The Outcome Economy: Product Performance Lifecycle (PPL) & Hybrid Twins

From « Industry 4.0 » to « CAE 4.0 + »

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ECOLE POLYTECHNIQUE PALAISEAU / FRANCE

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The Outcome Economy

"How the Industrial IoT is changing every business"*

Joseph Barkai – 2016
IDC Manufacturing Insights
Product Lifecycle Strategies

→ **Outcome** is not a Product nor a Service, but a **Solution** !

*IoT: Internet of Things

The Product *Performance* Lifecycle (PPL)

People don't want to buy a quarter-inch drill;

They want a quarter inch hole!

Theodore Levitt
HBS – Marketing Professor*

→ And … a **good** one!

*HBS: Harvard Business School

The context of the Digital Transformation

From a Good Product to an Effective Solution

The context of the Digital Transformation – Industry Disruption

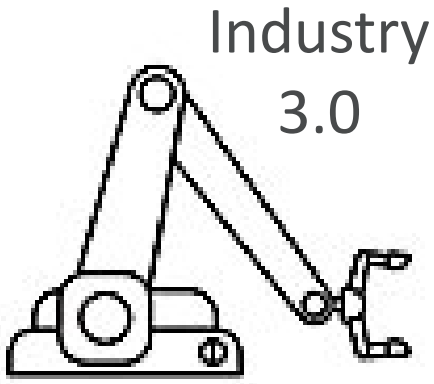
Product *from* 'Nominal' *to* 'in Life'

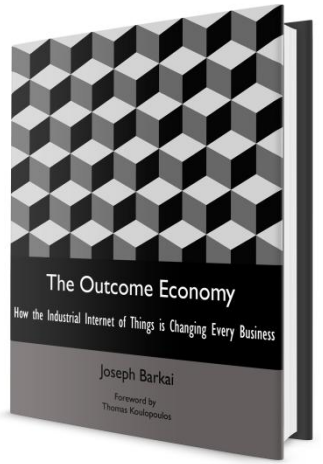
Technology	Simulation (HPC) 	IoT / Cloud 
Manufacture	Robotics 	Smart Factory 
Delivery	Certified 	In Operation 
	PLM *Product Lifecycle Management*	***PPL*** *Product Performance Lifecycle*

Effective Solution: **Hybrid Twin !**

The context of the Digital Transformation – Enterprise Disruption

From Automated to Smart to Outcome





Automated Production / Product Certification

Intelligent Production / Smart Factory

Solution Value / Performance

Eco-system !

The context of the Digital Transformation – Customer Disruption

Product:

from: ‘a Tool’ to ‘on Demand’ to ‘Enabler’

Product

Service

‘App’ based Solution

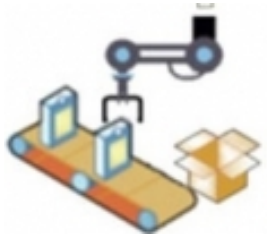
Anonymous!

The context of the Digital Transformation – Jobs Disruption

Impact on resources and customers – Distributed eco-systems

Democratize, Customize and Bring jobs ‘home’ ?

Conceive



Make

Connect

Ubiquitous !

The context of the Digital Transformation – International Initiatives

Heralding the impact of ICT* and IoT*

Industry 4.0
Fourth industrial revolution for the virtualization of manufacturing

'Industrie du futur':
Transform the industrial model by digital technology

'Innovate UK':
Innovation agency to drive the science and technology innovations

'Horizon 2020':
Funding program to support and foster research

'Manufacturing 2025':
Transition from '*made*' in China to '*design*' in China

National Network for Manufacturing Innovation (**NNMI**) Improve US Manufacturing Competitiveness

Smart Factory !

ICT: Information & Communication Technologies – IoT*: Internet of Things*

The Transformation of the CAE world

To « Industry 4.0 » with « CAE 4.0 + »

The CAE-4 disruptive challenges:

from Product *Management* "PLM" to Product *Performance* "PPL"

VIRTUAL PROTOTYPE

HPC → CAE 1+2

HPC + ICT + IVE → CAE 3

As calibrated per Silo

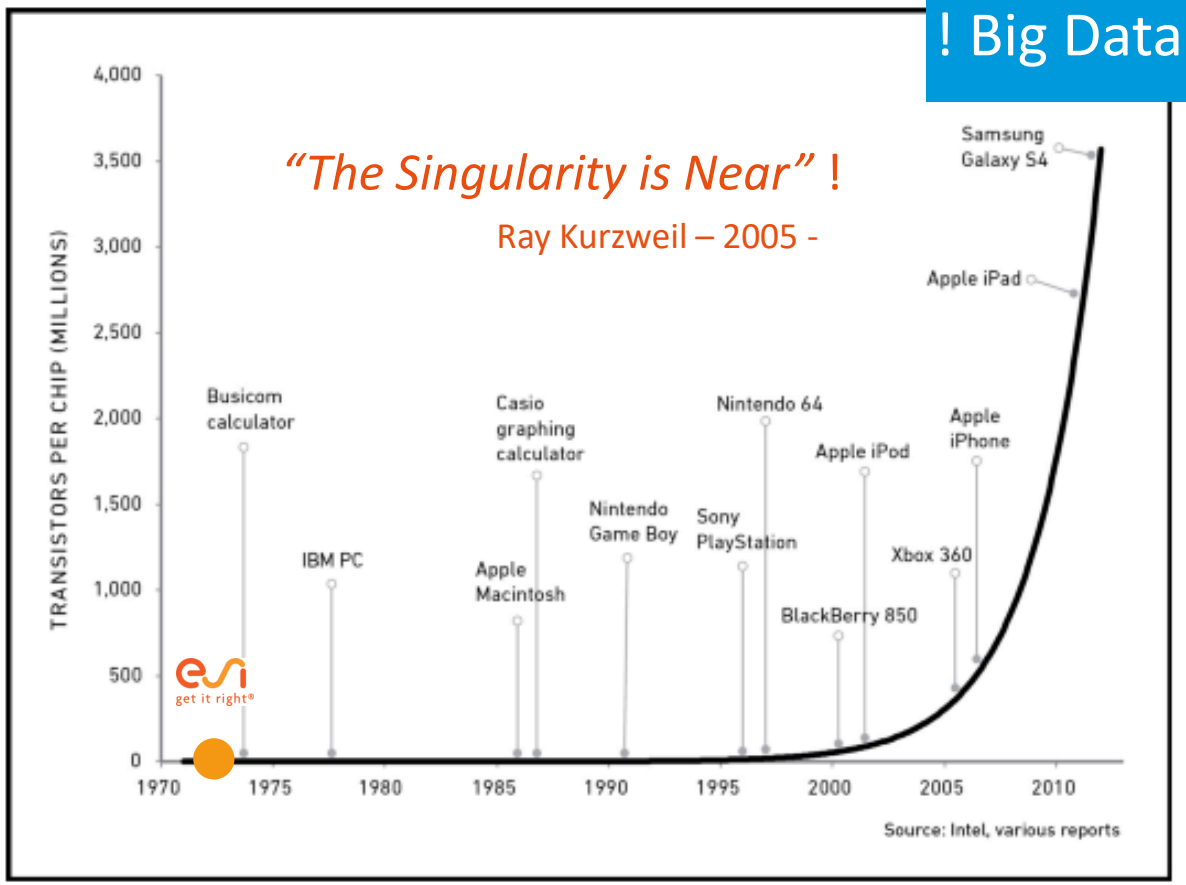
As built as tested per Component

Analysis & Simulation for design and validation

Virtual Prototype for multi-domain Pre-certification

Product *Development* Management

! Big Data !

