Digitalization in the development process of Aeronautic products: from drawing boards to development virtual platform along the Product Lifecycle from Concept to Certification

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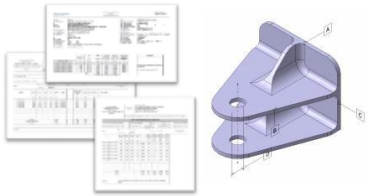
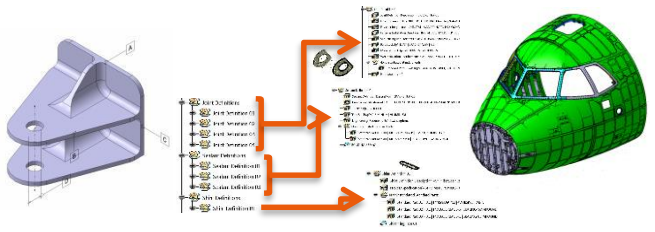
Evolution of Engineering Functional Model in Aerospace

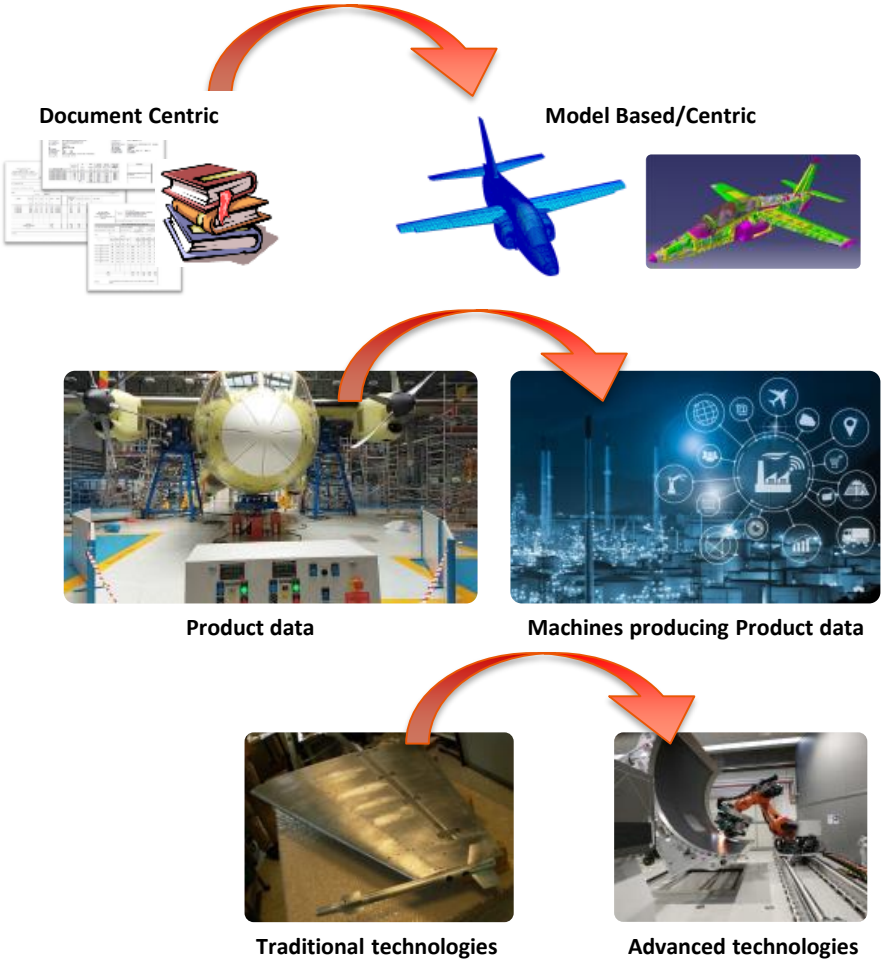
Single source of truth
Digital Thread

	2D DWG/Document	2D/Document vs 3D Model	3D Model
			
Description	• EBOM-MBOM separated lagacy configuration systems • DWG/Doc based configuration • DWG/Doc authority supported by 2D CAD model E-BOM → M-BOM	• PLM EBOM-MBOM separated configuration system • DWG-PN/Doc based configuration • DWG/Doc authority supported by 3D CAD model E-BOM → M-BOM	• PLM EBOM & MBOM full collaboration configuration system • PN based configuration • 3D Model authority • Configured DMU • Partner/Supplier controlled access E-BOM & M-BOM Collaboration PLM
YEARS	1980-1990	2000-2010	2010-Today

