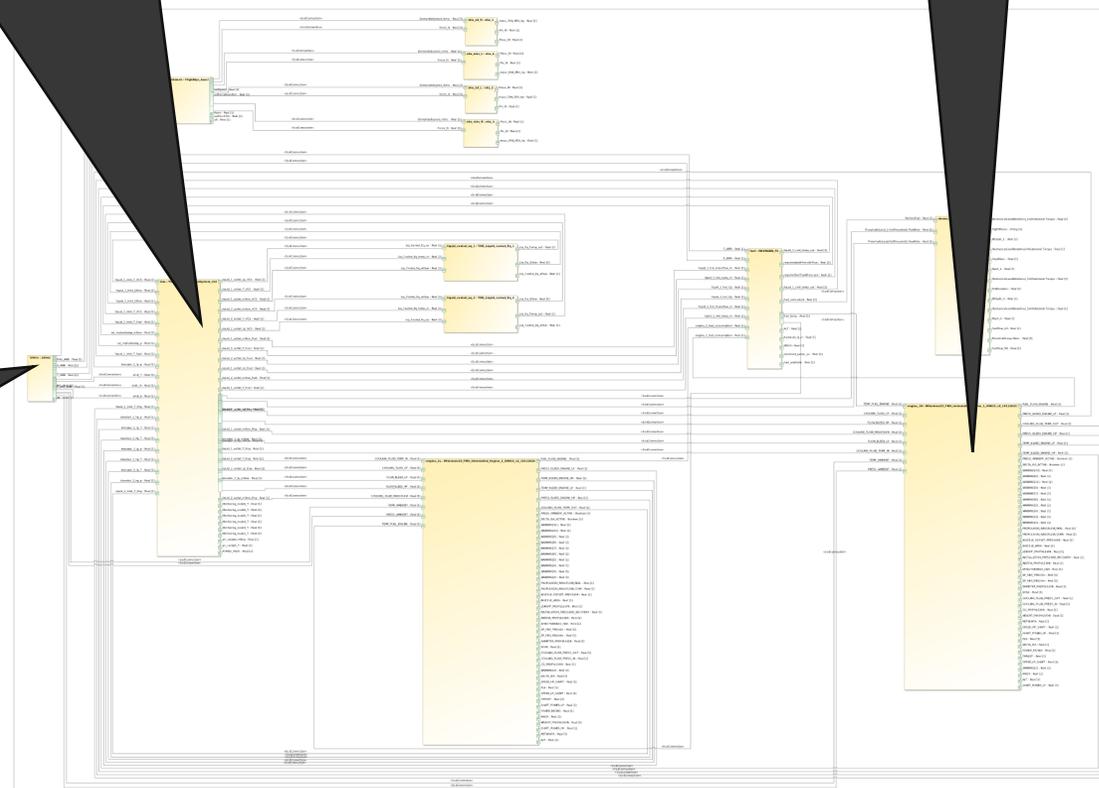Analysis Architecture Realized Based on

- Aircraft architecture and requirements
- Study analysis needs

Selected sub-system models

TMS (Modelica, Dymola and ModelonImpact, Simulink/Simscape)

Engine (Modelica, Modelon Impact)

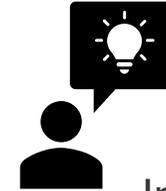Atmospehere (Modelica, OpenModelica)