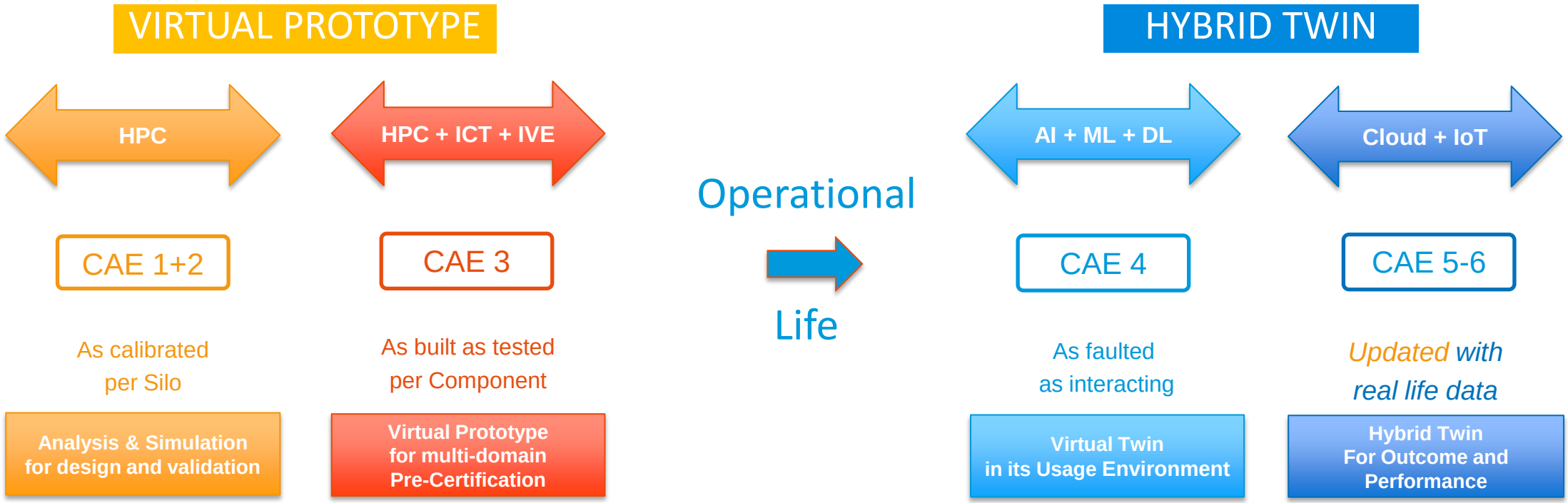


A.I.: Artificial Intelligence – M.L.: Machine Learning – D.L: Deep Learning – IoT: Internet of Things

HPC: High Performance Computing – ICT: Information & Communication Technologies - IVE: Immersive Virtual Engineering

The CAE-4 disruptive challenges:

from Product *Management* "**PLM**" to Product *Performance* "**PPL**"



Product *Development* Management

Product Performance **Lifecycle**

A.I.: Artificial Intelligence – M.L.: Machine Learning – D.L: Deep Learning – IoT: Internet of Things
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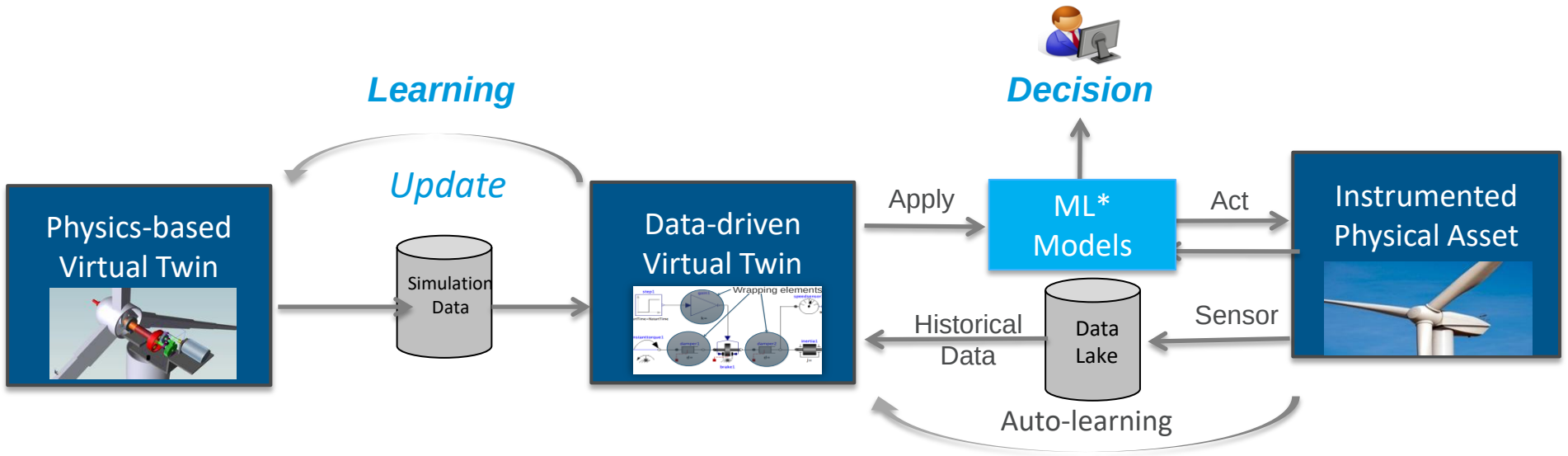
G.HC.17.016.A.

The transformation of the CAE-4 world

Hybrid Twin™



Math-based
Causal models
0d/1d **system** model
3d/4d **detailed** models

Machine Learning
Empirical models
Reduced order models
Faulted models

Foresight vs Hindsight

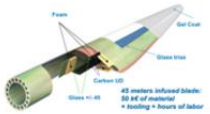
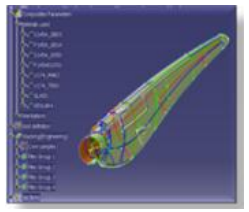
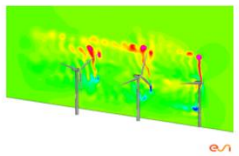
Actionable !

The context of CAE-4 Transformation

The Art of Modeling for Full Life Performance

Example of the **Wind Hybrid Twin™**:

Innovate UK

CAE 1/2	CAE 3	CAE 4	CAE 5/6
ANALYSIS & SIMULATION	**VIRTUAL FAB & TESTING**	**VIRTUAL TWIN**	**Hybrid Twin™**
			
DESIGN & CALIBRATION for VALIDATION	**MULTI DOMAIN MODELING for PRE-CERTIFICATION**	**VIRTUAL ENVIRONMENT for OPERATIONAL INTERACTIONS**	**DATA DRIVEN SOLUTION for PERFORMANCE**

agility3 modelling and simulation

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Brunel UNIVERSITY LONDON BIC

TWI

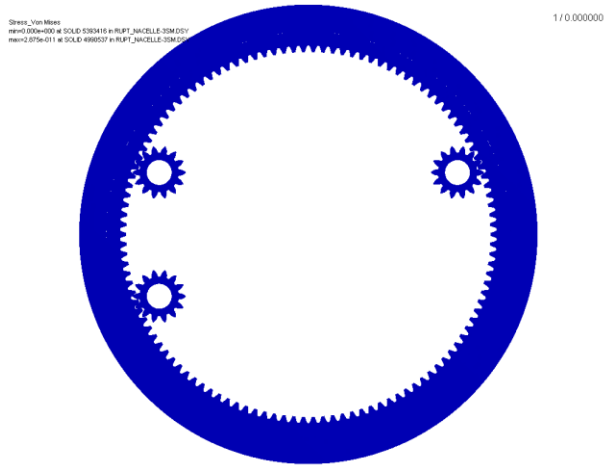
Outcome Value!