Evolution of Engineering Functional Model in Aerospace

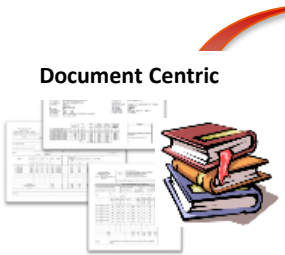
From decades of experience to time now

- Step change in digital/simulation
  - Traceability
  - Easy of changes
- Machine-data based decision
  - Diagnosis
  - Product oriented
- Skills and technological progress
  - Innovation
  - Competitiveness



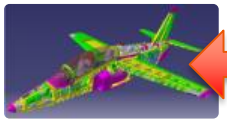
Steps forward

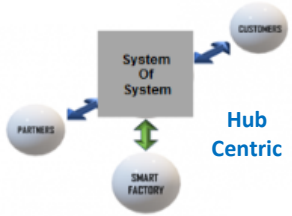
- Model-Based System Hub
  - Interoperability
  - Common Environment
- Data-interaction based decision
  - Predictions
  - Process oriented
- Technological Integration
  - Multi-Functional
  - Synergy



Document Centric

Model Based/Centric





Hub Centric

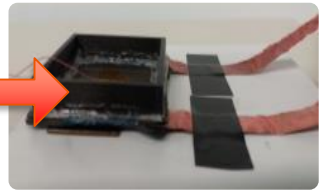
Product data

Machines producing Product data

Product data interaction

Traditional technologies

Advanced technologies



Multi-functional advanced technologies

Mixed/Augmented Reality Manufacturing

Digital Transformation journey

The overall **Digital Transformation journey** of the company has various fields of application that are related and dependent to each other, such as:

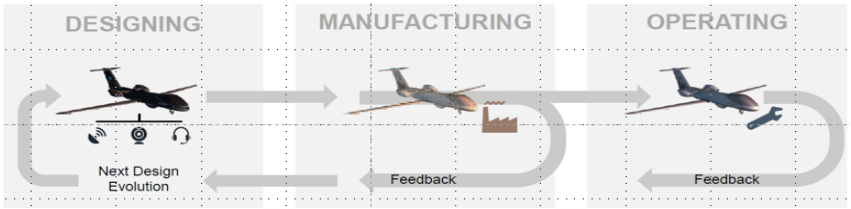
- **Digitalization of Data and Information**
- **Digitalization of Management Processes**
- **Digitalization of Technical disciplinary Processes**
- **Digitalization of Collaboration network**

Digital Engineering conceive and deliver the new applications with the aim:

- To encompass the methodologies, tools, and process of creating new digital products end to end
- To leverage **data and technology** to produce improvements to product development and applications
- To harnesses modern digital capabilities to improve an organization's efficiency and value, enhance process sequences and/or transform end-user experiences.

Objectives:

- **Reduce Time to Market**
- **Improve Customer Satisfaction**
- **Minimize rework in development, production and in service phase**



Aeronautic System Peculiarities

Aeronautic Products have peculiarities that characterize the design environment:

- High level of technology with small series
- Functional Complexity
- Airworthiness and Safety
- Use of leading-edge technologies and materials
- Very long life-cycle (> 30 years) and long definition/development phases
  - ~ 7 years from concept to first delivery for commercial aircraft (e.g. A-380, B-787)
  - ~ 15 years from concept to delivery for Advanced Jet (e.g. Eurofighter Typhoon)

The design phases of a modern aircraft involves thousands of designers (in a Extended/Virtual enterprise environment) for several years.

