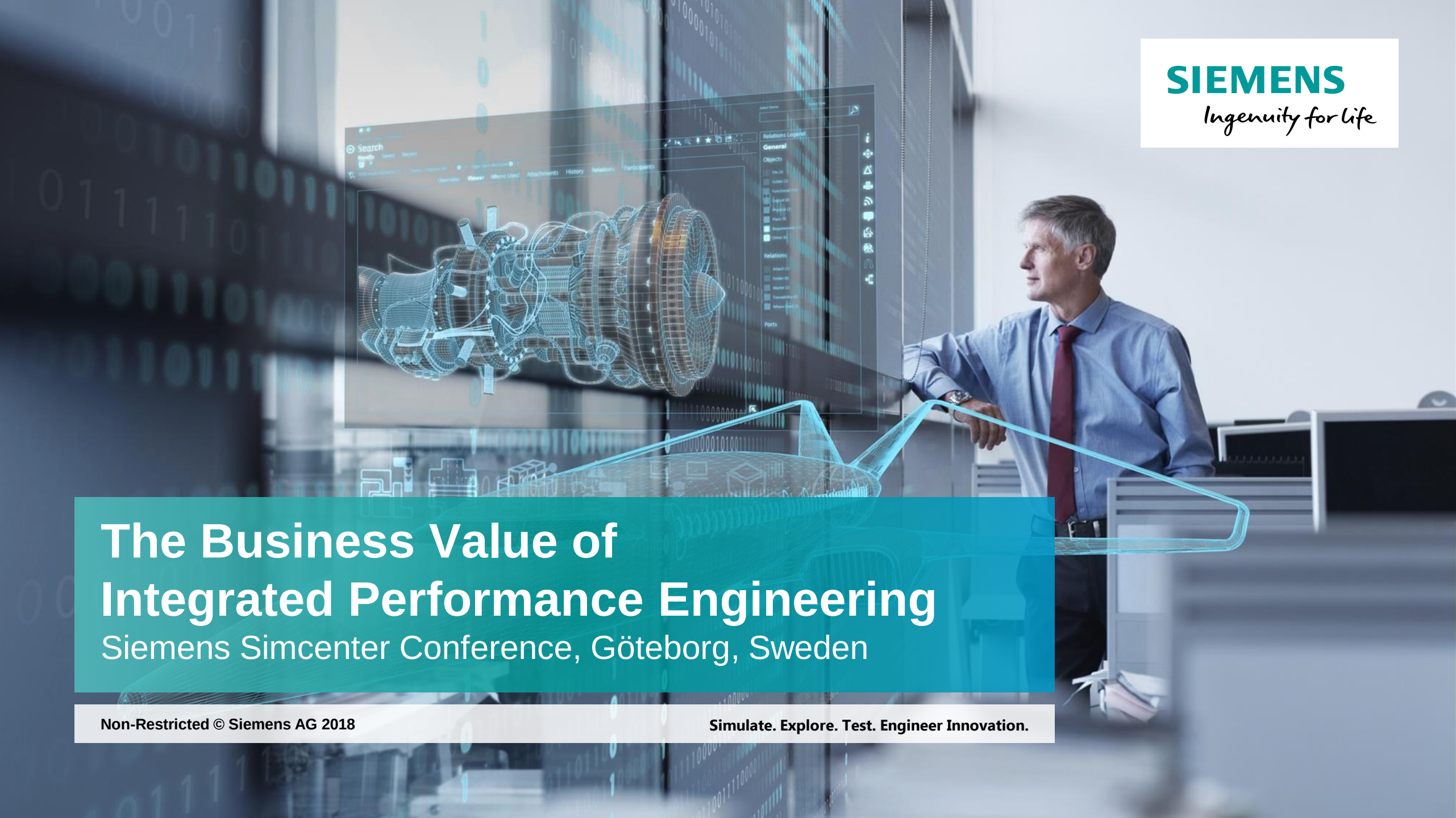

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The Business Value of Integrated Performance Engineering

Siemens Simcenter Conference, Göteborg, Sweden

Agenda

Copyright Airbus

Trends & Challenges - Complexity

Breaking Silo's - Performance Engineering

Business Value examples - Aircraft Program

Discussion

Agenda

Copyright Airbus

Trends & Challenges - Complexity

Breaking Silo’s - Performance Engineering

Business Value examples - Aircraft Program

Discussion

In the meantime in aviation industry…
… compete each other to boredom!

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The aviation industry needs Disruptive Technologies

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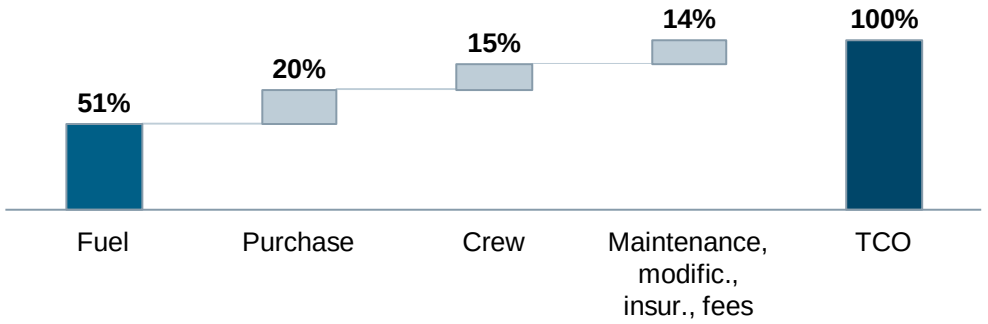
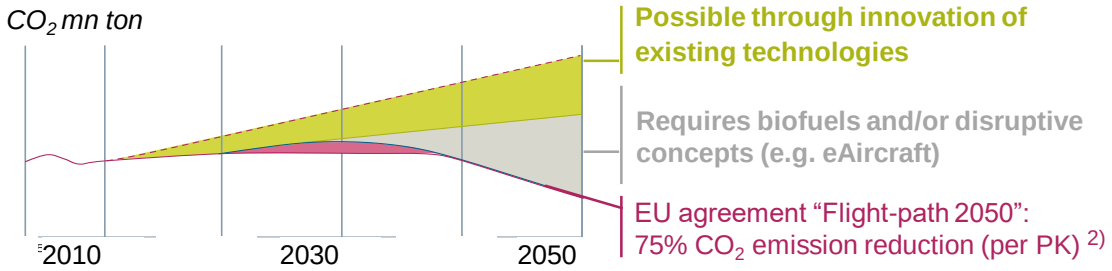
1. Reduction of fuel consumption: main lever to reduce aircraft TCO (example 737-800)



2. Projected emission goals: can only be reached with disruptive concepts [1)]



3. Customer perspective: extension of potential operating hours through noise reduction

Aviation Industry in need of New Disruptive Concepts
eg. Hybrid-Electrical Propulsion, New Business Models, …

1) IATA technology roadmap, June 2013

Integrated Aircraft Performance

A/C development will undergo paradigm shifts

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Product Complexity Increases

Innovative Aerodynamic, Systems and Structural Architectures

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Current

Future (+30 Yrs)

- New Aerodynamic Architecture
- New Propulsion Architecture
- New Structural Architecture
- New Systems Architecture
- New Passenger Experience
- New Business Models

The Cost of Status Quo

Inability to adapt results in poor financial and program performance

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The danger on-board the Boeing 747-8

JULY 19, 2015 2:21PM

BOEING'S shiny new 747-8 planes have a potentially dangerous problem.

The aircraft are at risk of "divergent flutter", a rapid and erratic vibration that could cause the wing to break up.

FlightGlobal
Pioneering Aviation Insight

NEWS & INSIGHT | PRODUCTS AND SERVICES | ABOUT

NEWS > MANUFACTURER & MRO > AIRCRAFT PROGRAMMES > MRJ CERTIFICATION REQUIRES EXTRA HOURS, MORE JETS

MRJ certification requires extra hours, more jets

26 APRIL, 2017 | SOURCE: FLIGHT DASHBOARD | BY: MAVIS TOH | NAGOYA

Mitsubishi Aircraft is reviewing the MRJ regional jet's flight test plans, and estimates that the programme will now require around 500 extra flight hours and up to two additional aircraft to achieve certification.

Irkut MC-21 missing ultimate load test

By Bjorn Fehrm DOWNLOAD

April 05, 2017, ©. Leeham Co: United Aircraft's IRKUT MC-21 passed 90% of the static Ultimate load test end February at the TsAGI test institute in Moscow, reports ATO.RU. But the aircraft failed the 100% test.

Airbus Profit Dives on Problems With A400M Military Jet

New costs for the long-troubled Airbus A400M military jet sent the European plane maker's profit commercial aircraft deliveries.

The Associated Press

FILE - This Thursday, June 20, 2013, file photo shows an Airbus A400M performing its demonstration flight during the Paris, France. Surprise new costs for the long-troubled Airbus A400M military jet sent the European planemaker's pro aircraft deliveries, Airbus reported Wednesday Feb. 22, 2017. (AP Photo/Francois Mori, File) The Associated Press

AP

By ANGELA CHARLTON, Associated Press

PARIS (AP) — Surprise new costs for the long-troubled Airbus A400M military jet sent the European plane maker's p company's financial prospects through next year, even as it forecast a rise in aircraft deliveries and demand.

Schedule & Cost Overrun

Underperforming Aircraft

Agenda

Copyright Airbus

Trends & Challenges - Complexity

Breaking Silo's - Performance Engineering

Business Value examples - Aircraft Program

Discussion

Agenda

Copyright Airbus

Trends & Challenges - Complexity

Breaking Silo's - Performance Engineering

- Domain Silo's
- Methods & Tools Silo's
- Process Silo's

What does HEAT the Aircraft?

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Passengers
50-100W/pax
300-500 pax
30 kW

Environment
Sun Radiation
Hot Air

Environmental Control
Air Cycle Machines

Acuators
Electro Mechanical
Electro Hydro-static

Avionic Systems
ELEC
Power Distribution
Avionics

Landing Gear
Aircraft Braking
Rejected Take-Off (RTO)

Engine Integration
Ventilation Air
Radiation
Lubrication System
Bleed Air

THO

What does COOL the Aircraft?

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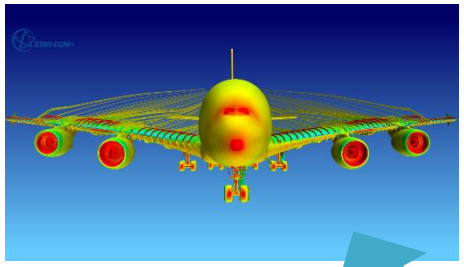
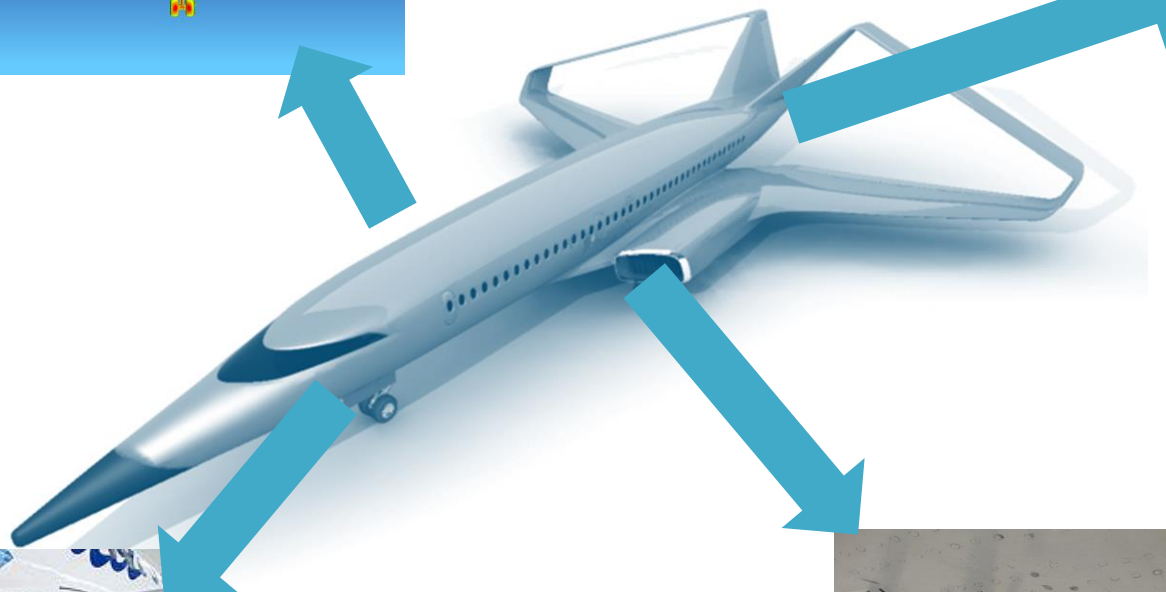
Environment
Convection
Through Structures
Through Heat Exchangers



Environment
Radiation



Environmental Control
Air Cycle Machines
Cabin Ventilation
Avionics Cooling
Heat over-board dump

FUEL system
Fuel capacity as
Heat Sink

THO

Organisational Challenge

… who does “Engineer” the Thermal Aircraft?