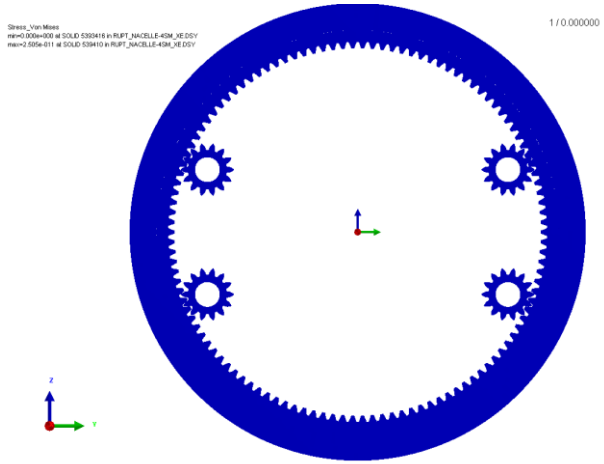
Design, visualize, analyze, take decisions using both data sets

The context of CAE-4 Transformation

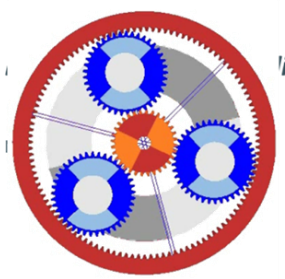
Example of **Hybrid Twin™**: Data driven solution performance for "**Outcome**" value

Gearbox Evaluation

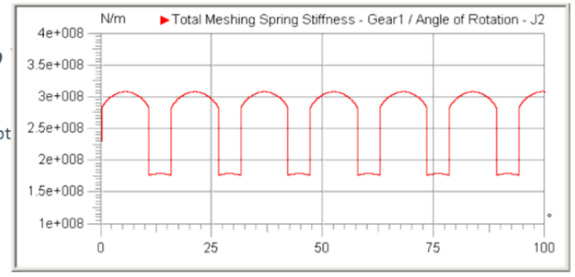




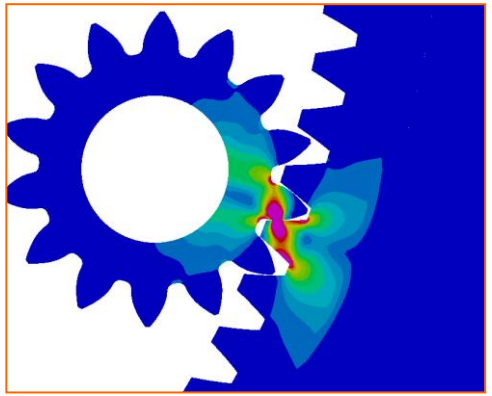
Results:



Natural Frequencies



Noise and Vibrations Analyses



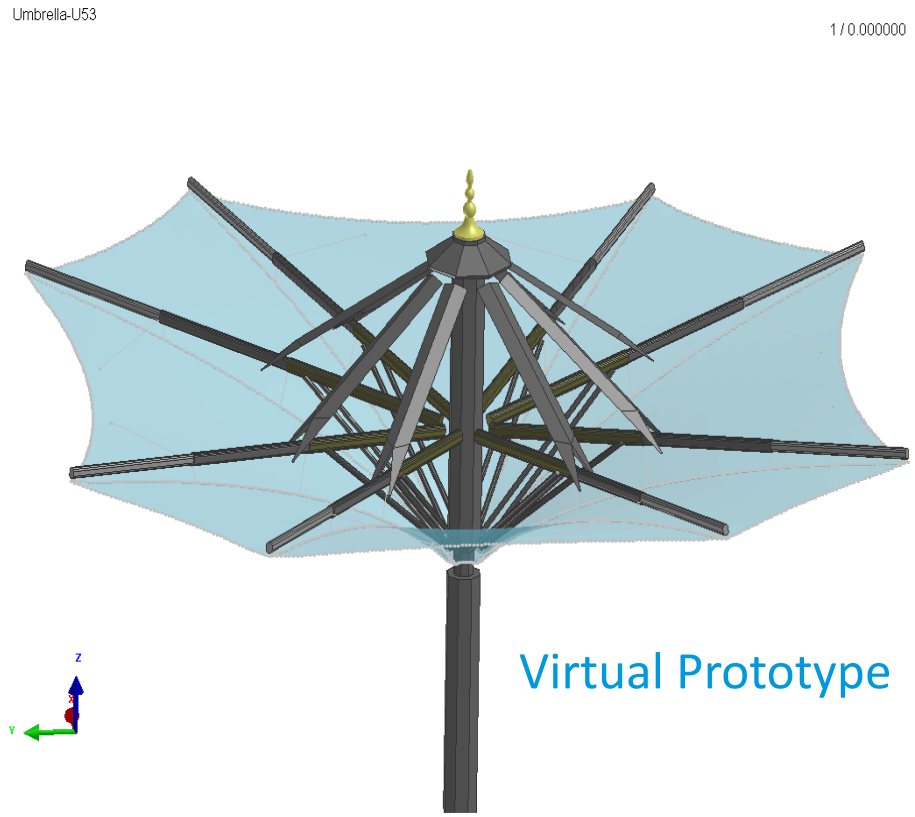
Add a
4th Crank

SIMULATION X by esi

Design, visualize, analyze, take decisions using both data sets

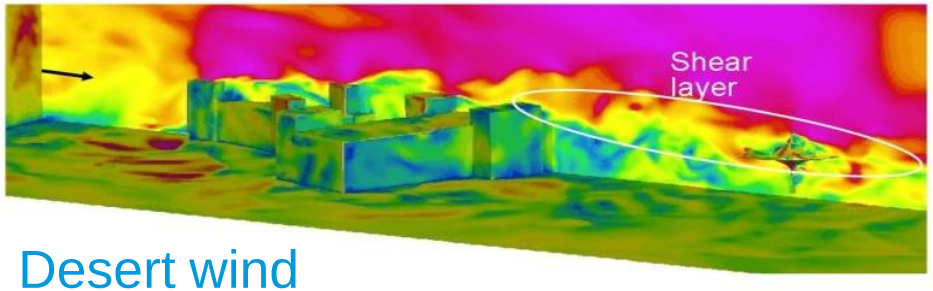
The context of CAE-4 Transformation

Example of The **Virtual Twin**: Multi-domain modeling for fabrication and testing