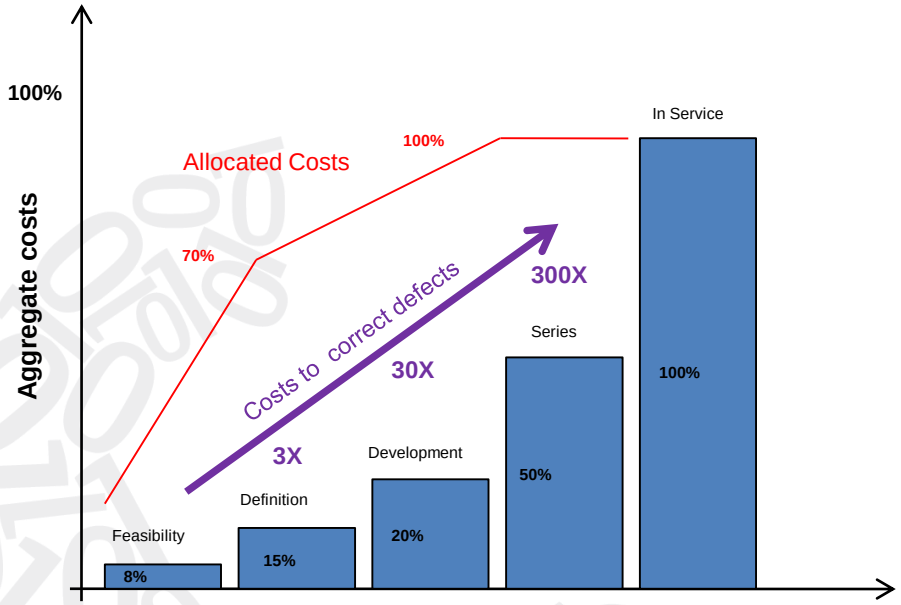
From CAD perspective the numbers on designed P/N (non standard parts)

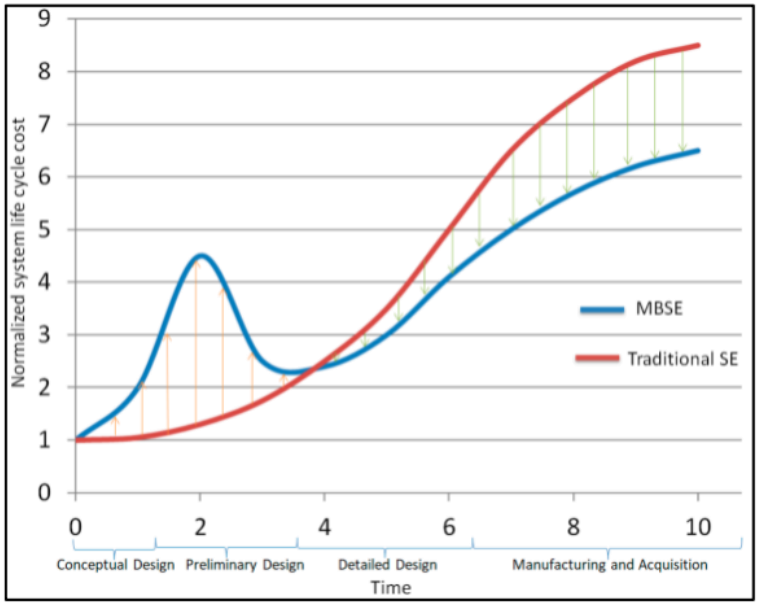
- Modern Fighter Jet: 70000 P/N
- Medium Military Transport: 50000 P/N,
- Trainer: 8000 P/N
- Advanced Trainer: 12000 P/N
- Special Mission Delta mod on civil aircraft: 15000 P/N

From CAE perspective

- CFD → 10 Terabyte for Aerodynamic database (Wet surfaces and Air Intake)
- CFD → 3-4 Terabyte on general systems studies (e.g. ECS and Fuel Sytems)
- Parametric Models for each Major System (12-20) some Gigabyte each (evolutive systems to be managed)

