DIGITAL TWINS FOR THROUGH-LIFE SUPPORT - SETTING THE REQUIREMENTS

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Through-life Engineering Services (TES) Centre: Features

Great pedigree: Evolved from the EPSRC TES Centre (£11.2m)

Aim: The new TES Centre aims to increase the maturity level of the TES application to enable rapid industrial exploitation.

The TES Centre is a rolling technology programme incorporating a wide range of projects (industry, collaborative, PhDs/Masters, internal projects)

A large team of experts at Cranfield to deliver the technology

5 major industrial TES programme members

BOMBARDIER

MINISTRY OF DEFENCE

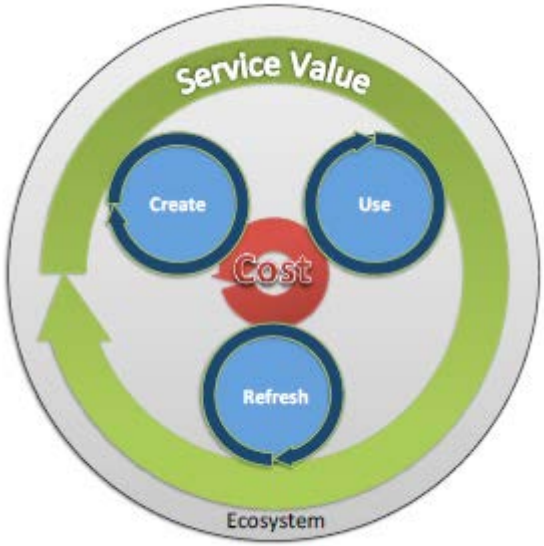
Rolls-Royce

babcock trusted to deliver™

BAE SYSTEMS

Through-life Engineering Services

The design, creation and in-service sustainment of complex engineering products with a focus on their entire life cycle, using high-quality information to Optimise their availability, predictability and reliability at the optimum through-life cost.



The continuous and cyclic nature of TES

TES Centre: Overview

Degradation studies

- Mechanics degradation
- Electronics degradation
- No Fault Found
- Inspection Automation
- Materials: metals, plastics and composites
- Physical Experiments, Modelling and Analytics
- IoT Lab (industrial “sandpit”)

Certified Inspection Services:

- Thermography
- Eddy current, Phase array

Digital Services Engineering

- Virtual reality
- Augmented reality
- Digital Twin
- Manufacturing and service modelling and simulation
- Risk and uncertainty quantification
- Cost modelling
- Life cycle and process optimisation
- Obsolescence management
- Servitization and organizational transformation
- Machine learning

TES Centre: Facilities

Digital Services Laboratory (Equipment)

- Hardware: Full immersive Virtual and Augmented Reality kit
  - Art Trackpack optical tracking system
  - NVIS ST50 VR/AR headset
  - Flystick2 3D mouse
  - Oculus Rift VR Headset
  - Dell NVIDIA Quadro K5000 workstation
  - Optomo HD projector
  - Dual screen display
  - Google glasses, HoloLens, Epson Movario

- Software:
  - Virtalis Visionary Render
  - Unity
  - Unreal

- **Virtual conferencing studio** (Tele-con facility for up to 500 participants at the same time)

- 9 screen video wall
- 3D scanner
- 3D printer MakerBot Replicator

Conceptualisation of “Digital Twin” in the Service Environment

- MSc Through-Life System Sustainment - Group Project 05/09/2016

Results – Pan-Industry Survey

- 49 complete responses
- 31 different organisations from variety of sectors such as Aerospace, Consulting, Software, Defence, Maritime, Manufacturing and Academia
- 64% of respondents understand what the Digital Twin Idea is
- 31% believe that Digital Twin will transform their business