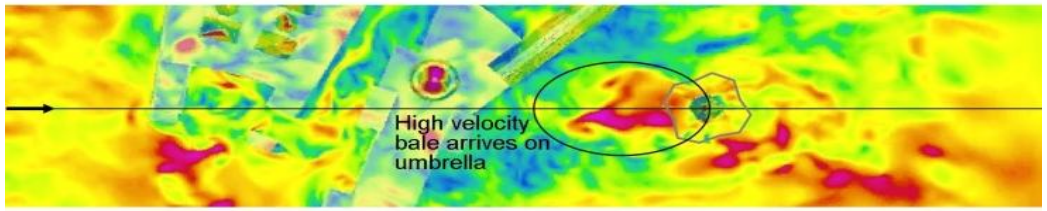


Virtual Prototype

Mecca
Giant Umbrellas



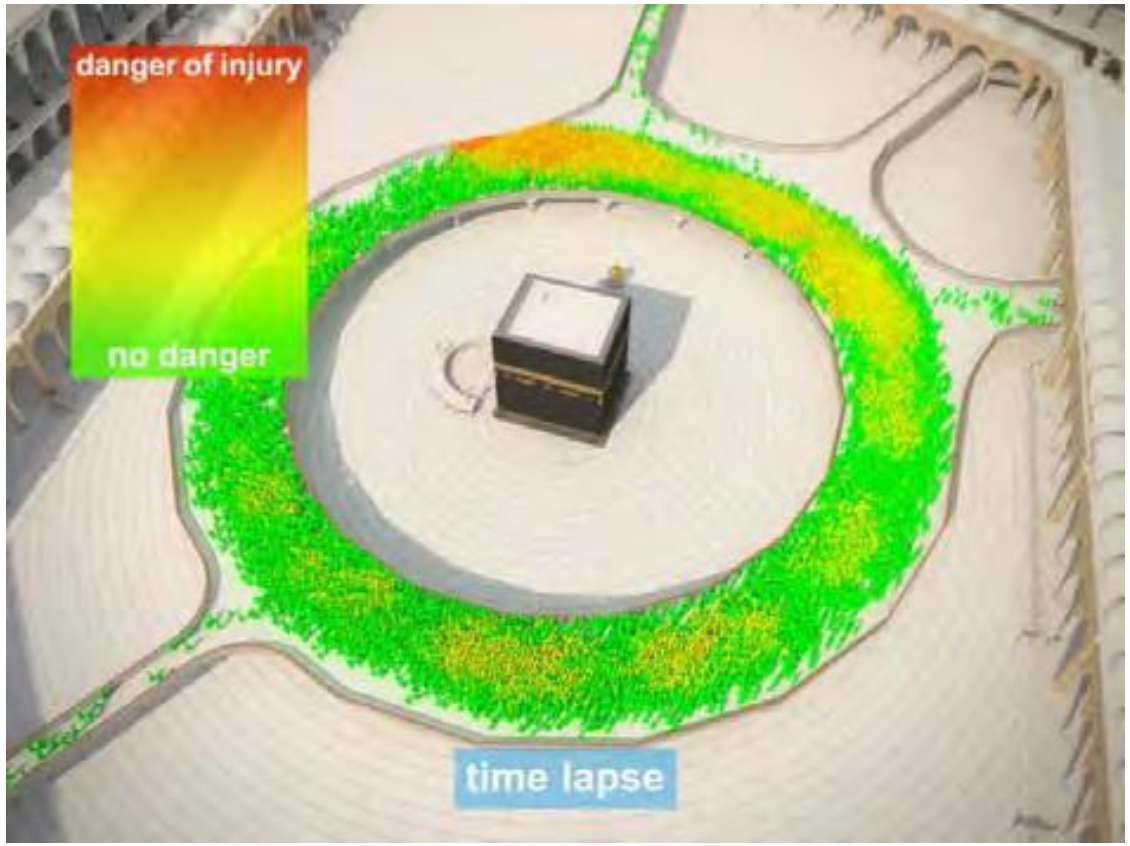
Desert wind

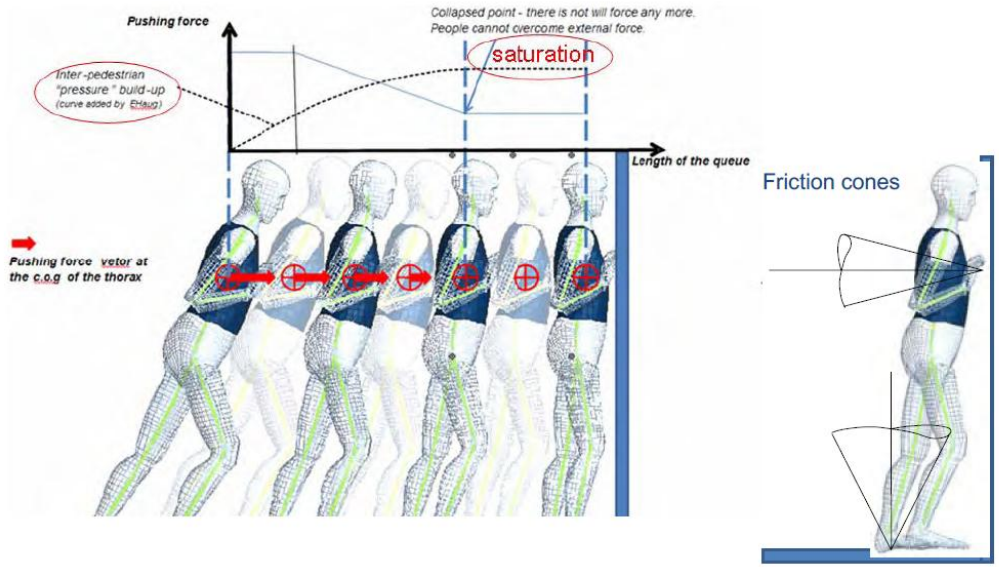


Environment
Interaction

The context of CAE-4 Transformation

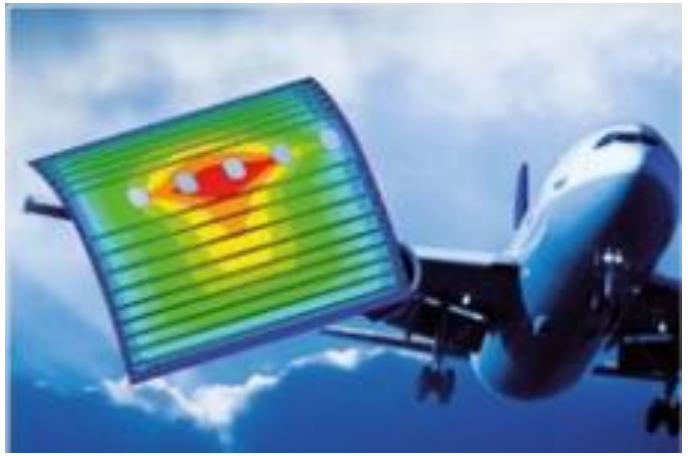
Motion of pedestrian – example of crowd flow





Environment Interaction: people

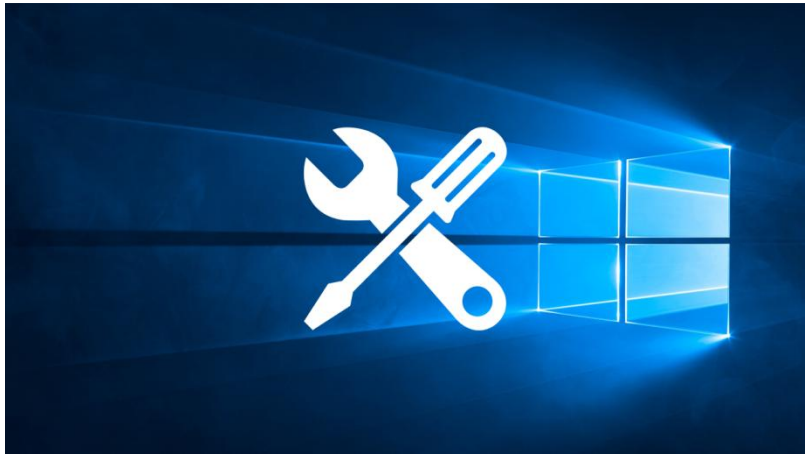
Smart Factory for fabrication and repair



Smart Factory

Actionable factor: Right '*Materials*' for better Quality products

Fabrication
/ Assembly Line



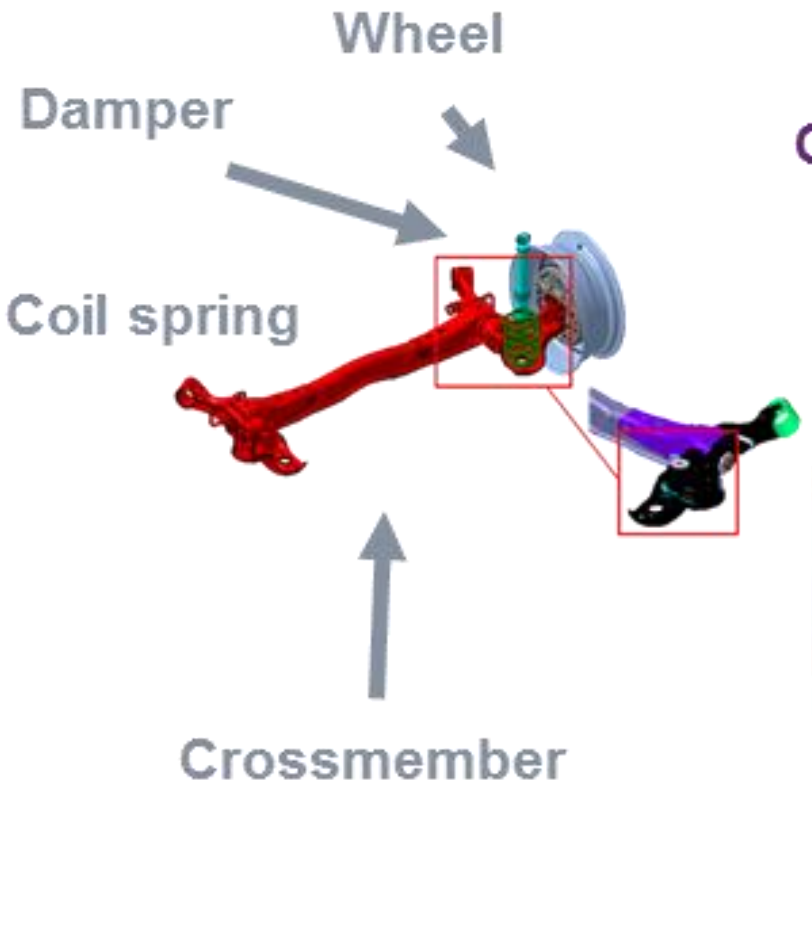
Maintenance
/ Repair

Materials
/ as used & damaged

"*Engineering*" materials !