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Aircraft Level
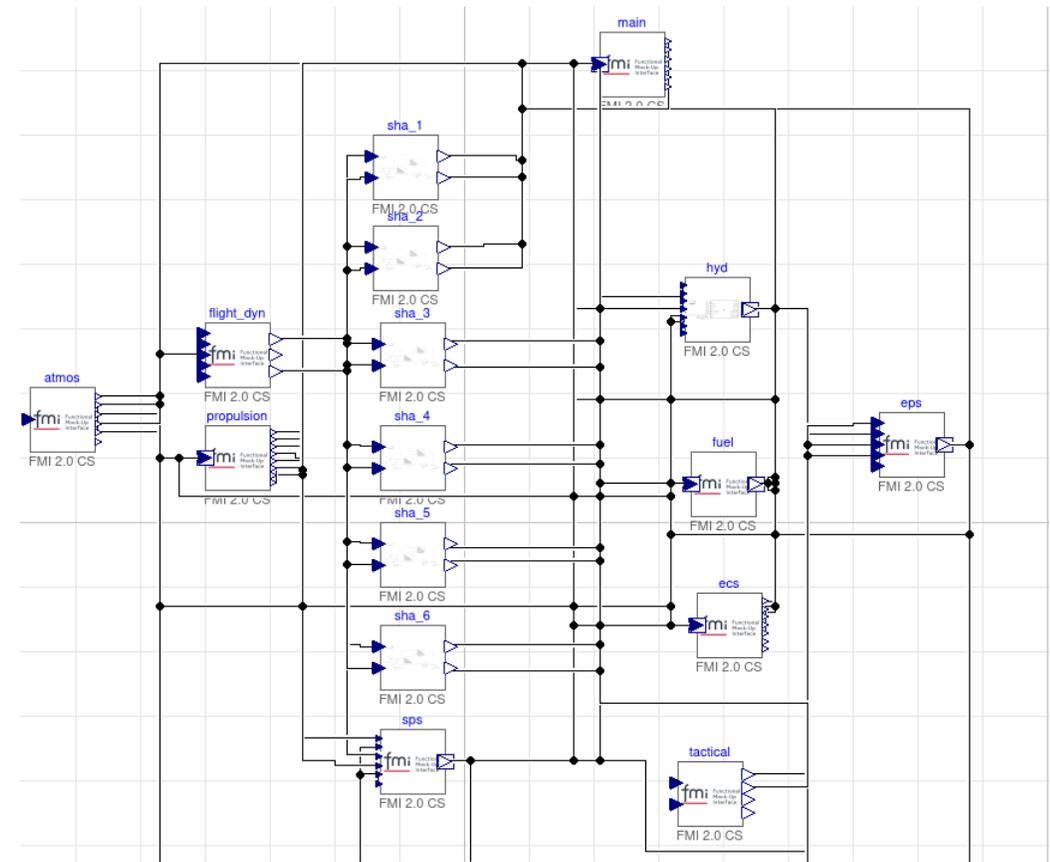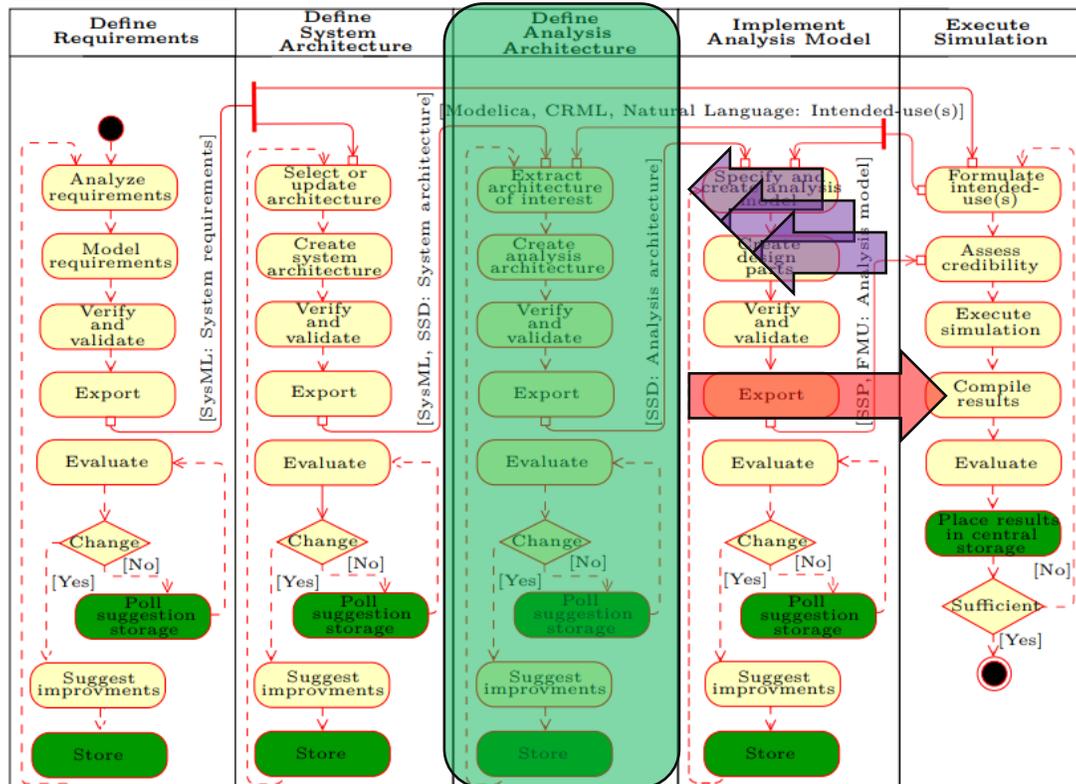# Thermal Management System (TMS)