SE Costs along life-cycle phases



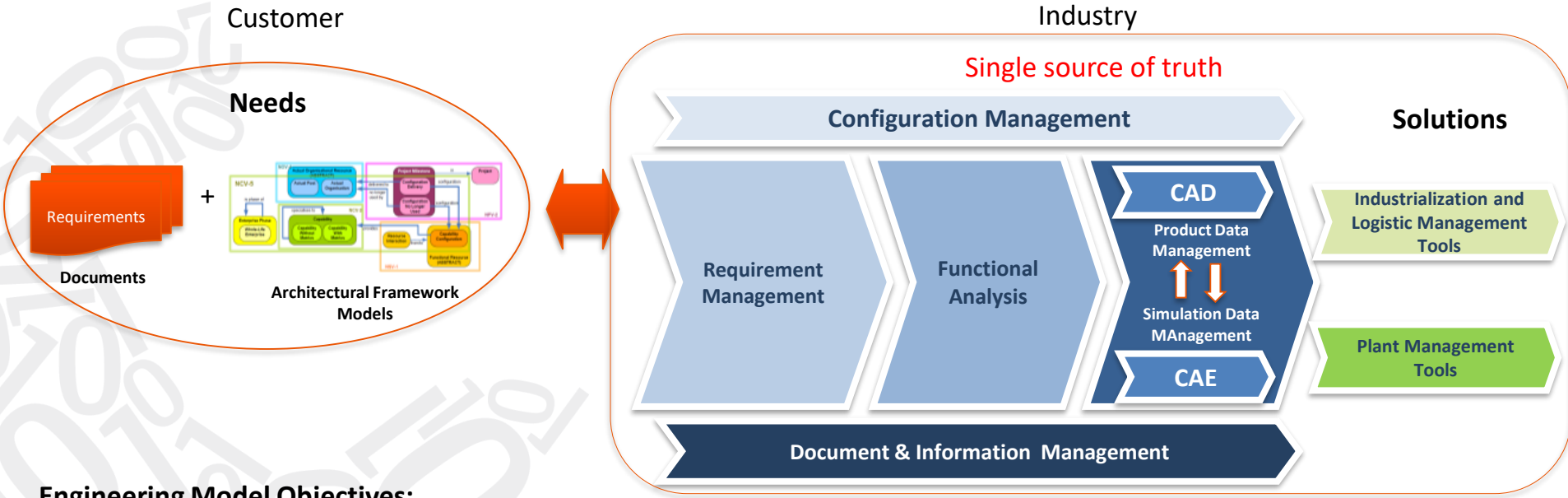


While early phases are relatively inexpensive if related with latest ones, the choices done in these early phases allocate most costs of the product over its complete life-cycle. Changing the project/product for any reason (requirement change or correcting defects) in the advanced phases become exceptionally costly as long as the project advance.

Setting up a robust MBSE and MBE along the early phases of the product life-cycle by mean of virtual simulation and testing technologies enables a faster convergence to a mature project (*right the first time)* and reduces the costs of qualification and certification.

Digital Transformation: Engineering Functional Model

The Aerospace Business Process in a context of Extended Eco-System (multiple Customers and Industries, but also Research Centres, Academia and other stakeholders) is challenging. While ensuring data continuity and traceability, Industry shall manage the increased complexity of the Extended Eco-System with Multi-disciplinary Models and Digital Twin.



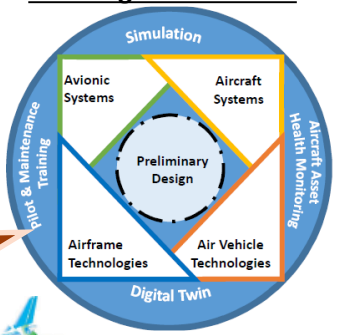
Engineering Model Objectives:

- Data, tools and process digitalization/integration
- To configure all Simulation and CAE data to the product structure

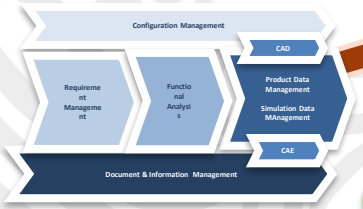
From Engineering Functional Model to Common Working Environment