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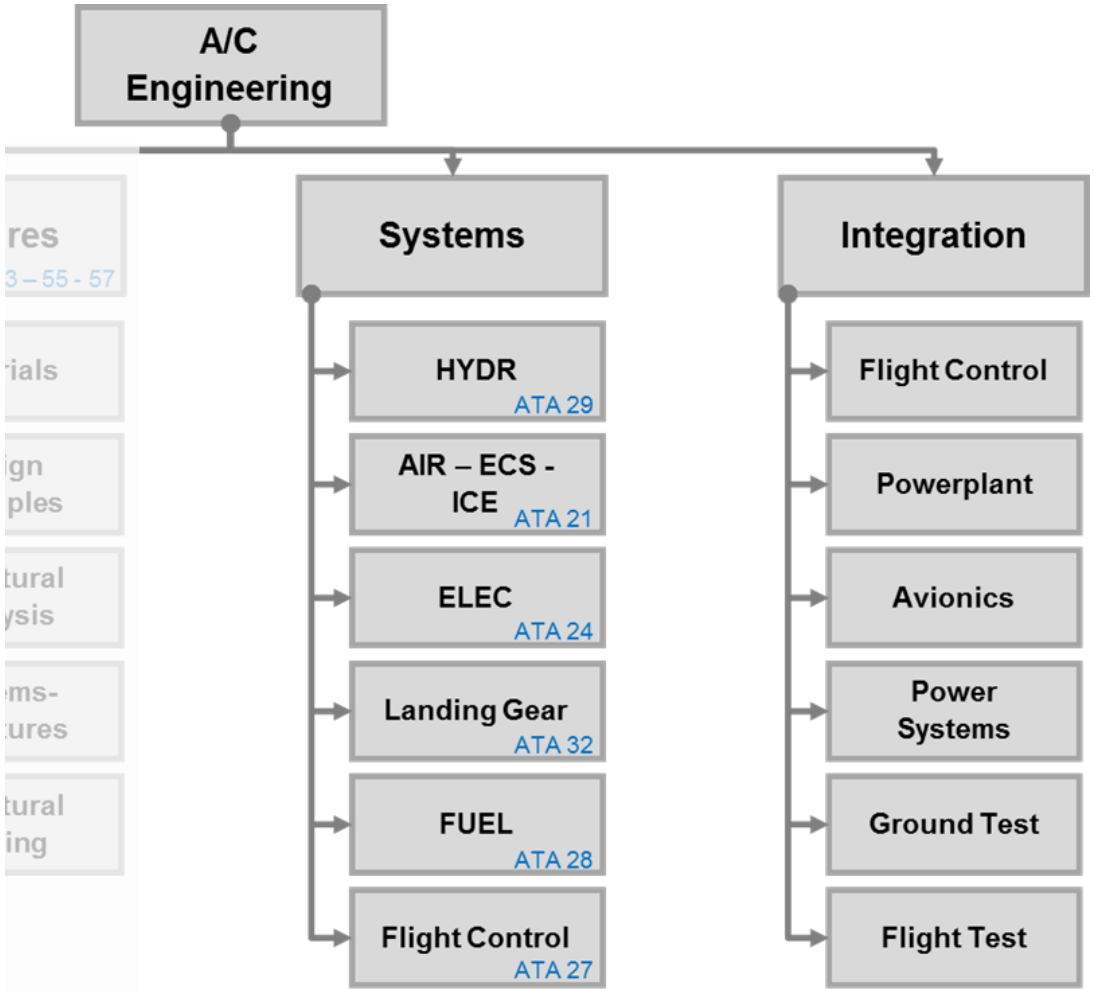

The Systems Organisation typically work as Silo’s.
Each System Dept. Uses different Tools.

Thermal / Energetic Synthesis Fails.

THO

Virtual Integrated Aircraft (VIA)

Enabling aircraft thermal & energy balance analysis

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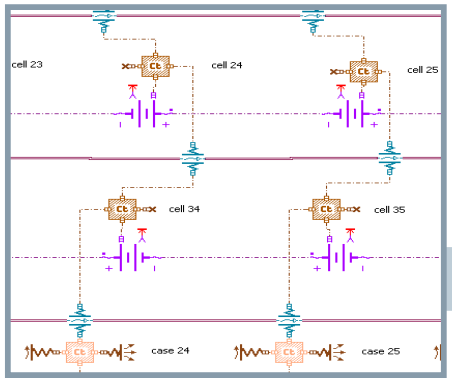
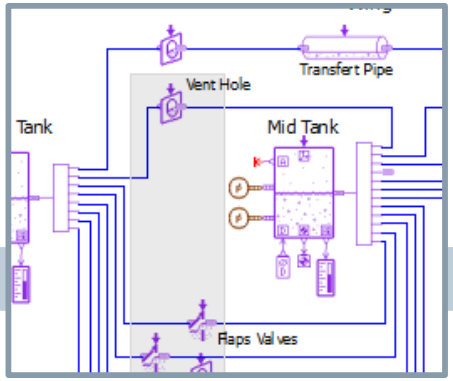
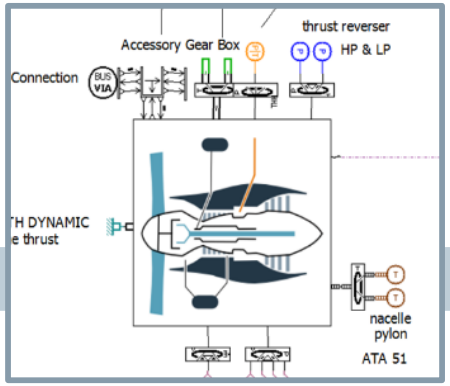
Ingenuity for life



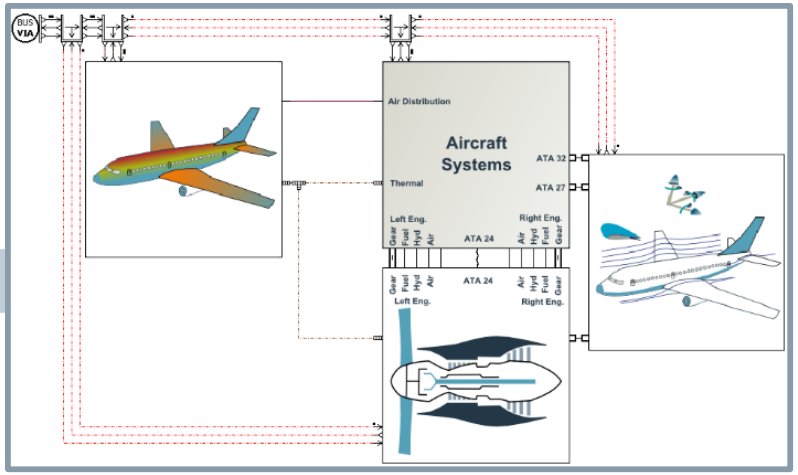
Electric



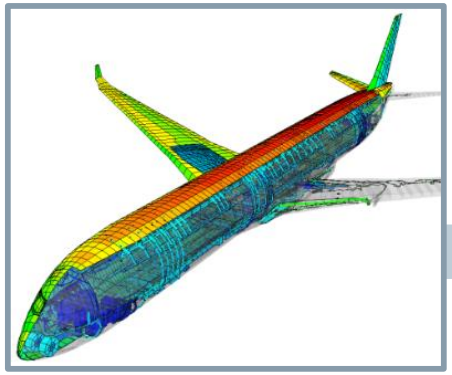
Fuel



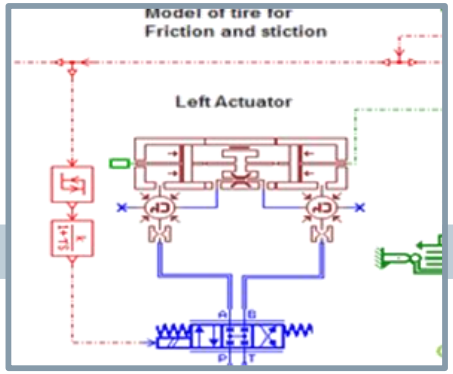
Propulsion



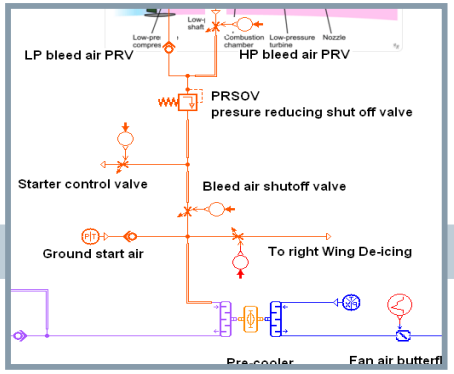
Virtual Integrated Aircraft - VIA



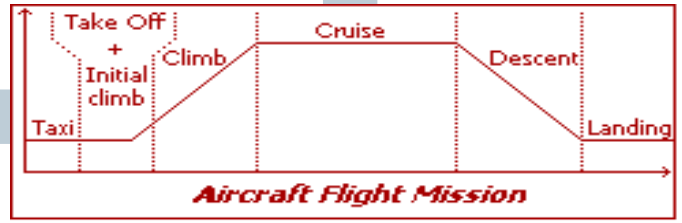
Structural-Thermal



Hydraulic



Pneumatic



Mission & Environment

EC – Project TOICA
NSR 2030+ Trade-Off studies

TOICA
Thermal Overall Integrated Concept Aircraft

Scalable Physical representation of Engineering models
from Conceptual till Very Detailed

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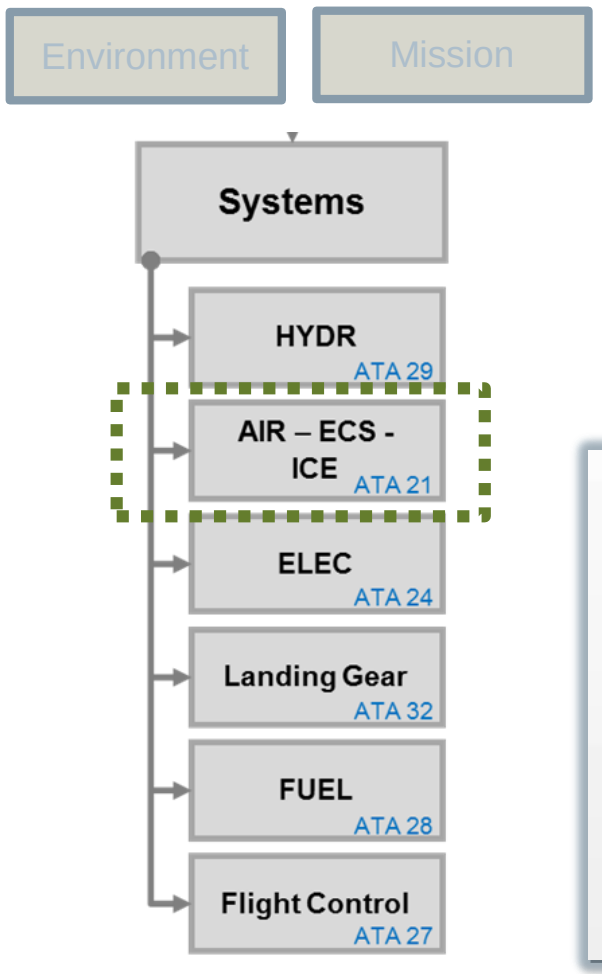