Smart Factory for fabrication and repair - Component

Virtual Manufacturing Solution – Virtual Prototype



'as built'

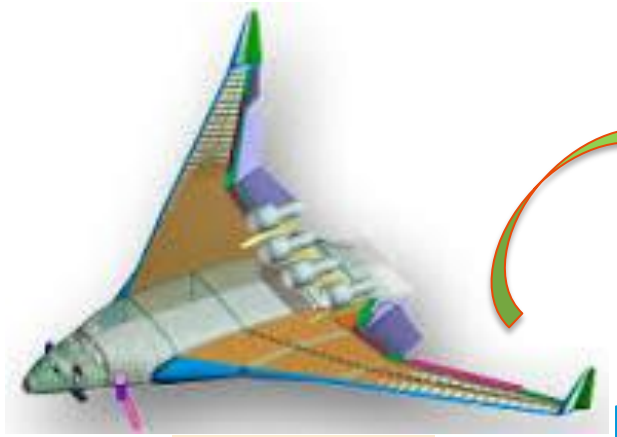
Clamping

Weld joints

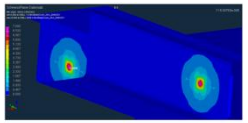
Fatigue
Performance

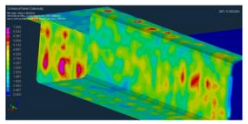
Smart Factory for fabrication and repair

Structural Health Monitoring Solution – **Hybrid Twin**

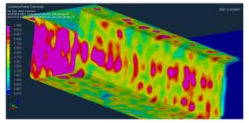


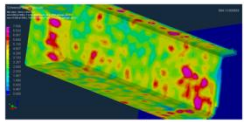
Virtual





Pristine





Damaged / Cracked

Model Reduction
for near-real-time

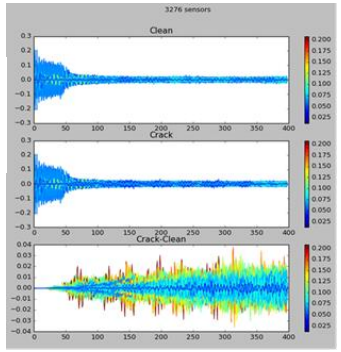
Virtual Confusion Matrix

	No Detection	Detection
Damage 0 PRESTINE	True No Call	False Alarm
Damage D1 > 0	?	?
Damage D2 > D1	?	?
Damage D3 > D2 CRACK	Missed Call	True Call

Affects Maintainance !

Continuous learning and improvement of
data driven virtual model from real aircraft

mineset



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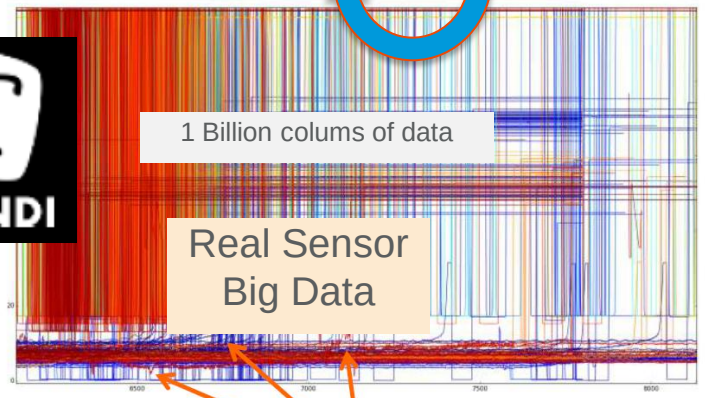
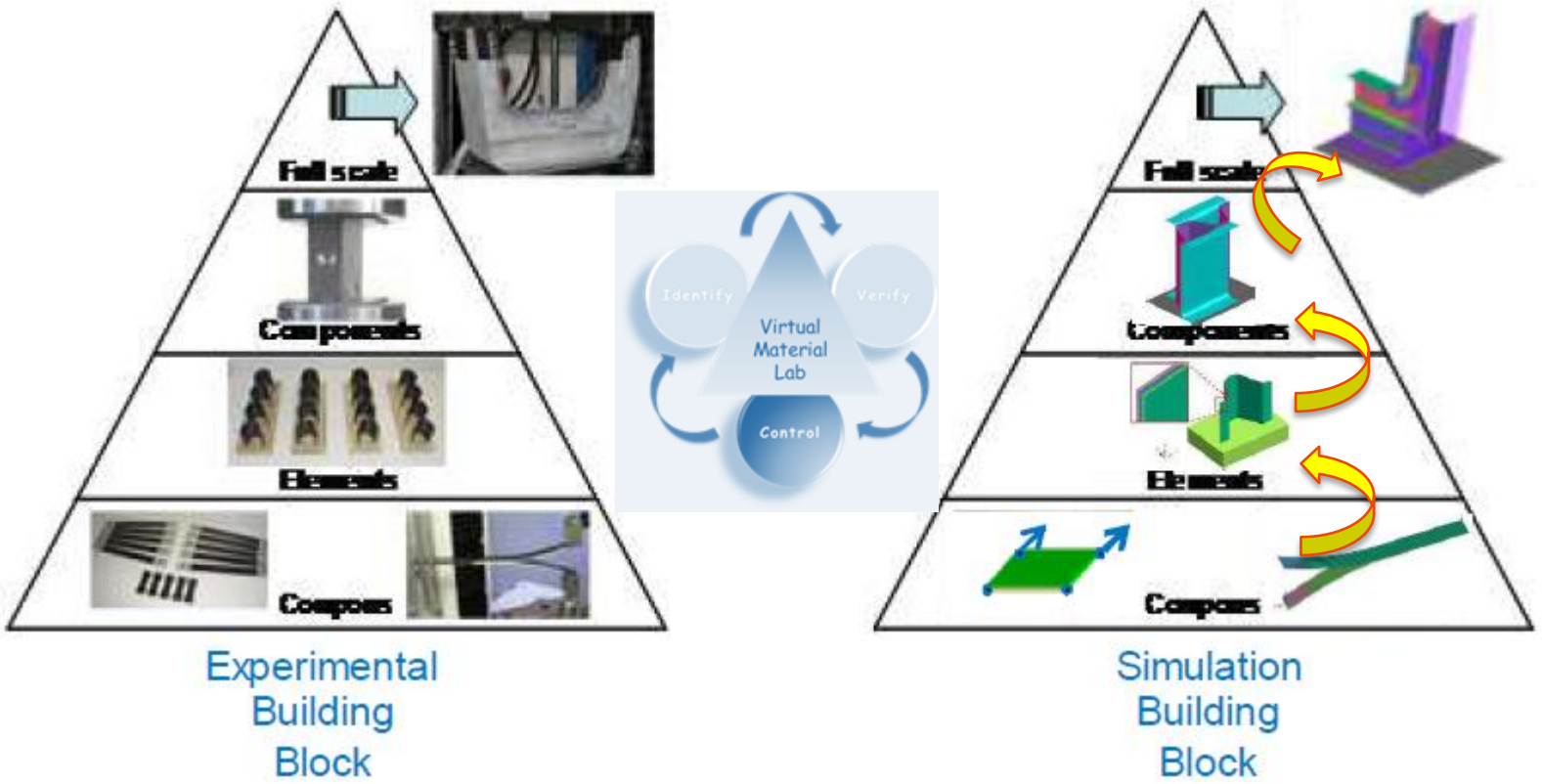