- **Modelling of Complete Product Architecture -> fully multidisciplinary logical and behavioral framework**
- **Open System Architecture Integrating higher fidelity models home made and COTS based in an Extended Enterprise context**
- **Early Phases Product/Project Simulations and Prototyping**
- **Model Based Architecture optimization**
- **Virtual Integration Testing prior to physical V&V tests at its full extent**
- **CWE as Single Source of Truth for Design, Manufacturing and Customer Support Engineering**

Common Working Environment



Engineering Functional Model



Preliminary Design Model

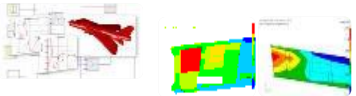
Functional Model

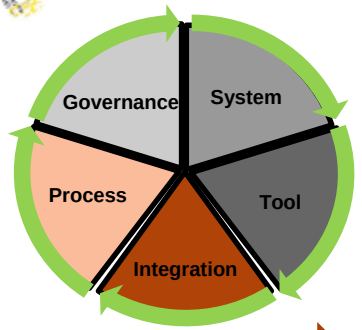
Mathematical Model

Multidisciplinary Model

Industrialization Model

MBSE / AGILE / Digital Twin





2022 on

Evolving System Engineering approach: Single product V-Diagram

Strategic

Concept

Definition

Development

Manufacture

In Service

Replacement

Operative and Logistic Scenario Models

Feasibility

Concept of operations

System Validation Plan

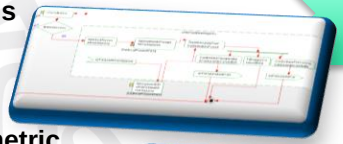
System Validation

Logical/Functional models

System Requirements

System Verification Plan

System Verification & Deployment

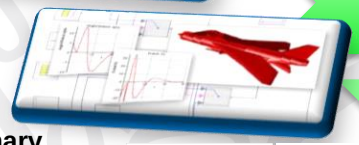


Parametric Models

High Level Design

SubSystem Verification Plan

Subsystem Verification

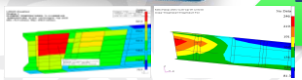


Multi-disciplinary Model Analysis

Detailed Design

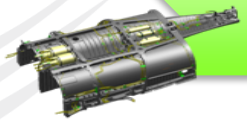
Element Test Plan

Element Testing



CAD/CAM Models

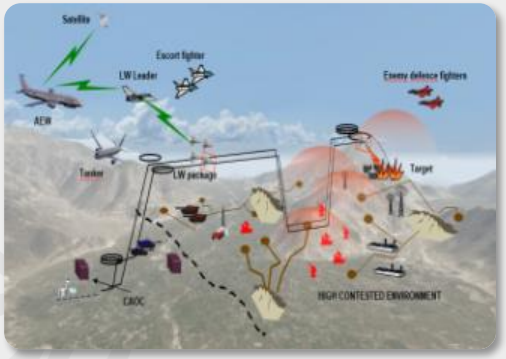
SW/HD Development



System Manufacturing

Operation & Maintenence

System of Systems Concept



- SoS components with specific roles and configuration (sensors, communications, weapons, etc.) plus cooperative systems
- Multi assets, both manned and unmanned in the context of next-generation scenarios
- High Level of Autonomy as enabling factor
- Force multipliers by Collaborative teaming & Cooperation modes
- Distributed network to improve shared situational awareness and scenario management
- Trusted communications point to point links
- Multiple mission and scenarios including future challenged environment
- Tasks distribution with mission re-planning capabilities

The Design of a System of system has to deal with several aspects that multiply the its complexity:

- **All the nodes of the SoS can operate independently**
- **All the nodes have different Life cycles and obsolescence rates**
- **Either for the SoS and for each node the needs and requirements can change during the life cycle**
- **Complexity: the level of complexity is exponentially related to the number of nodes**