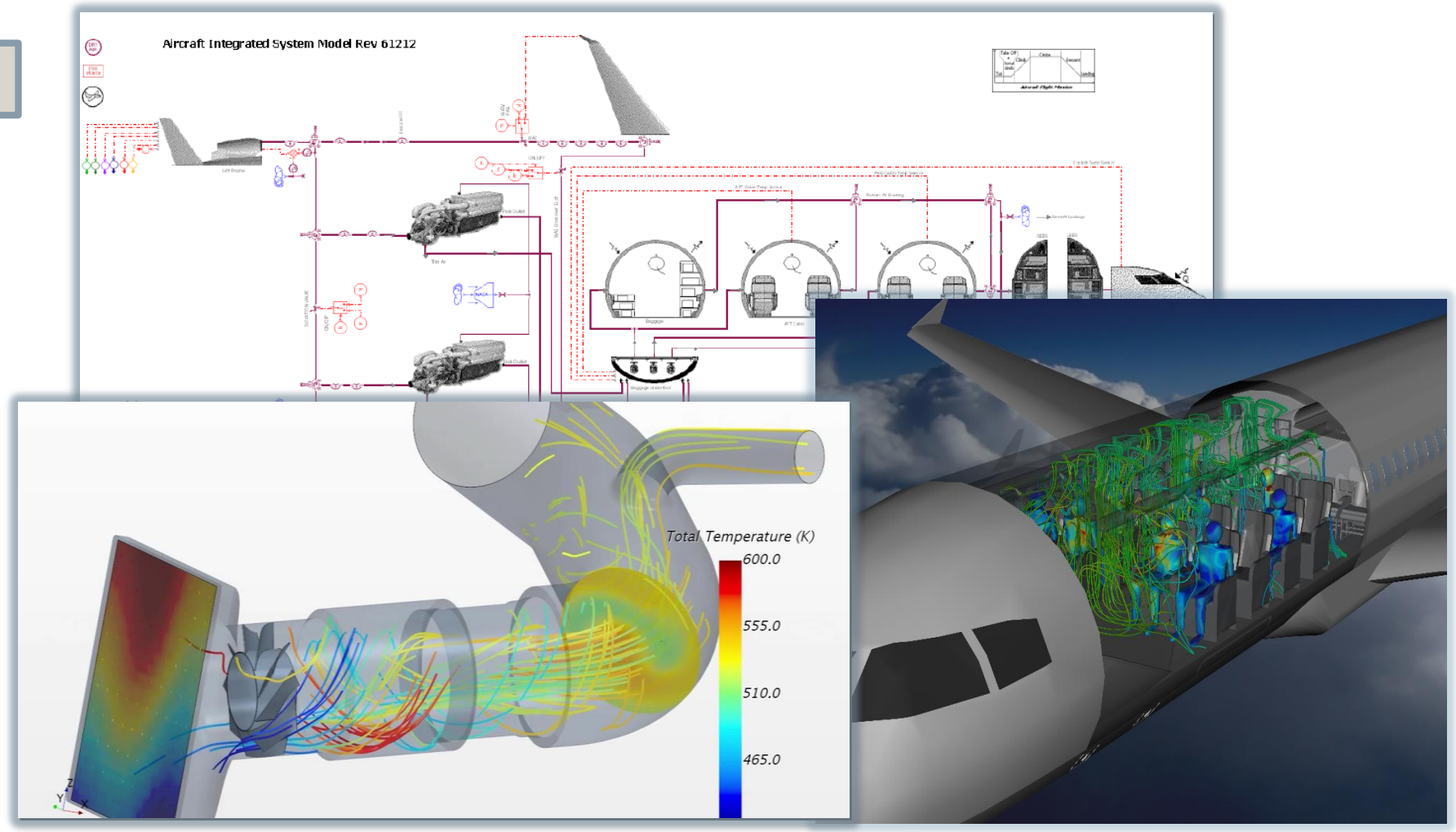

Scalable Physical representation of Engineering models
from Component Level till Integrated System Level

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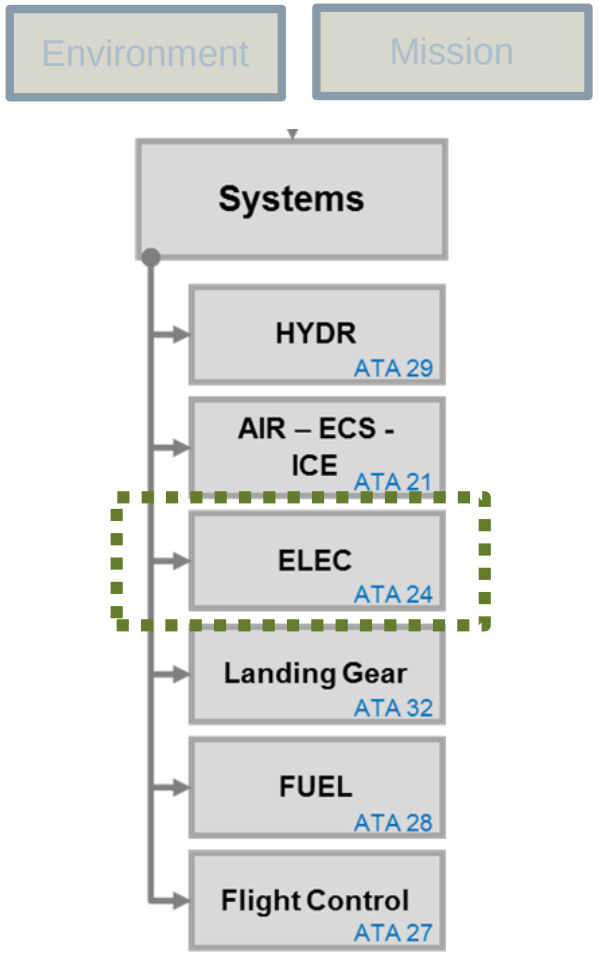

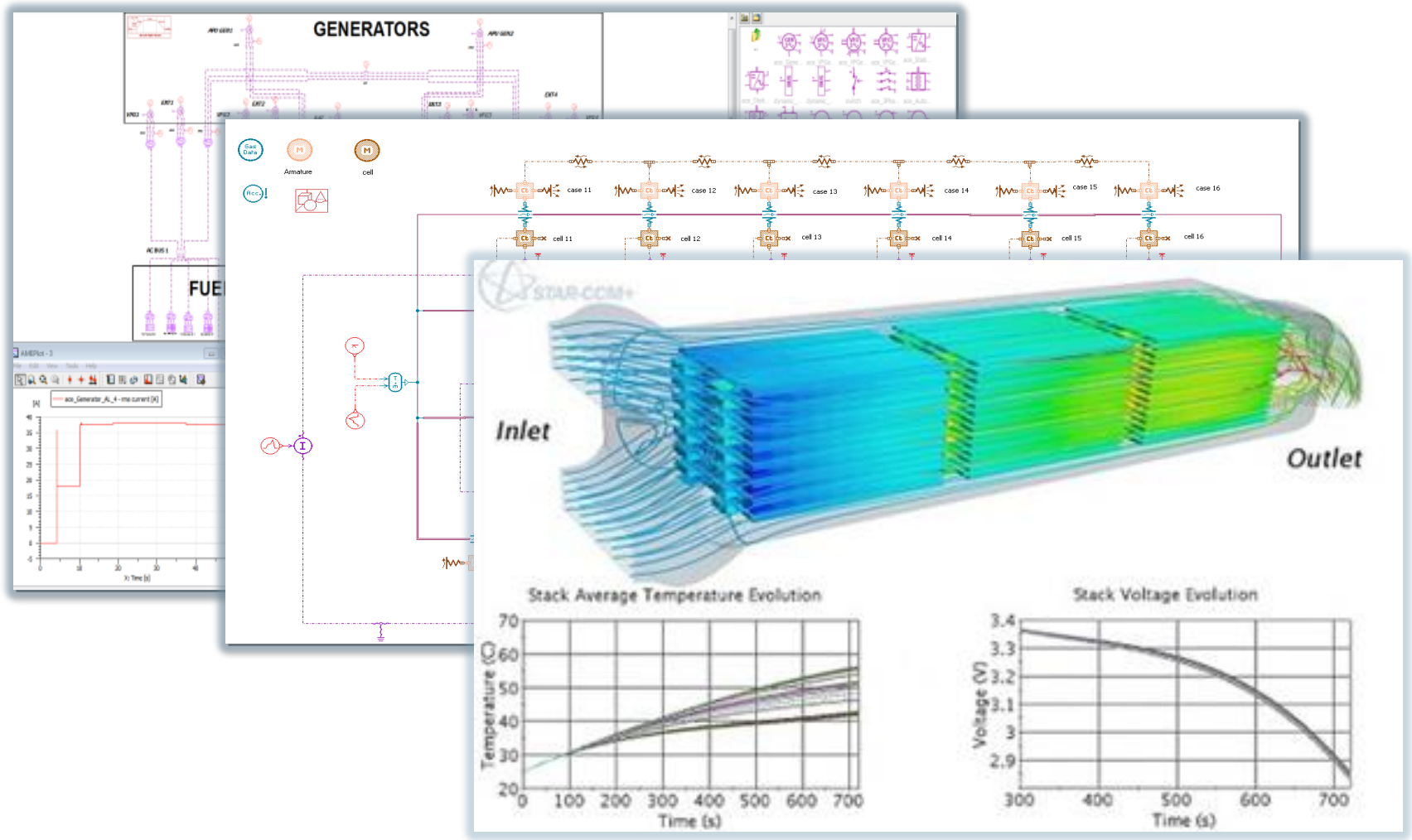

Digital continuity to verification and integration testing

"Shift Left" through virtualization of iron bird

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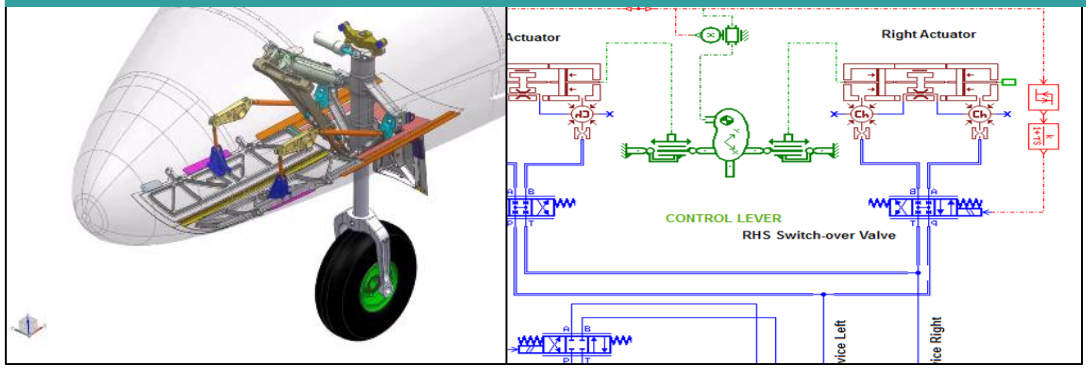
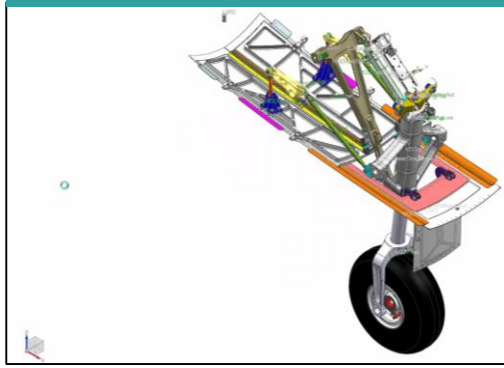
System Development Models