Definition

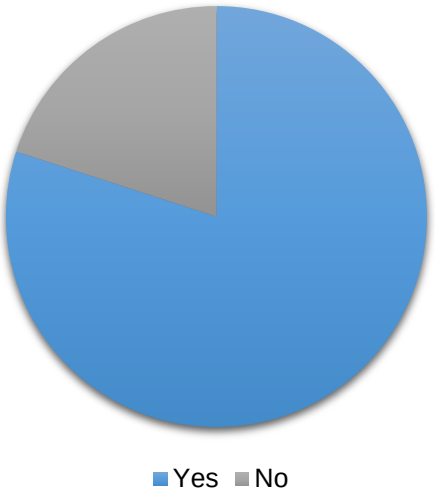
The definition below has been developed from previous literature, survey results and discussion:

“A digital representation of a physical item or assembly using integrated simulations and service data”

- The digital representation holds information from multiple sources across the product lifecycle.
- This information is continuously updated and is visualised in a variety of ways to predict current and future conditions in both design and operational environments in order to enhance decision making.”

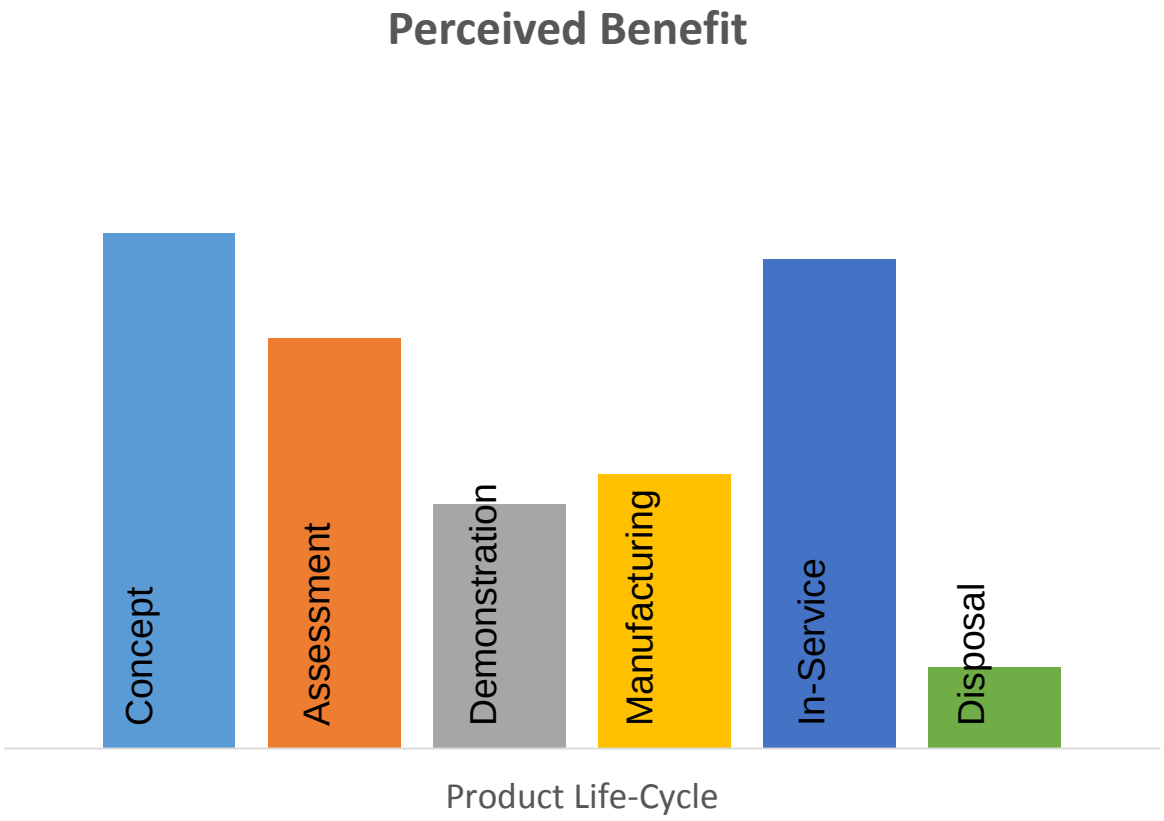
Results – Pan-Industry Survey

Are elements of the digital twin present in your company?