Real

Smart Factory for fabrication and repair

Multi-Scale characterization of ***Engineering*** materials

The Virtual Material Lab to climb the pyramid of models

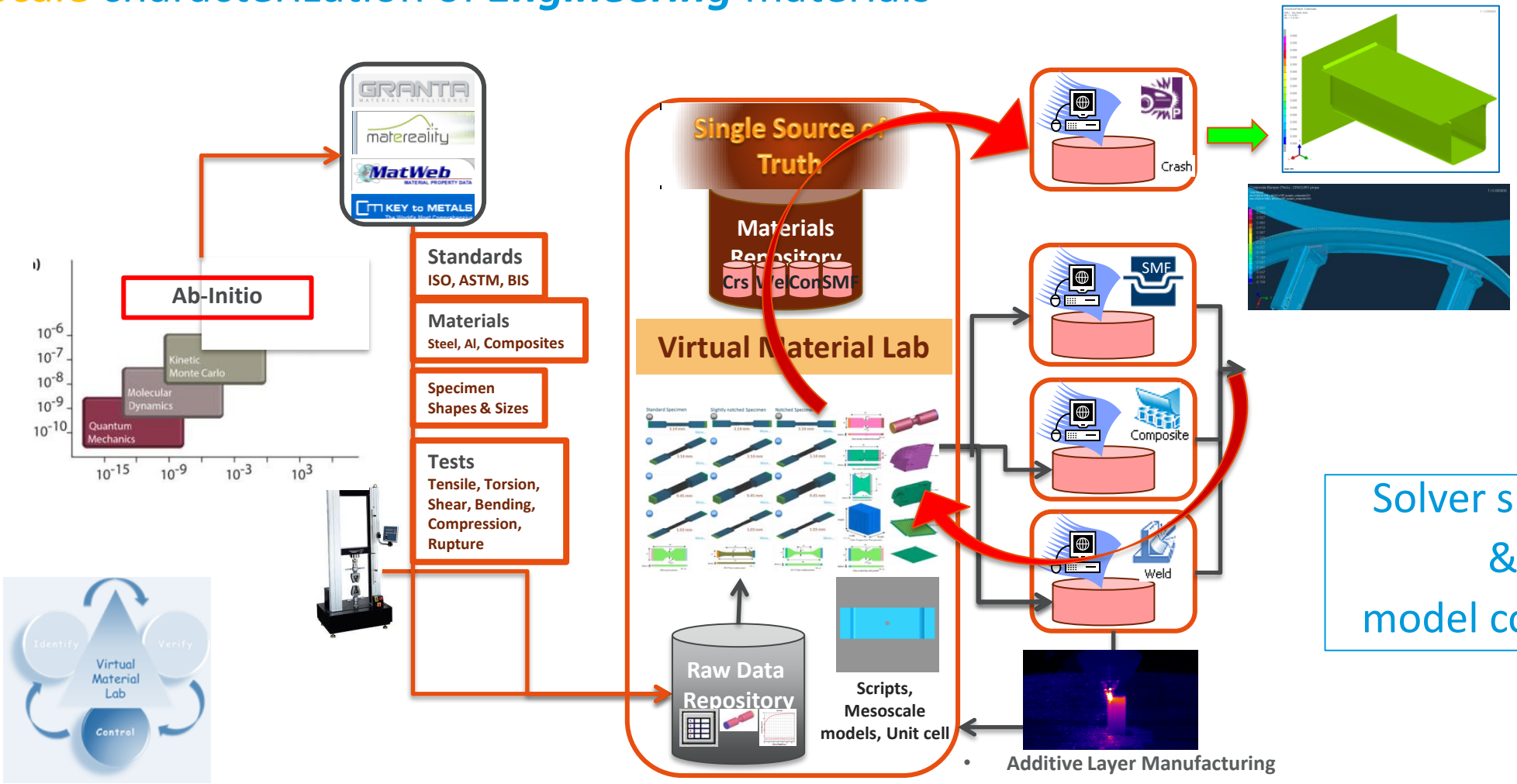


micro
meso
macro
scales

From “coupon”, to “element”, to “component”, to “full scale”

Smart Factory for fabrication and repair

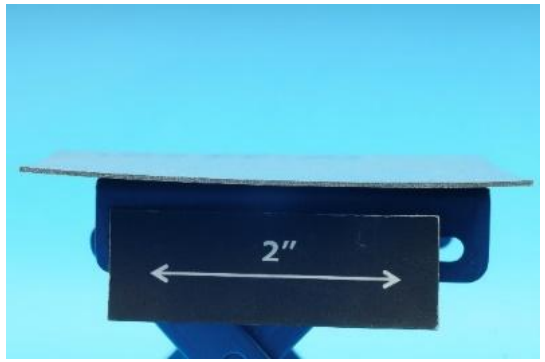
Multi-Scale characterization of ***Engineering*** materials

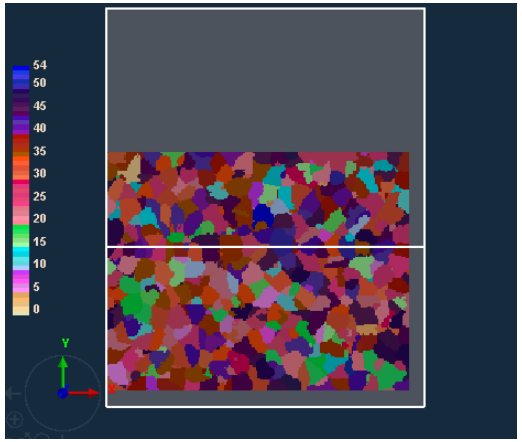


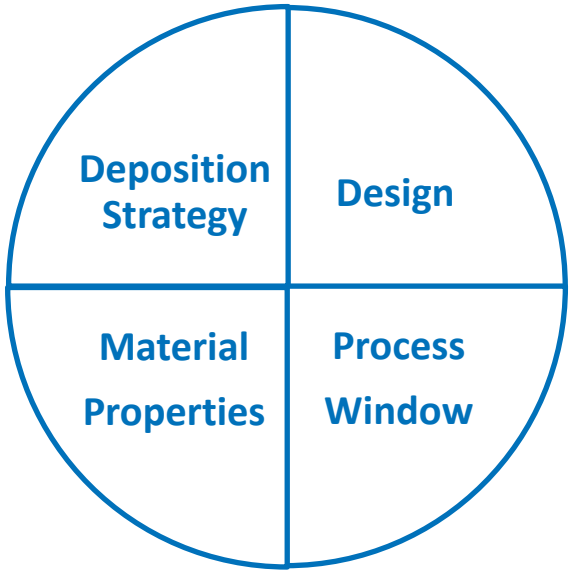
Solver specific
&
model coherent

Smart Factory for fabrication and repair

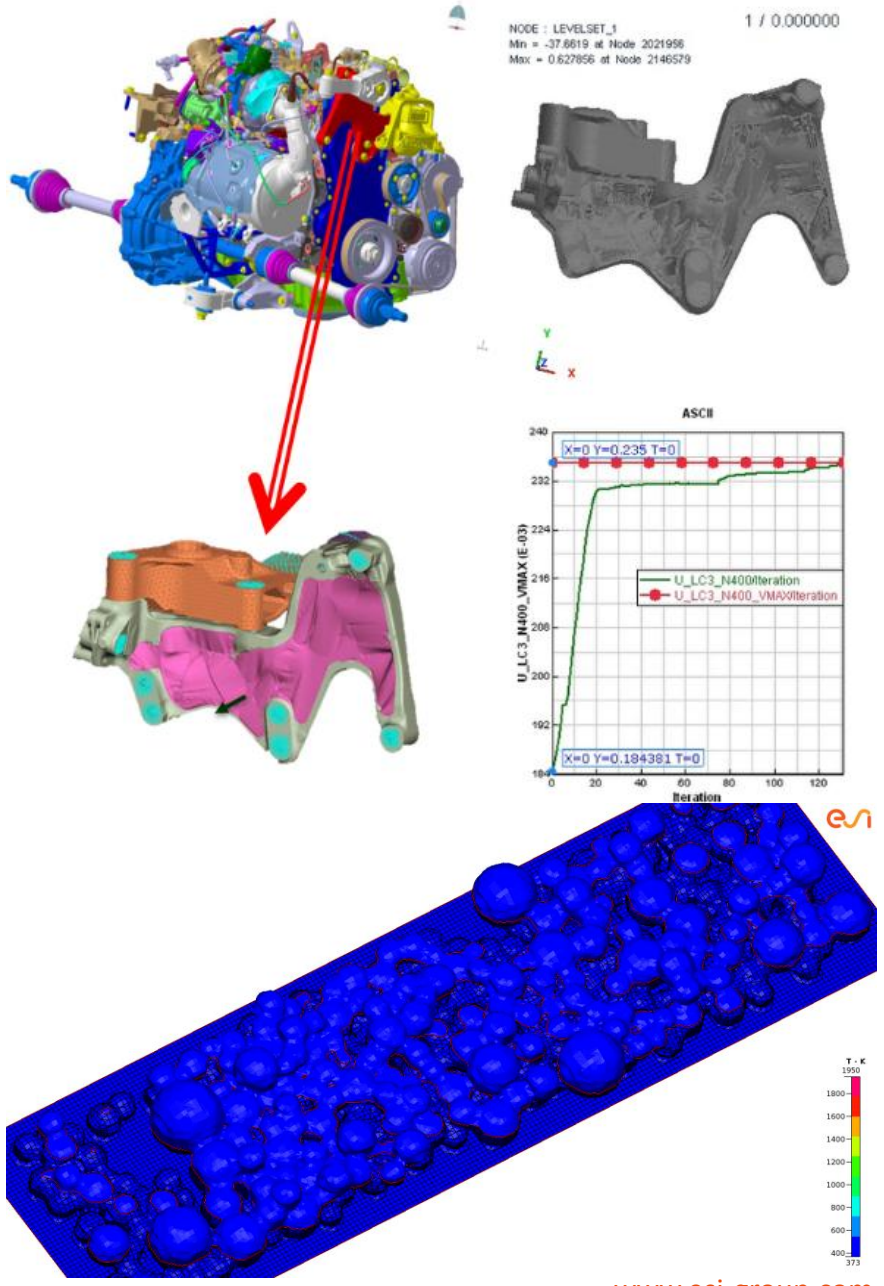
Fabrication of ***Engineering*** materials – Additive Layering Manufacturing (ALM)