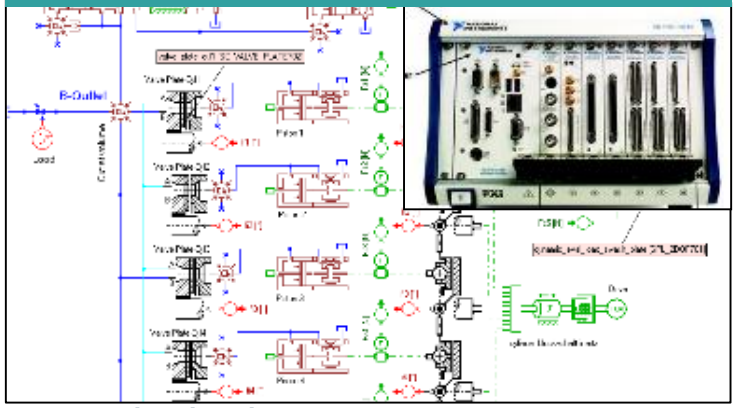
System Verification Models



Real-Time
MiL – SiL – HiL
Sub-system Benches
Pilot-in-the-Loop

⇩ FF -3 Year | ⇩ FF -1 Year | ⇩ First Flight | Certification ⇩

Virtual Iron Bird



(Physical) Iron Bird

Flight Testing

Innovating airframe structural architecture…

Digital Thread - loads - structures - manufacturing

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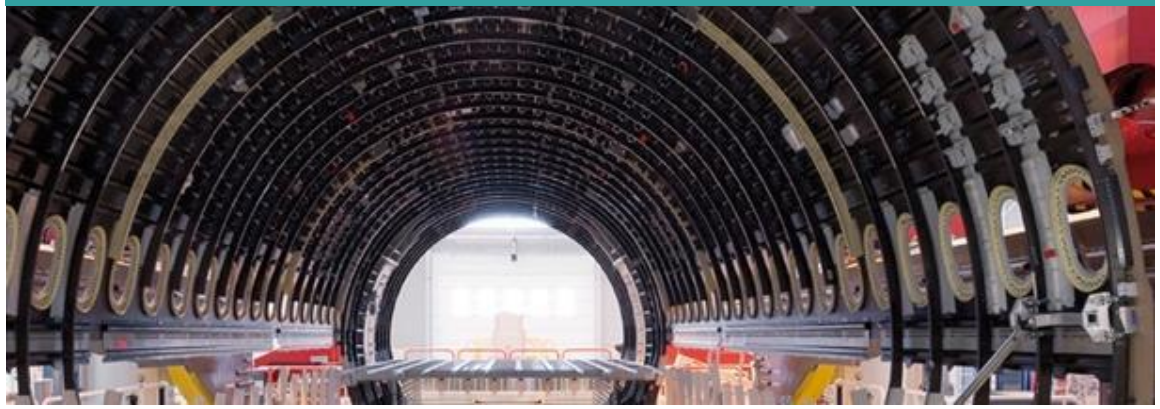
Today



Flight physics | Structures | Manufacturing

Tomorrow

Flight physics | Structures | Manufacturing

Digital Thread

Digital Thread for Loads, Structures and Manufacturing Engineering

Simcenter connections to A&D Value Streams
Aircraft Design & Engineering – (Advanced) Structures

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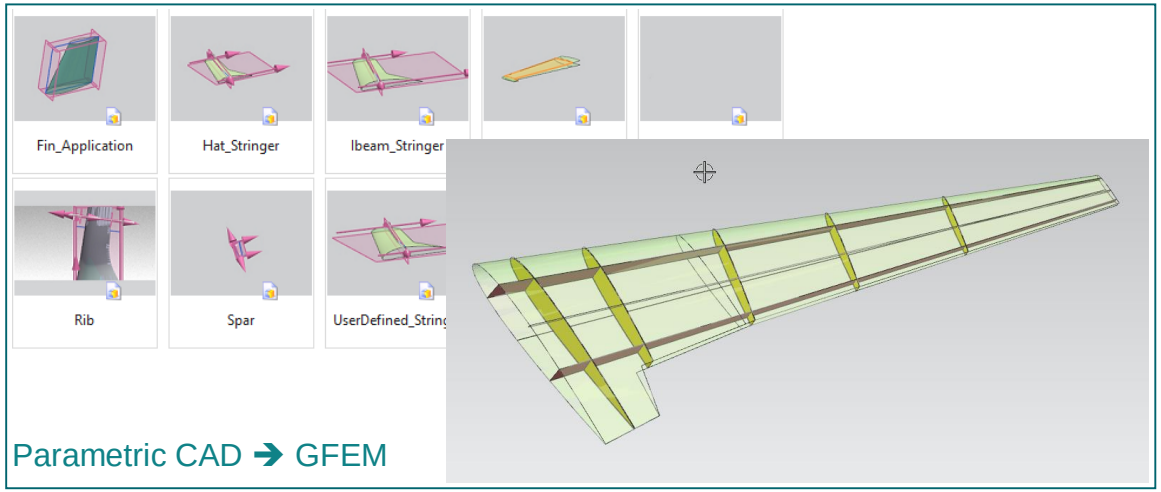
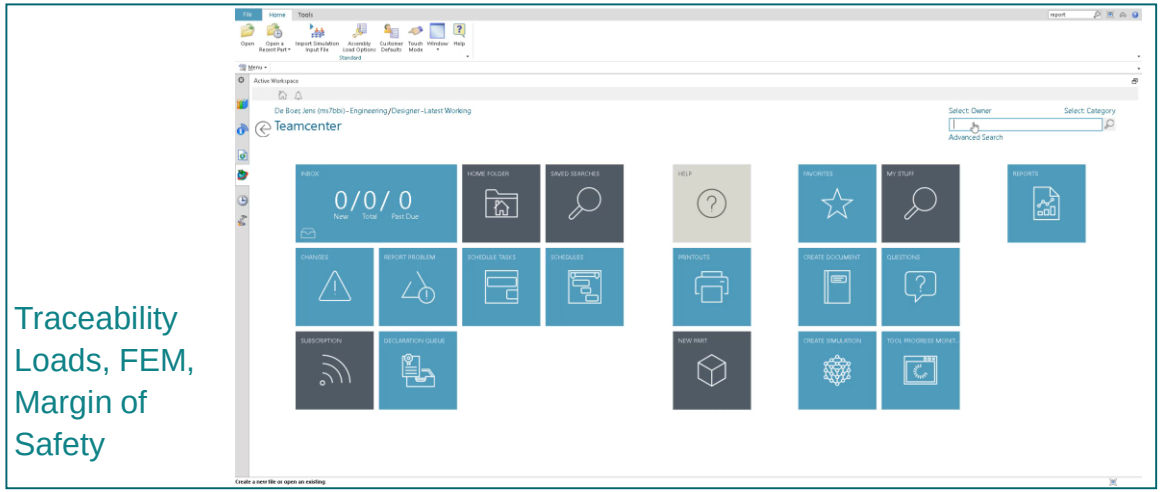
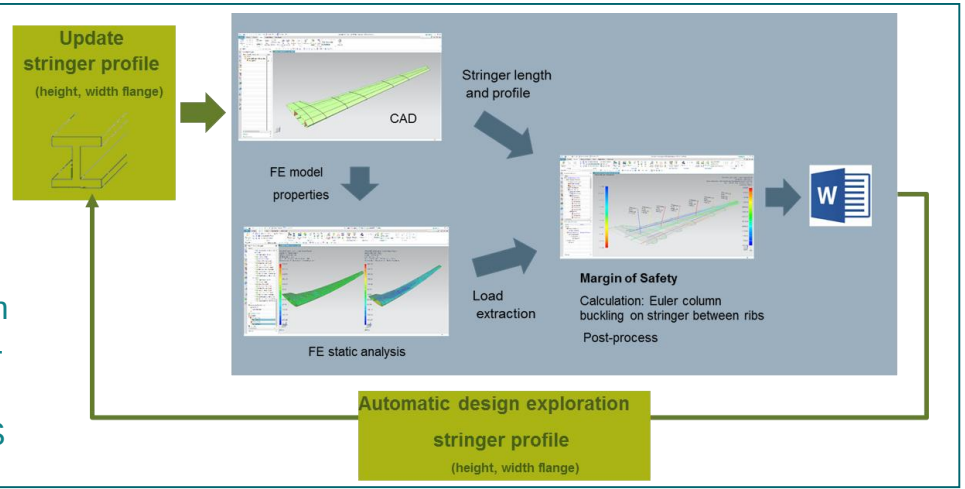
Ingenuity for life



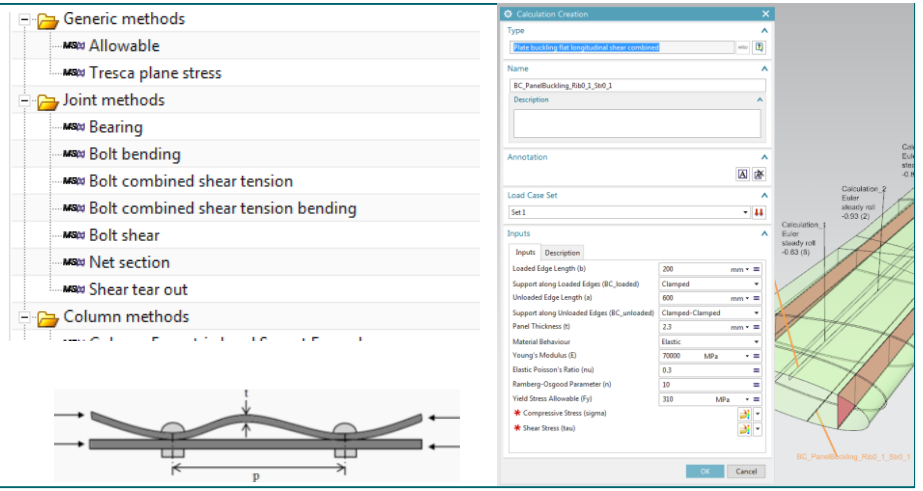
Parametric CAD ➔ GFEM



Traceability Loads, FEM, Margin of Safety



Optimization over GFEM-DFEM-MoS with HEEDS



MoS methods integrated in NX/SC Associative & traceable!