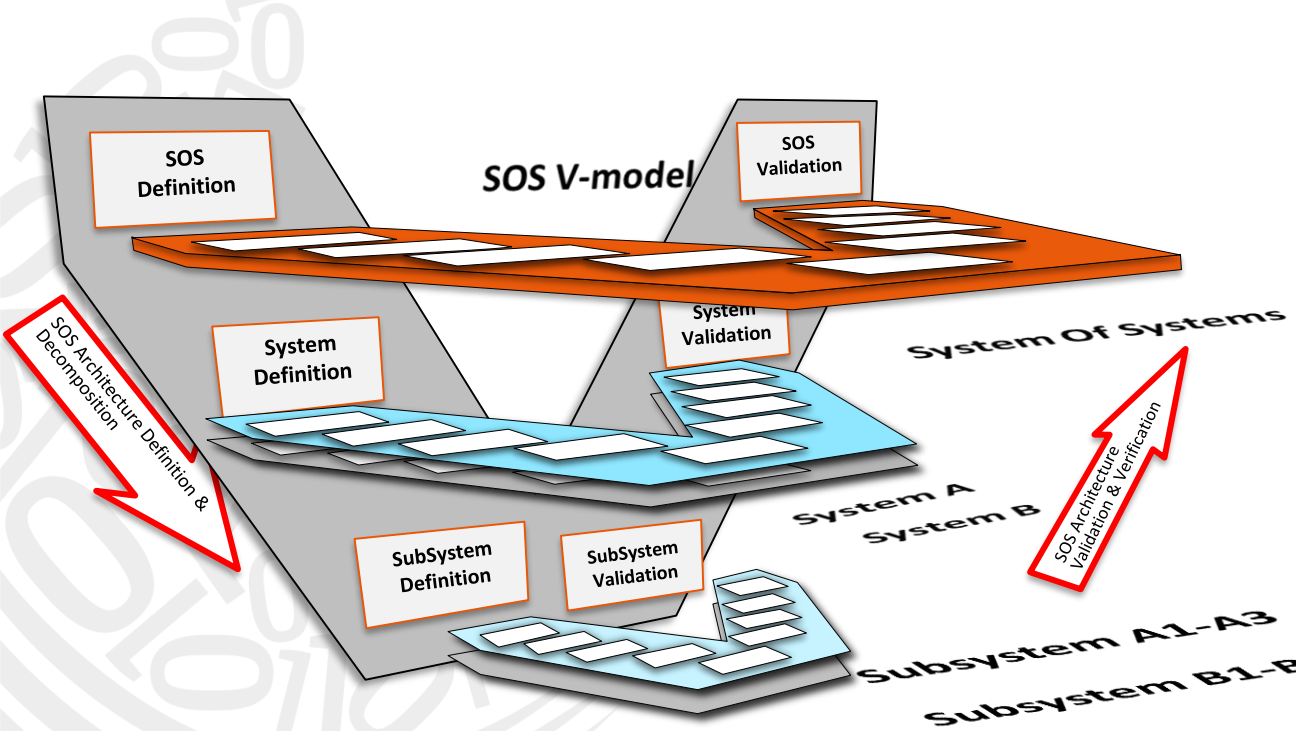
Real / virtual manned/ unmanned assets
operating in advanced scenarios: manned/unmanned and unmanned/unmanned teaming

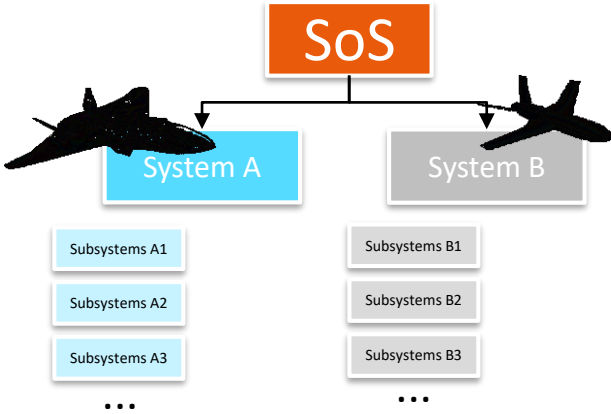
Powered mock-up
Digital twin complemented with a powerful decision support HMI to mature MuM-T concept