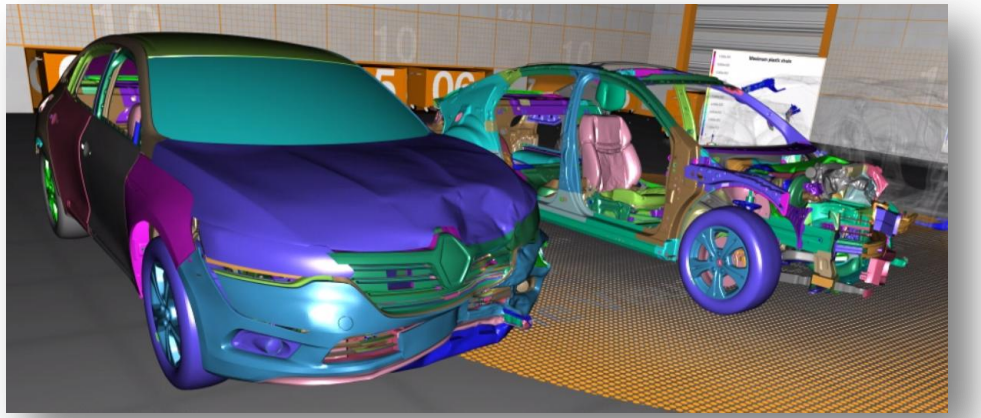


Process Efficacy
&
Part Quality

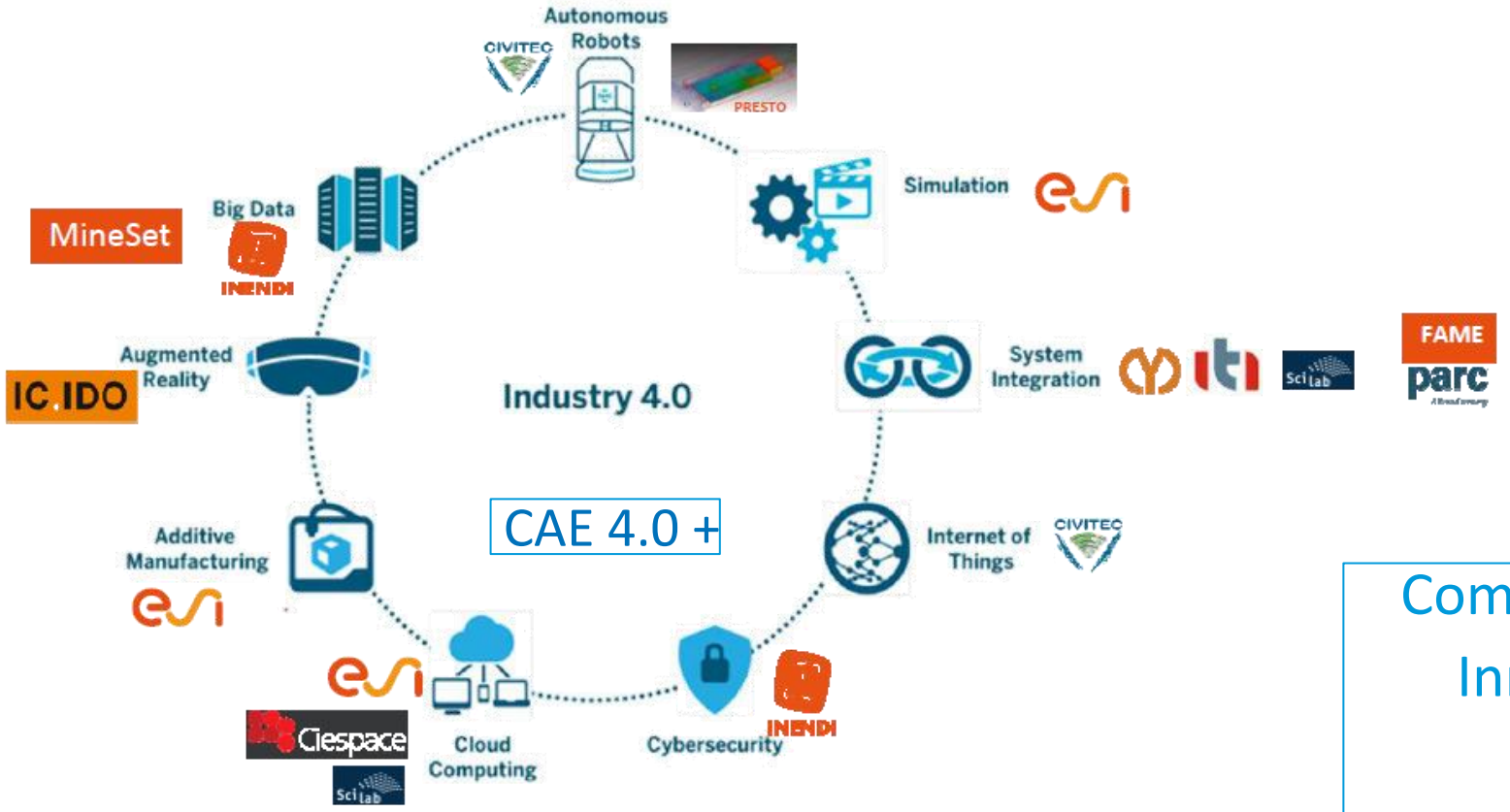


ESI as a ***catalyst*** and digital solution ***integrator***

Within the Eco-system(s)



ESI as a ***catalyst*** and digital solution ***integrator***



Combinational
Innovation
&
Industry Transfer

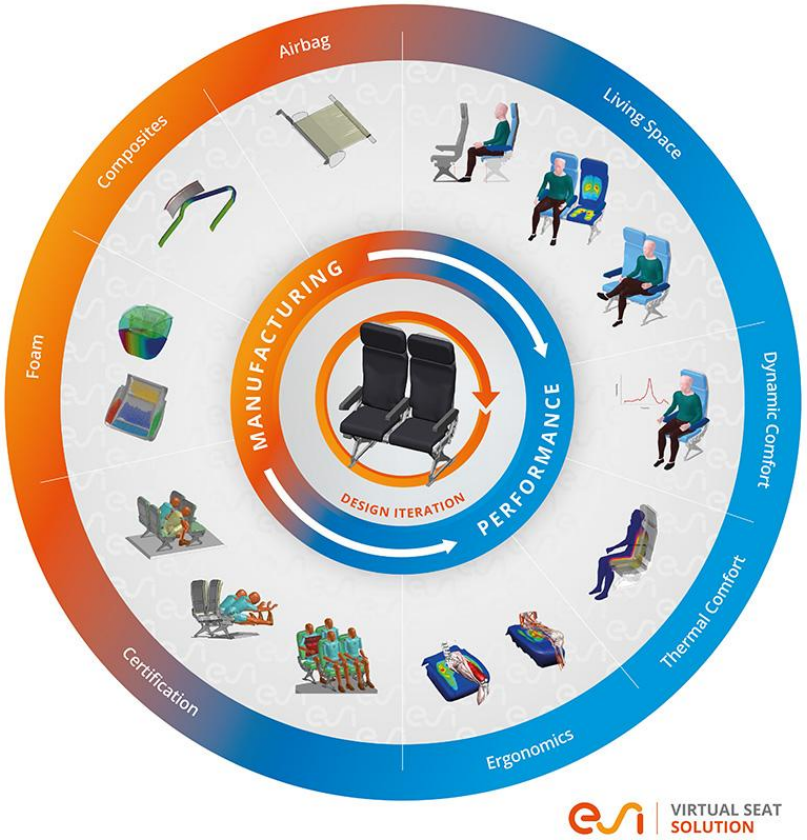
Aeronautics

Focus

ESI as a ***catalyst*** and digital solution ***integrator***

Expliseat: Get it right *'as built' & 'as tested'*

VIRTUAL SEAT SOLUTION



Foam-Tissues-Composites-Metals-Assembly-

Virtual Twin

Titanium Seat

Ergonomics-Comfort-Safety-Certification

Achieved EASA certification at first try-out

ESI as a ***catalyst*** and digital solution ***integrator***

Key partner of the Aeronautic sector

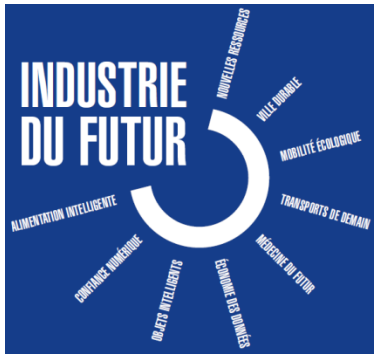
Aeronautics Factory of the Future (UAF)