Integration, Verification & Certification

Verification – contributor to Poor Program Performance

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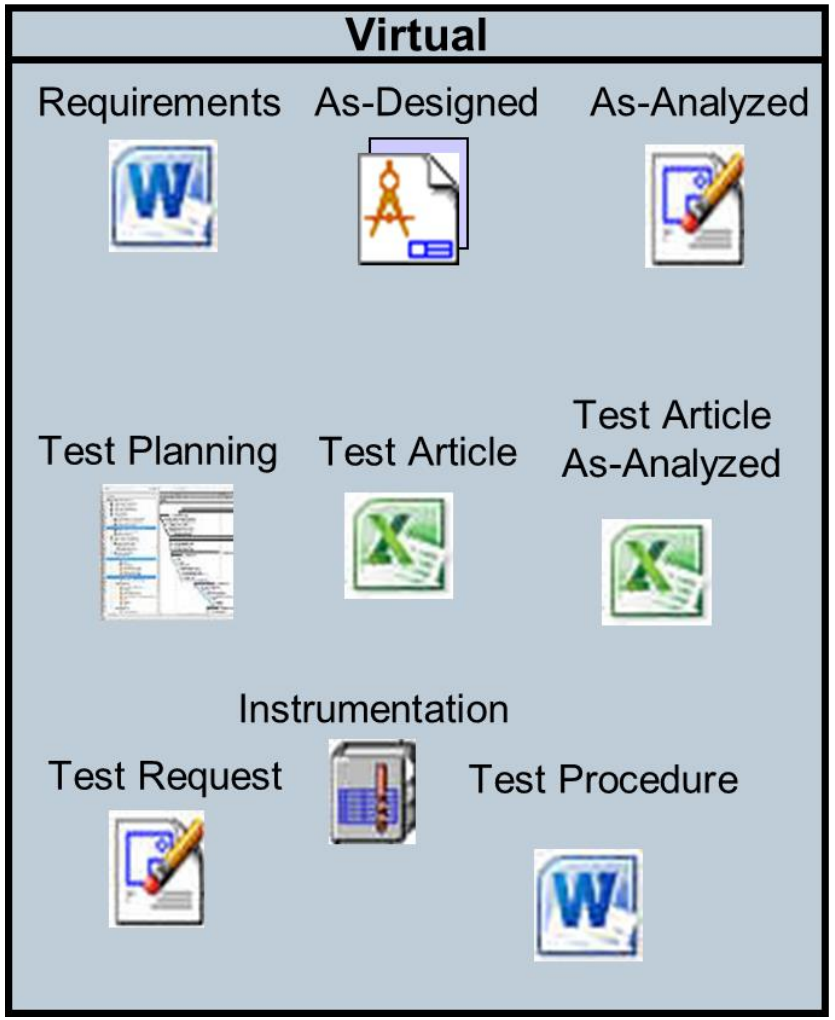

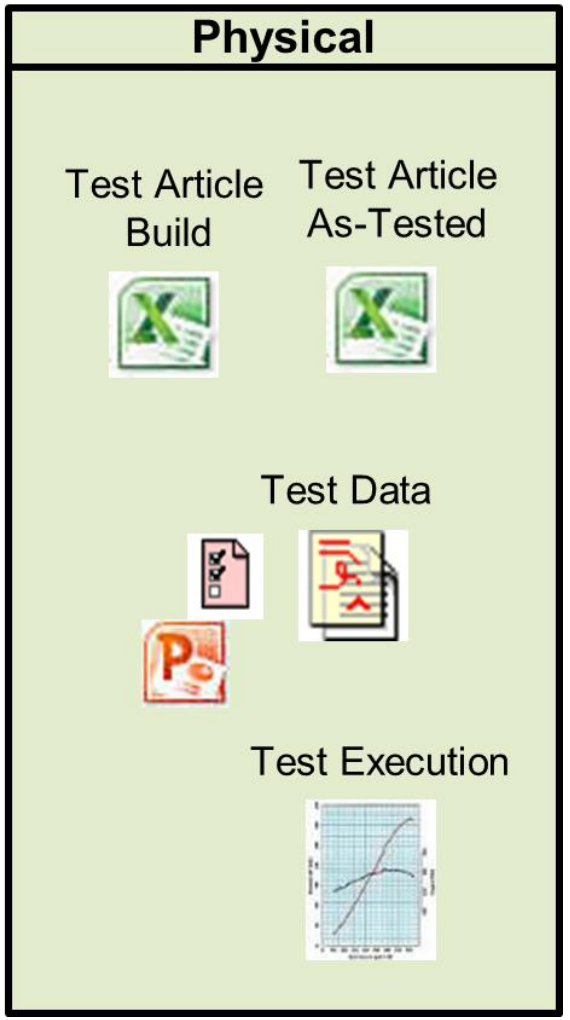

Complex Verification

Configuration

Documents

Change Management

What did we Test?

Engine Verification
Complex to Manage
Causes significant Budget & Time Overrun

Verification Management
Closed Loop Requirements to Compliance – Qualification Digital Thread

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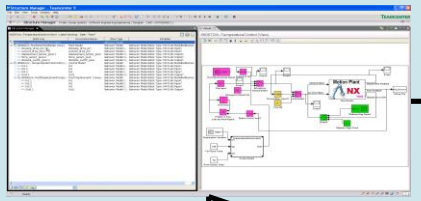
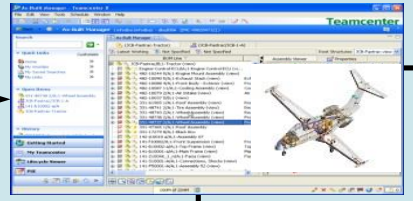
Virtual

Physical

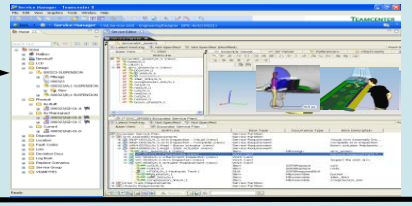
Requirements



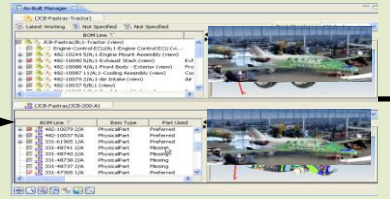
Product As-Designed



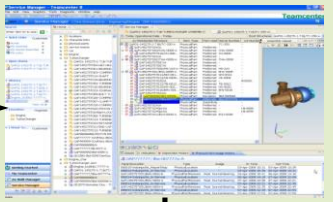
Product As-Analyzed



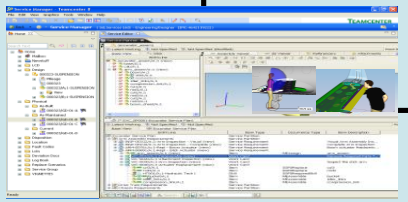
Test Article Build



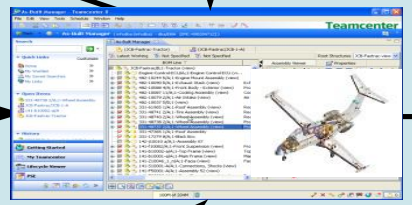
Test Article As-Tested



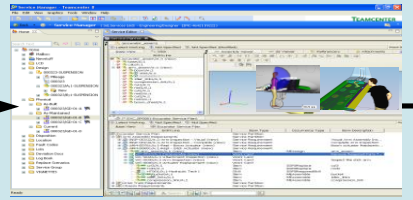
Test planning



Test article

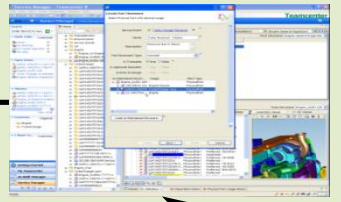


Test article As-analyzed

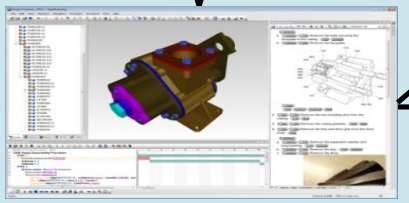


CORRELATE

Test Data

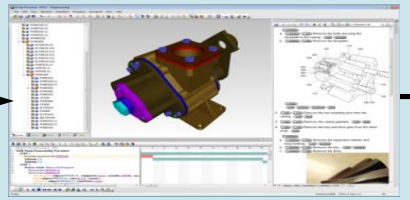


Test request

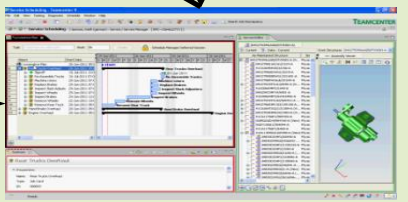


Instrumentation

Test Procedure



Test Execution



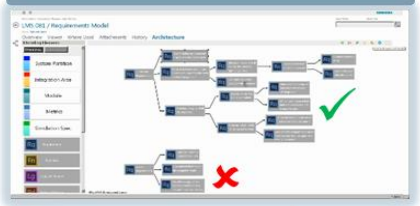
Simcenter for Integration, Verification & Certification

Enabling a smarter verification strategy

SIEMENS
Ingenuity for life

Requirements allocation | Verification planning | Verification by Inspection/Analysis/Testing | Compliance reporting