Advanced environment monitoring System
of Systems based on multiple RPAS

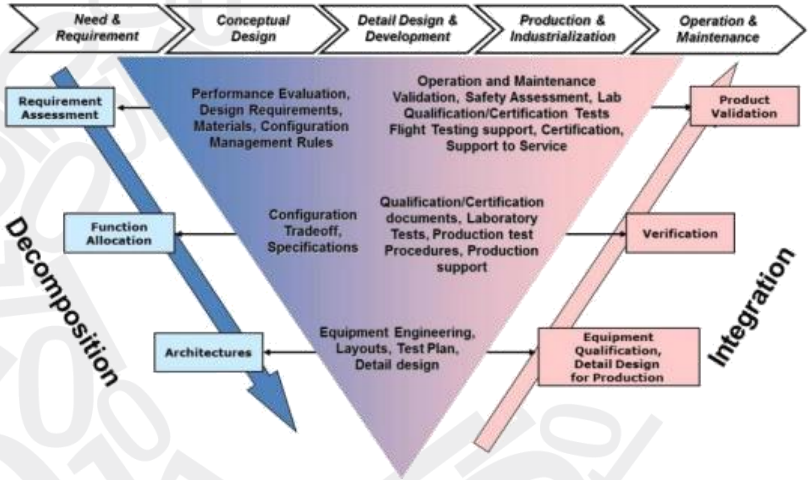
Evolving System Engineering approach: SoS V-Diagram

Implement robust System Engineering process across the SoS definition, design, validation and in service support leveraging competence matured across 50+ years of air combat system design, manufacturing and in service support

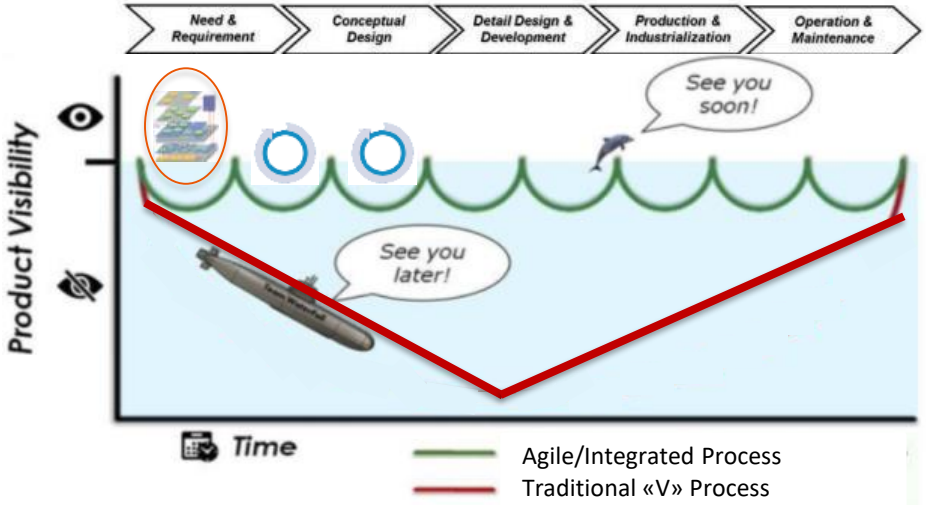




Evolving System Engineering approach: V-Diagram vs Agile Diagram



From “V” Diagram



To “Agile” Diagram

Digital Transformation: Simulation from design to training

Flight Simulator to support configuration changes, in particular in the development, verification and upgrade the FCS control laws

New generation Flight Simulators

Real cockpit in a fully virtual environment
Design / Training

Advanced Interactive HMI

Collaboration Scenarios in an Extended/Virtual Enterprise

In Aerospace and Defence the "product" complexity is so high that sharing resources/risks in an international Extended/Virtual enterprise is mandatory. This scenario brings issues to be managed:

- Shared Processes Agreement
- Design Authority boundaries
- IPR protection
- Different National Laws (e.g. Infosec)
- License usage agreement on Common Working Environment
- Interfaces between Common and Local environment (Legacy)
- Involvement of widespread supply chain
- Involvement of standardization bodies to support federated architectures.

A synergic collaboration between the industry and the tool vendors and the usage of standard protocols are essential to minimise the cost of the set up of the extended/virtual enterprise environment.