Analysis Architecture Realized Populated with

- Executable Analysis Models integrated utilizing FMI

- Executable Analysis Architecture Communicated as a portable package via SSP
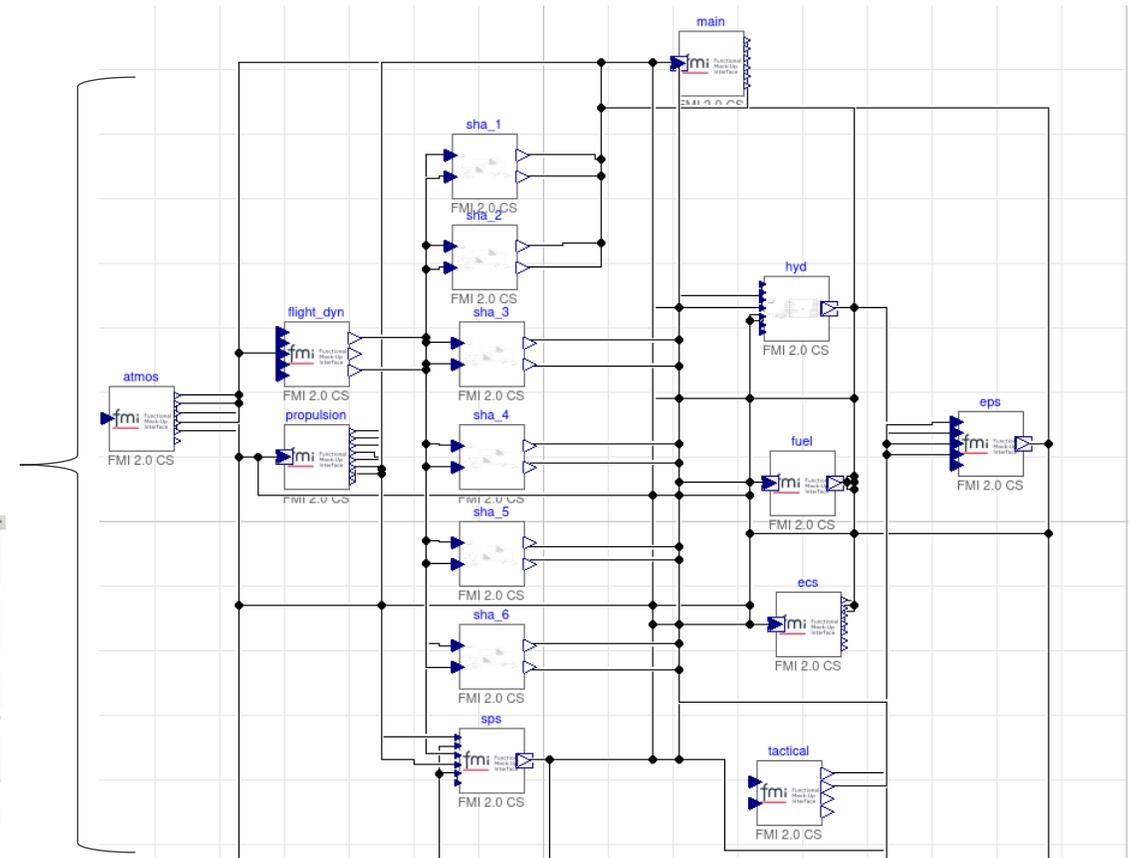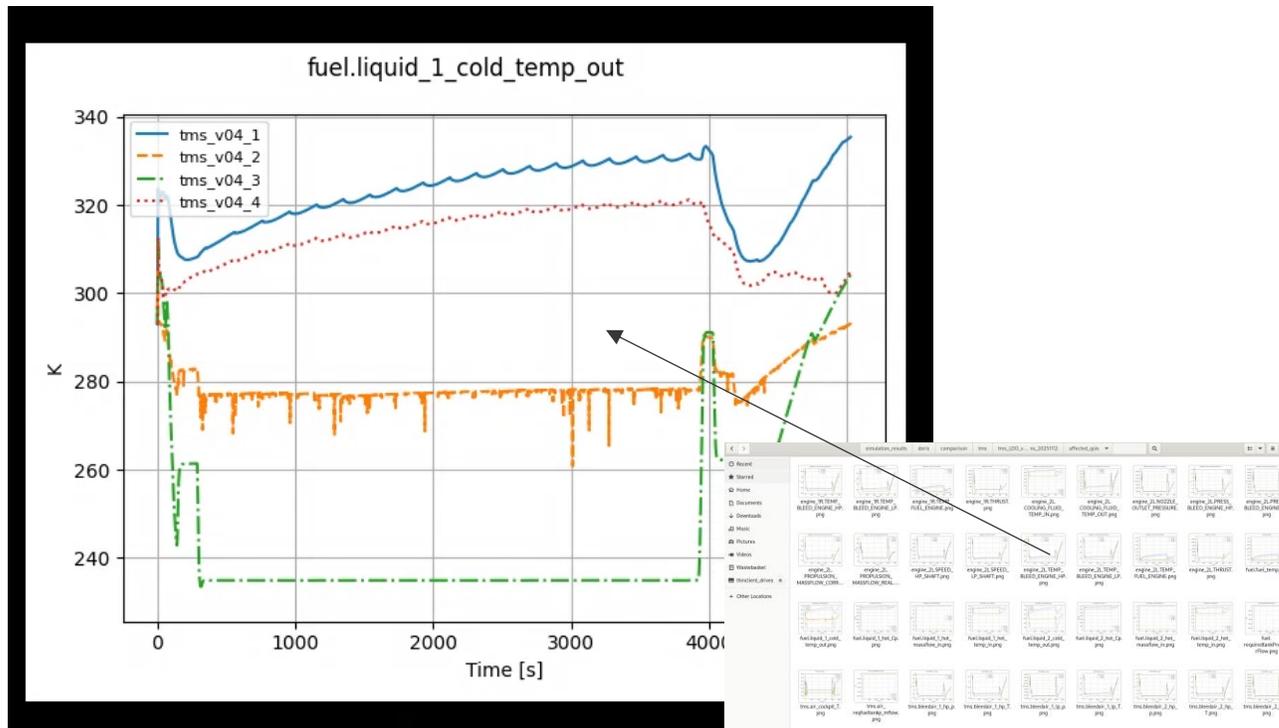
Import and simulate in tool of choice

Thermal Management System (TMS) Teaser:Results

- Composite model simulation results generated using
  - OMSimulator
  - DORIS
  - Desmo

Outcomes and Status

- Model-based collaboration (intra and cross organizational/national) established in novel ways for the community in focus

- Model based analysis, from aircraft to component level, iteratively conducted

- Improved or novel support of standards in relevant tools established or refined (Catia Magic/Cameo, Desmo, OMSimulator, Modelon Impact).

- Requirements on future standard versions communicated (FMI, SSP, SSP LS-Traceability)

- Application of novel/refined Modelica modeling libraries such as
  - Thermo Fluid Stream
  - Jet Propulsion Library

Acknowledgements

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the European Union

Questions?

Kristian Amadori and Robert Hällqvist

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