Product Requirements

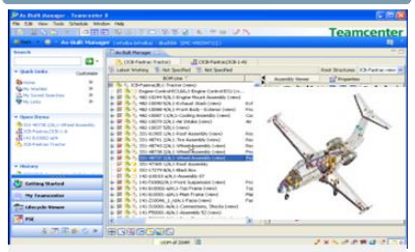


Verification Strategy

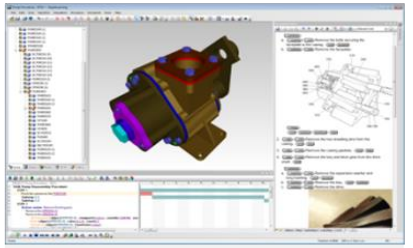
Numerical - Experimental

Experimental Configuration

Verification Planning

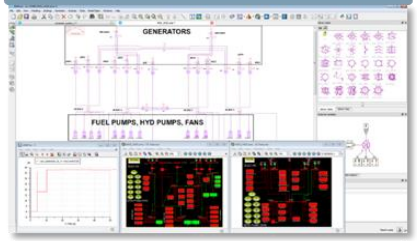


Test Request & Procedure



Test Article & Bench Build

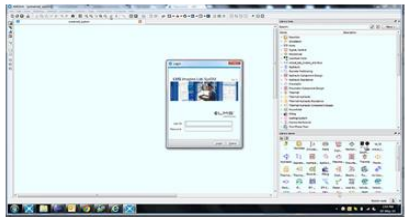
Verification Execution

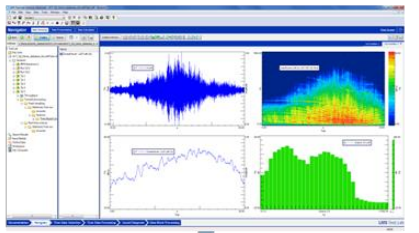


Virtual Test Data

Physical Test Data

Verification Reports





Trace to Requirements

Re-use in next program

Hybrid Electric Propulsion Units (EPU) with high power/weight requirements

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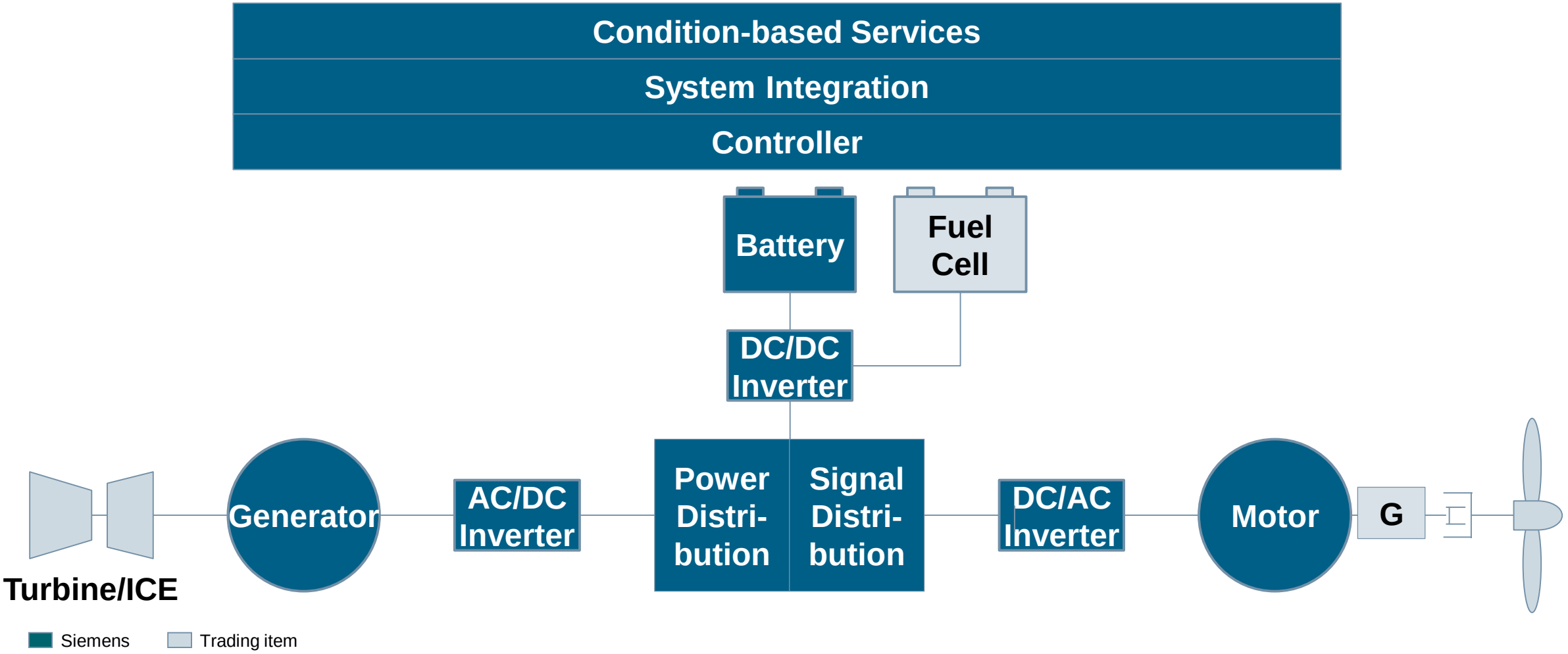
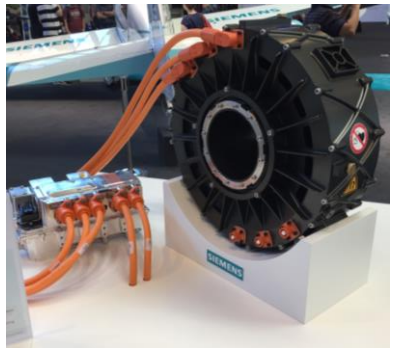


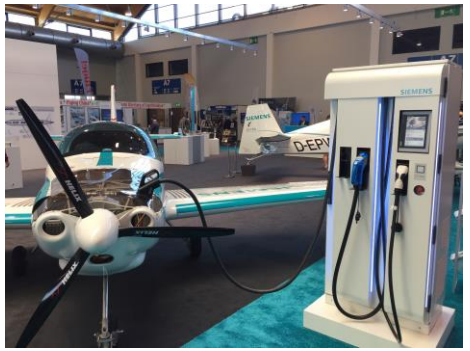
Achievements



SP260D

Direct Drive Permanent Magnet
MTOP 260 kW @ 2500 RPM
Weight 44kg
Power Density 5.9 kW/kg

On Extra 330LE Battery Configuration

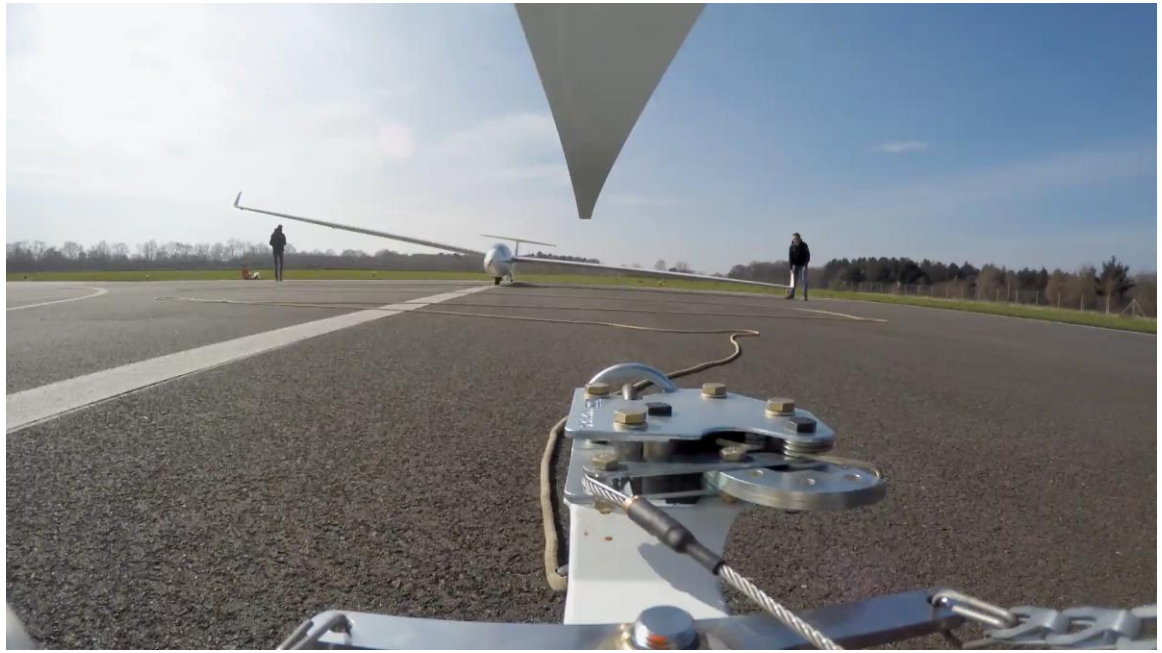


SP55D & SP70D

On Magnus eFusion

- (exchangeable) Battery config.
- Hybrid Electric (FlyEco Smart eng.)

New 57 kW Inverter SD104 900g
Take-Off & Landing 100% Electric



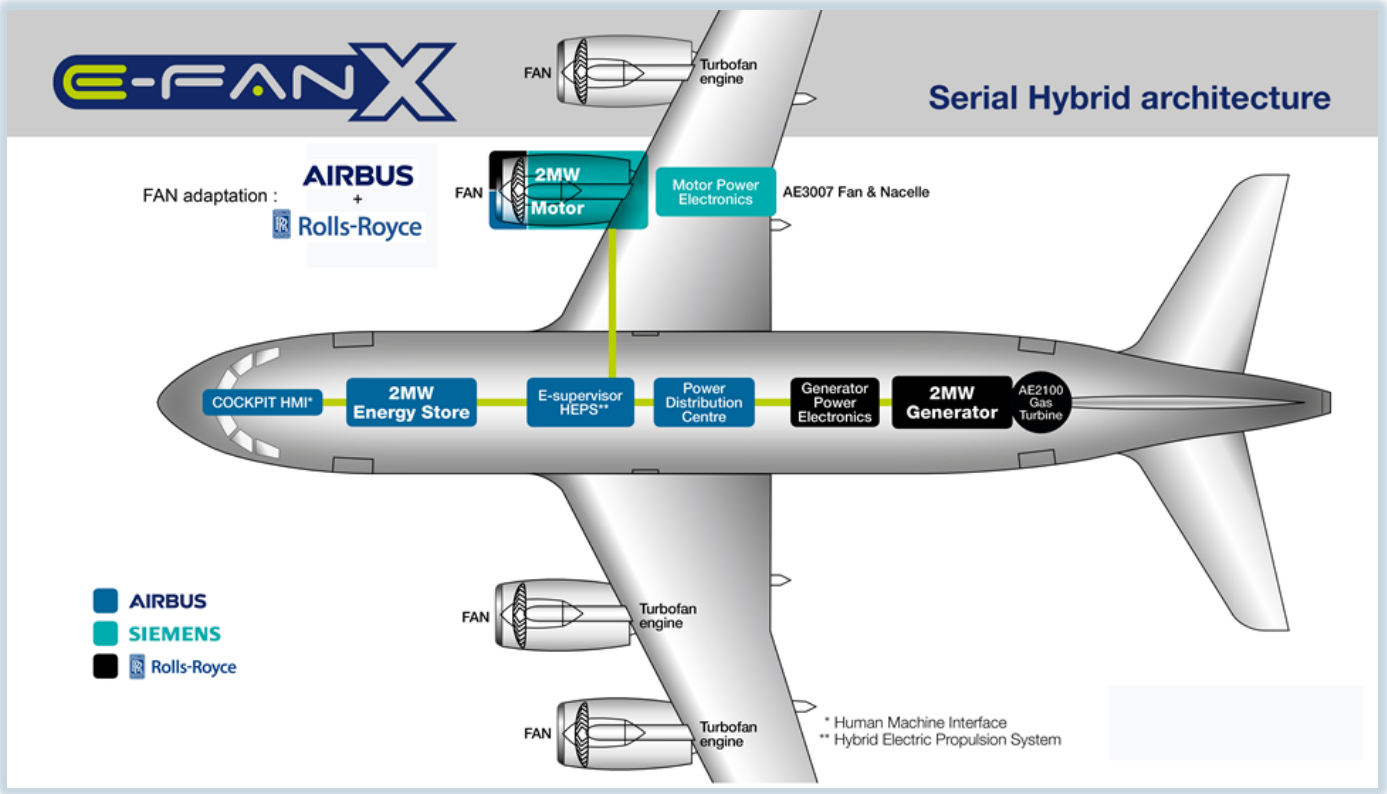
Airbus, Rolls-Royce & Siemens

28
November 2017

EN FR DE ES

Commercial Aircraft

Airbus, Rolls-Royce, and Siemens team up for electric future Partnership launches E-Fan X hybrid-electric flight demonstrator



Source: http://www.airbus.com/newsroom/press-releases

EPUs with Record Power Density are Complex & Highly Integrated Products

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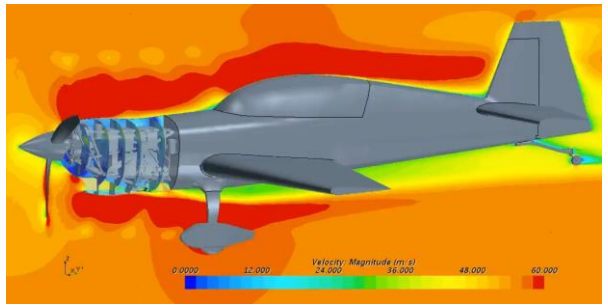