Embedded Systems and Advanced Functions (SEFA)

SOlutions For Industrial metal Additive manufacturing (SOFIA)

LUDWIG BÖLKOW CAMPUS AEROSPACE | SECURITY

Aerospace Factory Additive Manufacturing

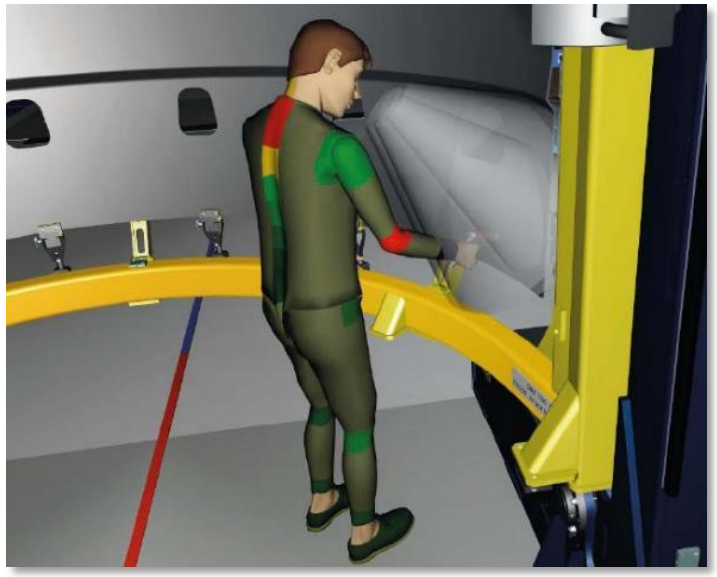


Co-creation & Collaborative Innovation

ESI as a ***catalyst*** and digital solution ***integrator***

SAFRAN Aircelle

Virtual Reality Solution – Safran Nacelles



*"Virtual reality represents a technology of the future that will have an impact on the efficiency of our developments. The **factory of the future** is already here."*

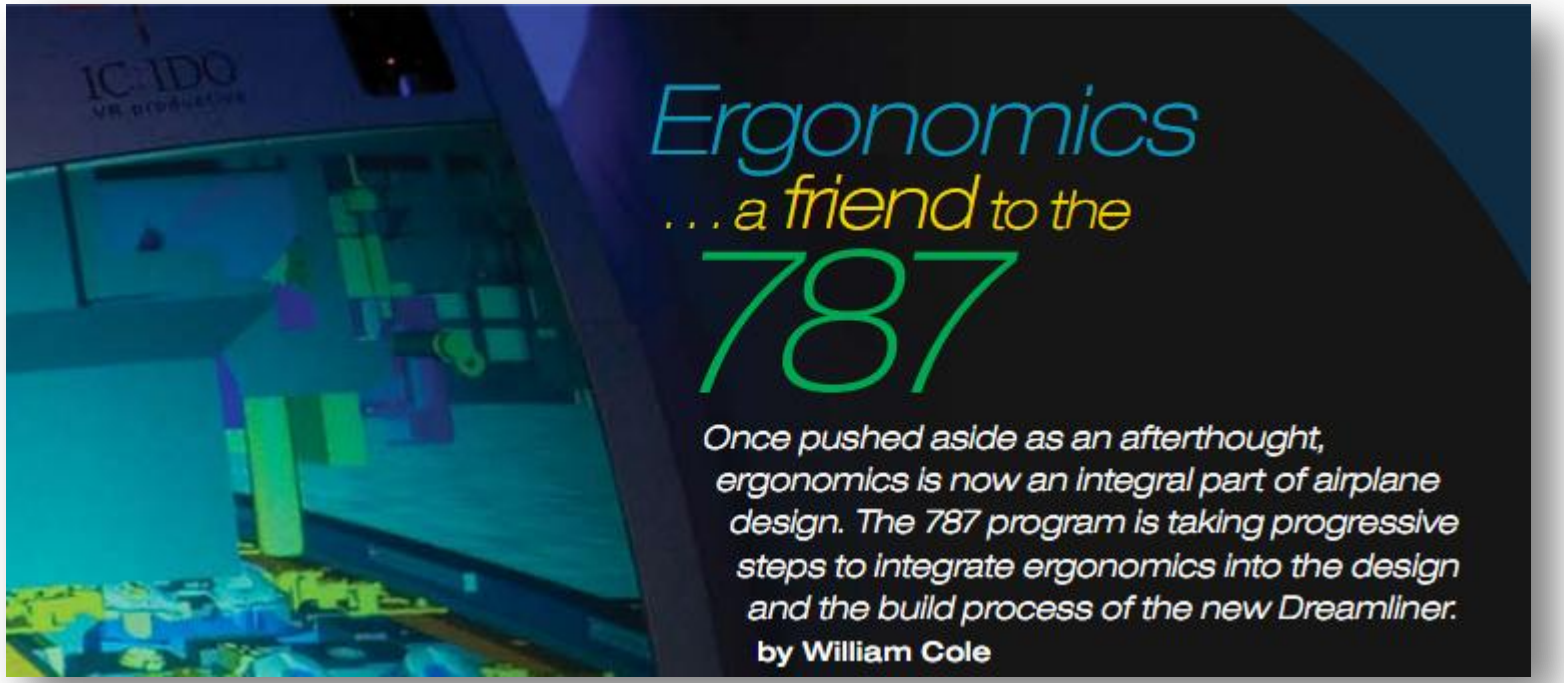
Nicolas Lepape
Virtual & Augmented Reality R&T Project Manager
Safran Nacelles

Awards «Operational Excellence and Competitiveness Innovation»

esi IC.IDO

get it right®

ESI as a ***catalyst*** and digital solution ***integrator***



"Due to increased awareness of ergonomics and advances in design capabilities, we now have a seat at the design table."

Rich Gardner

Collaborative Peer review

ESI as a ***catalyst*** and digital solution ***integrator***

Growing Eco-system

CORAC
Aéronautique
Environnement
Recherche

Innovative propulsive systems

Innovative propulsive Architecture

Innovative nacelle, structure and integration

Virtual Test

Co-creation
Integration
& Transfer

cea ALTRAN MEDYSYS LIEBHERR SAFRAN AEROSPACE · DEFENCE · SECURITY AIRBUS SKF SilMach
dgac DASSAULT AVIATION AIRFRANCE

Take Away

Take Away: The Digital Transformation – 1/2

The Outcome Economy :

- Solutions Performance
  - Enterprise → Eco-system
  - Customer → Anonymous
  - Jobs → Ubiquitous

- Industry 4.0
  - Smart Factory
    - 'As built' 'as tested' theory/*causal* based modeling
    - Data driven modeling *update*
    - Virtual Lab for *Engineering* materials

- CAE 4.0 +
  - Virtual Prototyping
    - Multi-Trade chaining per Domain
    - Multi-Domain integration per Component within Systems and Operational Environment
    - Immersive Virtual Engineering **(IVE**) for Collaborative Peer review

Take Away: The Digital Transformation – 2/2

The CAE-4 Outcome Value Proposition

PLM
Product Lifecycle Management

Virtual Prototype

"As built As Tested"

for Pre-Certification

Theory
based
&
Data driven
updated

PPL
Product Performance Lifecycle

Product Development Lifecycle

get it right®

Product Performance Lifecycle

keep it right and use it right

Smart Factory for fabrication and repair – Assembly Cell

Hot forming - AP&T

Thank you for your attention!