Greener & Cost Effective Aircraft Operations

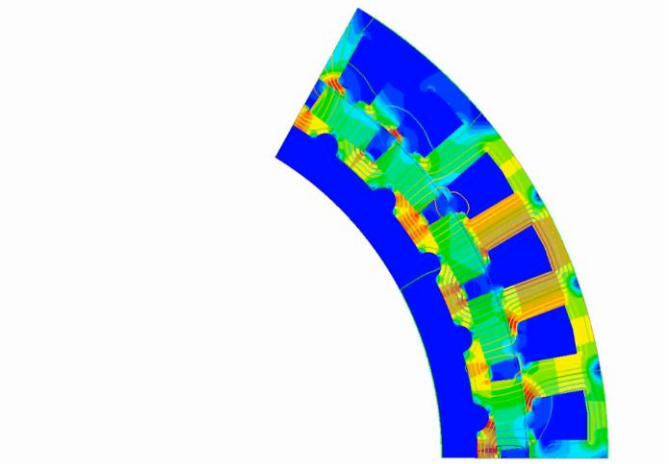
Aircraft | Mission | Environment

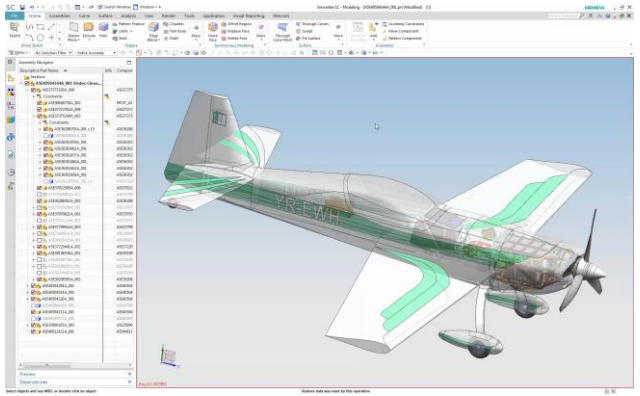
Efficient & Reliable Motor Performance

Electro-Magnetic | Structural

Electrical | Software

Thermal | Systems





EPUs with Record Power Density are Complex & Highly Integrated Products

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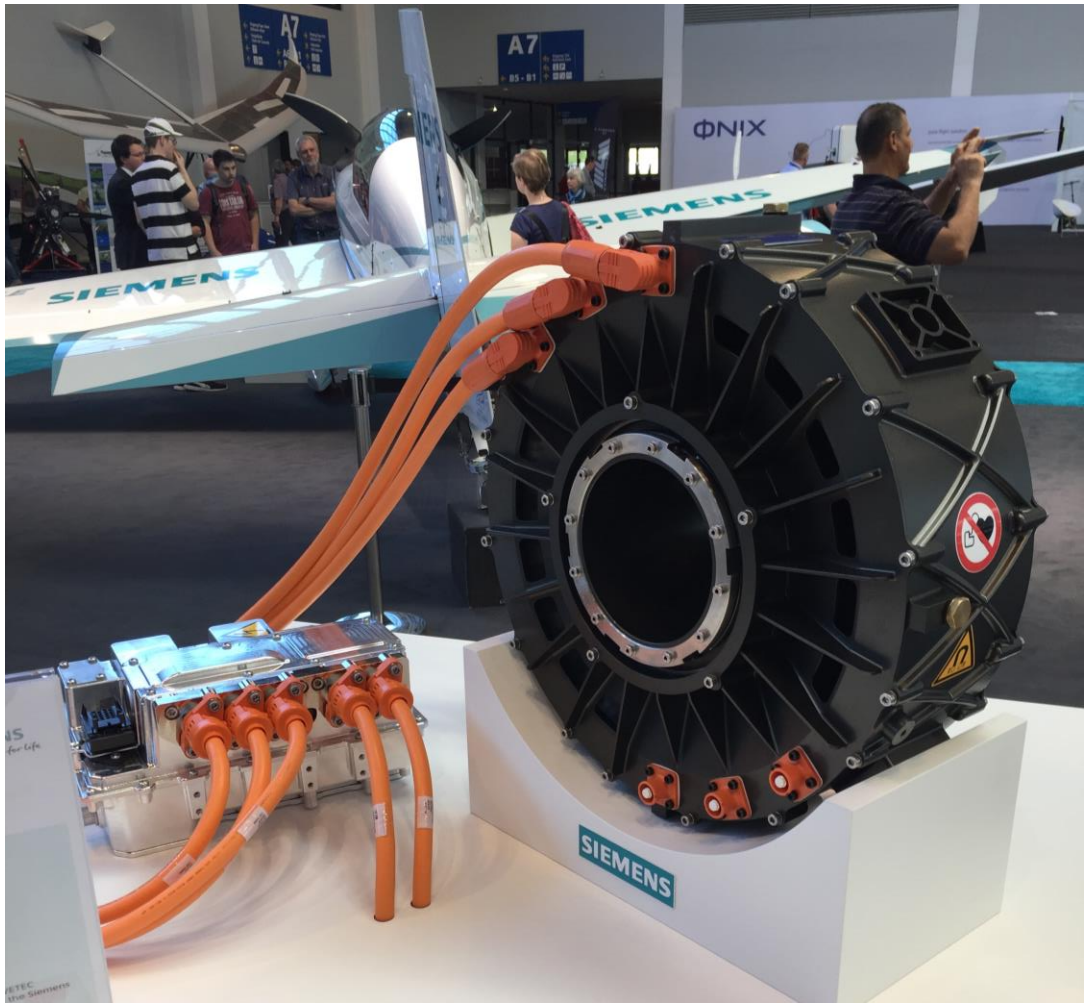

CityAirbus uses Siemens SP200D EPU Direct Drive: Based on SP260 technology - 50% increase in Torque to Mass Ratio

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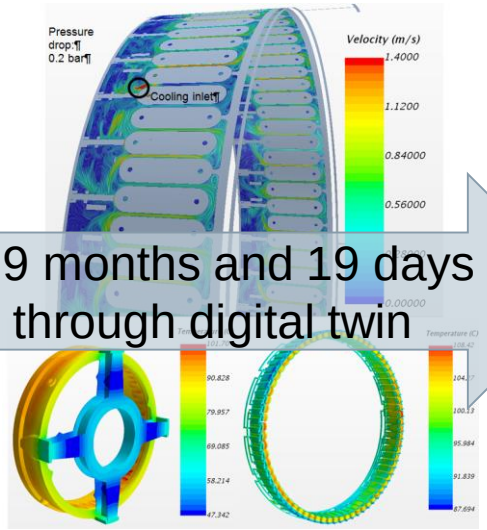
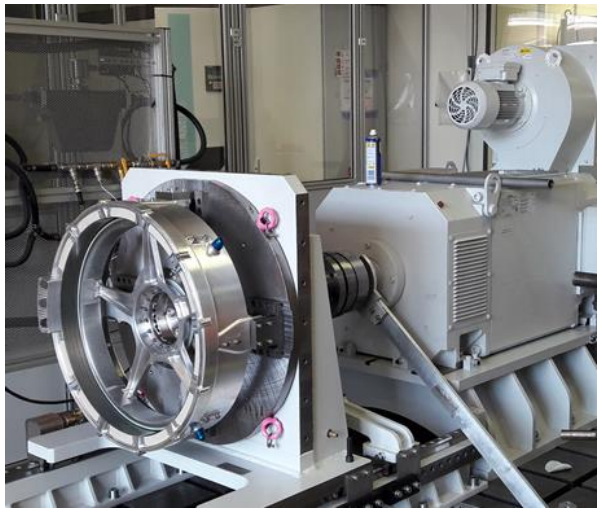
Ingenuity for life



In 9 months and 19 days through digital twin



	SP260D 2015		SP200D 2017
Continuous Power	260 kW		204 kW
Rotational Speed	2500 RPM non-geared		1300 RPM non-geared
Continuous Torque	**1000 Nm**		**1500 Nm**
Mass	50 kg		49 kg
Torque to Mass Ratio	**20 Nm/kg**	**Increase by 50%**	**30.6 Nm/kg**
Inverter Type	Si		SiC

Agenda

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Trends & Challenges - Complexity

Breaking Silo's - Performance Engineering

Business Value examples - Aircraft Program

Discussion

Possibilities to Improve Program Performance

… Non-Recurring Cost Structure of Civil Aircraft

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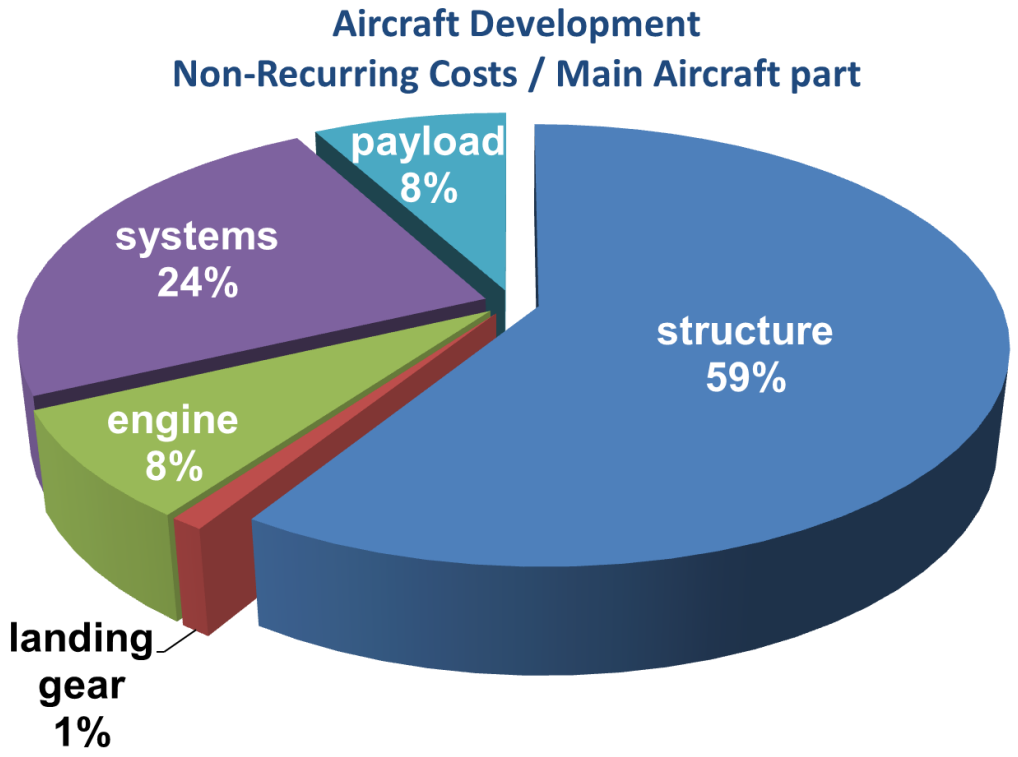

Sources:
"*Valuation Techniques for Commercial Aircraft Program design*", Jacob Markish, MIT ACDL, 2002
"*Development Cycle Time Simulation for Civil Aircraft*", NASA/CR-2001-210658

Modified with Modern trends towards More Integrated & Electrical Systems

Biggest impact of improvement expected on:

- Harmonize **Structural Development Methods**
  - Architectural Choice, Design, Analysis, Manufacturing…
- Harmonize **Systems Development Methods**
  - Architecture Choice, Design, Analysis, Manufacturing…
- Secure **Engineering, Manufacturing & Verification**
  - Digital Process Thread
  - Secured Data Consistency

Possibilities to Improve Program Performance

… Non-Recurring Cost Structure of Civil Aircraft

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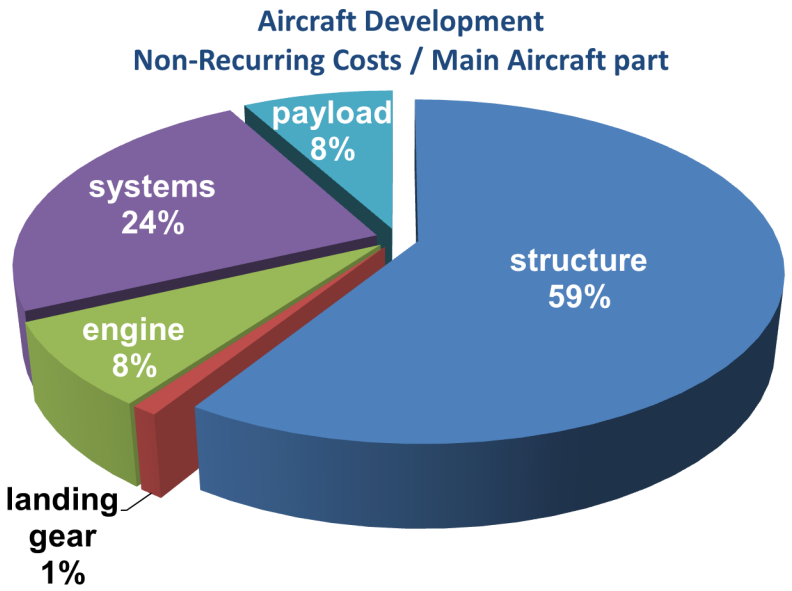
Ingenuity for life



Assume Development of 150-175 pax. A/C	
Initial NRC Estimate	**6.000 M€**
Likely delay	2 years
Cash Burn / Year delay	600 M€
Cost of Delay	1.200 M€
Total Likely NRC	**7.200 M€**

	"Current" Processes	
	Total Dev. Costs	
	Structural Dev.	Systems Dev.
	59%	25%
		without Engine
Initial Cost	3.540 M€	1.500 M€
Cost of Delay	708 M€	300 M€
Total Cost	**4.248 M€**	**1.800 M€**

Example look into details of:

- **Structural Stress Certification Process**
- **Systems performance analysis Process**

Possibilities to Improve Program Performance

… Non-Recurring Cost Structure of Civil Aircraft

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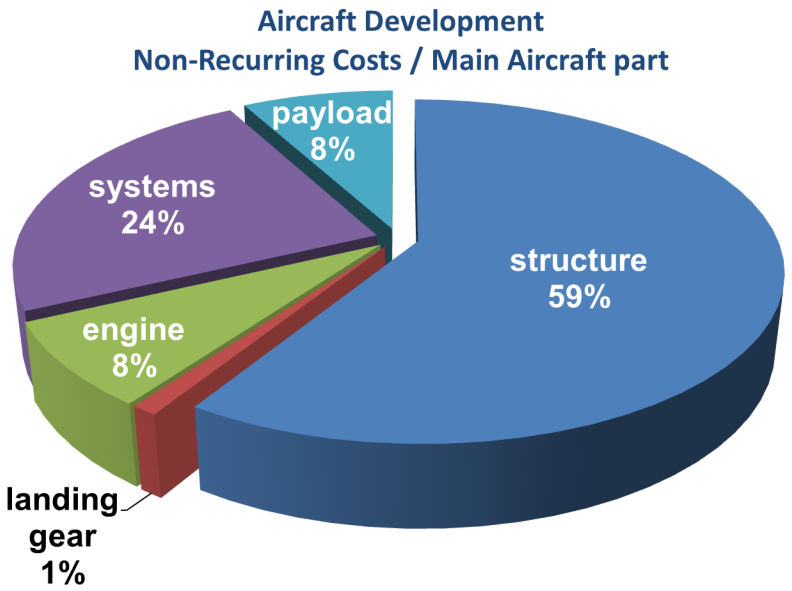

	"Current" Processes			
	Total Dev. Costs		"Analysis" Costs	
	Structural Dev.	Systems Dev.	Structural Dev.	Systems Dev.
	59%	25%	19%	22%
		without Engine		*without Engine*
Initial Cost	3.540 M€	1.500 M€	669 M€	330 M€
Cost of Delay	708 M€	300 M€	134 M€	66 M€
Total Cost	**4.248 M€**	**1.800 M€**	**803 M€**	**396 M€**
				1.199 M€

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Possibilities to Improve Program Performance

… Non-Recurring Cost Structure of Civil Aircraft

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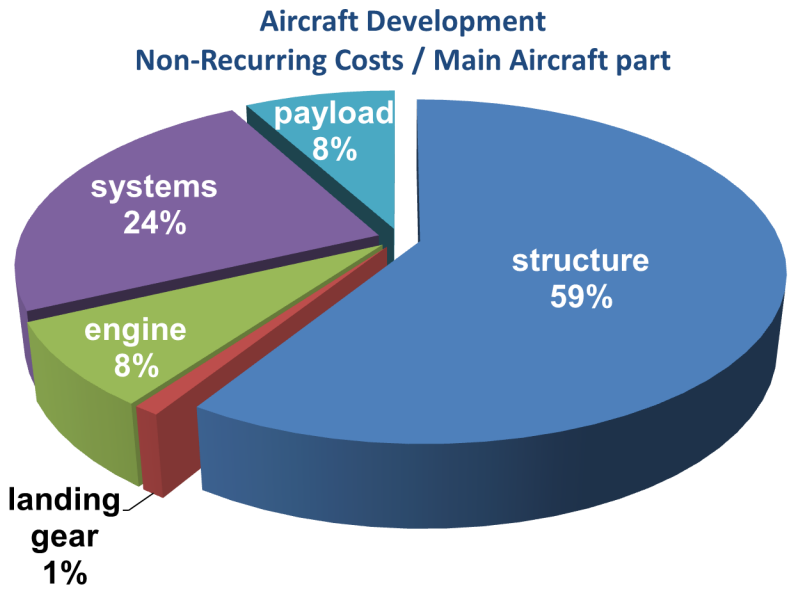

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Cost of Delay	1.200 M€
Total Likely NRC	**7.200 M€**

	"Current" Processes				"Improved" Analysis Processes					
	Total Dev. Costs		"Analysis" Costs		Process Improvement Potential		"Analysis" Costs		Gain on "Analysis" costs	
	Structural Dev.	Systems Dev.	Structural Dev.	Systems Dev.	Structural	Systems	Structural	Systems	Structural	Systems
	59%	25%	19%	22%						
		without Engine		*without Engine*				*without Engine*		*without Engine*
Initial Cost	3.540 M€	1.500 M€	669 M€	330 M€	-20%	-25%	535 M€	248 M€	134 M€	83 M€
Cost of Delay	708 M€	300 M€	134 M€	66 M€	-40%	-40%	80 M€	40 M€	54 M€	26 M€
Total Cost	**4.248 M€**	**1.800 M€**	**803 M€**	**396 M€**			**616 M€**	**287 M€**	**187 M€**	**109 M€**
				1.199 M€				**903 M€**		**296 M€**

Possibilities to Improve Program Performance

… Non-Recurring Cost Structure of Civil Aircraft

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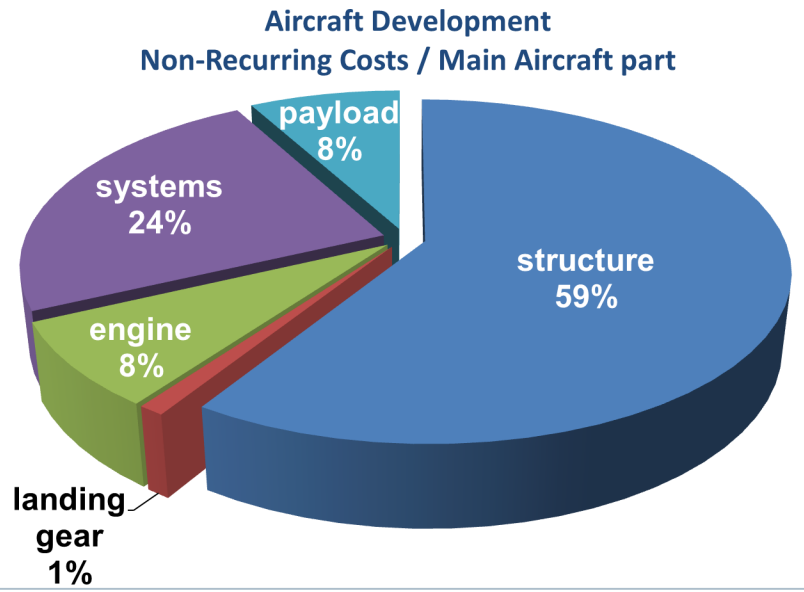

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Cost of Delay	1.200 M€
Total Likely NRC	**7.200 M€**

Improved Processes for Structures & Systems Analysis

Potential Savings

*300M€ or +5% NRC**

ONLY counting improvements on Analysis Processes –
Not counting potential savings based on improved Digital Thread & Processes like Verification Management.

Improved Structures & Systems Integration

… Direct Impact on Reducing Aircraft Recurring Cost

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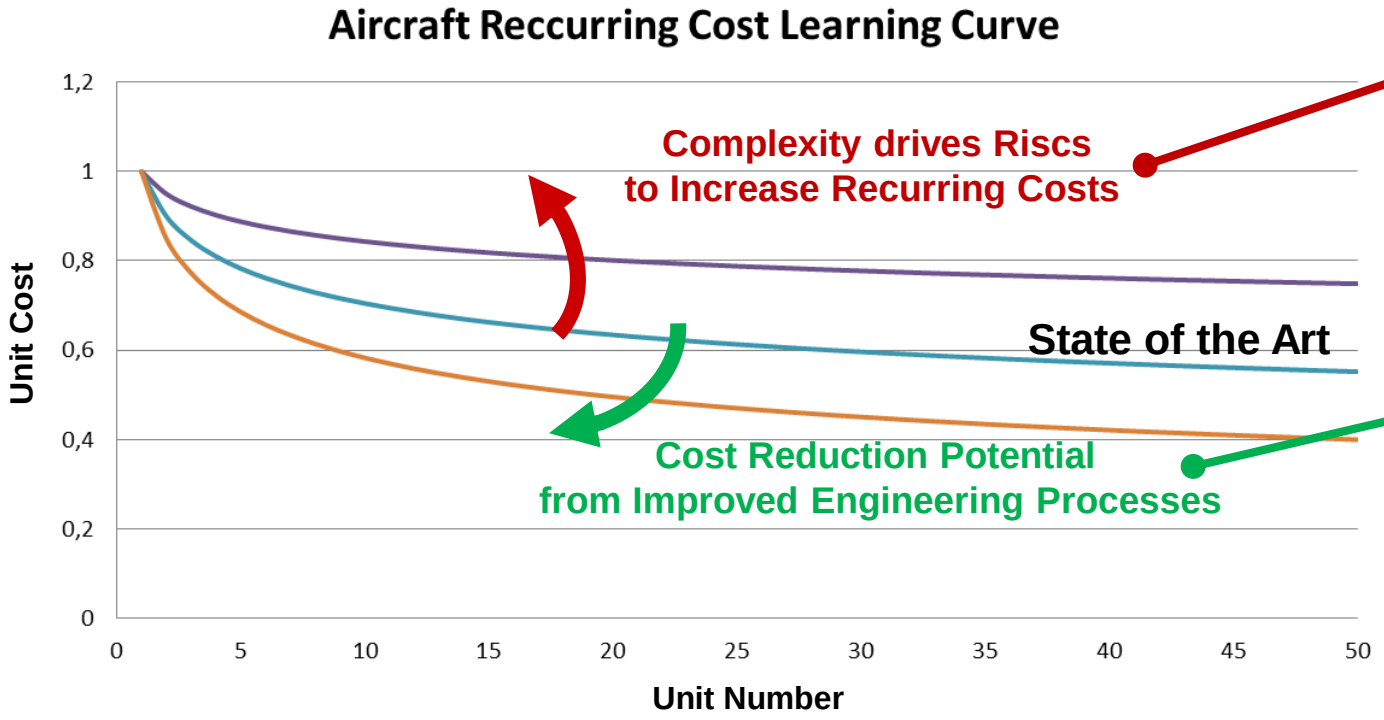

Risks when not addressing complexity:

- New Structures / Composites
- Complex & Innovative Systems
- Process Complexity Collaboration model
  Risk Sharing Partners "complicate"

Investment in improved Engineering Processes:

- Modern Structure Sizing & Definition
- Model Based Systems Engineering
- Aligned & Model Based Collaboration model
- Align Risk Sharing Partners in program
- Integrated Manufacturing Planning
- …

Aircraft Recurring Cost Learning Curve - State of the Art:
Improved Structures & Systems Model Based Process Contributes to:

- Cycle time reduction and related costs
- Earlier maturity and readiness w.r.t. competition
- Improved aircraft program economics and business case

Agenda

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Trends & Challenges - Complexity

Breaking Silo's - Performance Engineering

Business Value examples - Aircraft Program

Discussion

Discussion

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At what moment in your development do you have a reliable confirmation of the Integrated Product Performance?

Discussion

With the increasing amount of “Software Functions”, from when and how do you Verify Integrated Performance?

Discussion

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What fraction of your product performance issues are Integration Issues?

Discussion

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How traceable is your data?

Data continuity from Concept Trade-Off studies till Verification?

Discussion

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How tight is the handshake between Virtual and Physical Verification?

Discussion

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How easy is it for your organization to compare simulated and “evidence” data?

Discussion

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What fraction of your NRC is consumed by Performance Engineering?

(NRC Non-Recurring Cost)

Contact

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Thierry Olbrechts
Director Simcenter Aerospace Solutions
Siemens Industry Software n.v.
Mobile: + 32 497 518 259

E-mail:
thierry.olbrechts@siemens.com