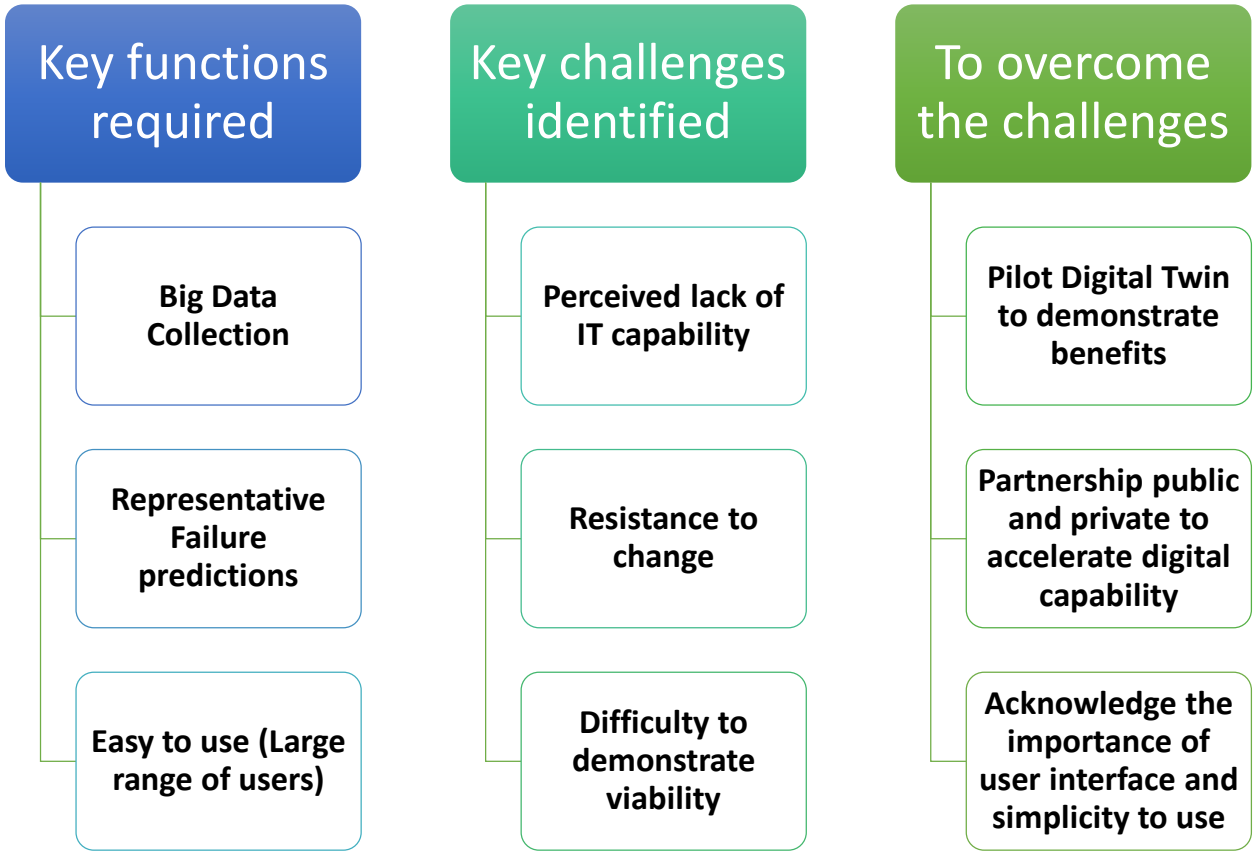


- Independent sectors recognise the concept
- The majority of participants see benefits in the implementation
- Several companies have already started to develop Digital Twins
- Individuals see different advantages, causing a lack of focus on a standardised aim
- Difficulties creating tangible business cases lead to conservative investments in the subject

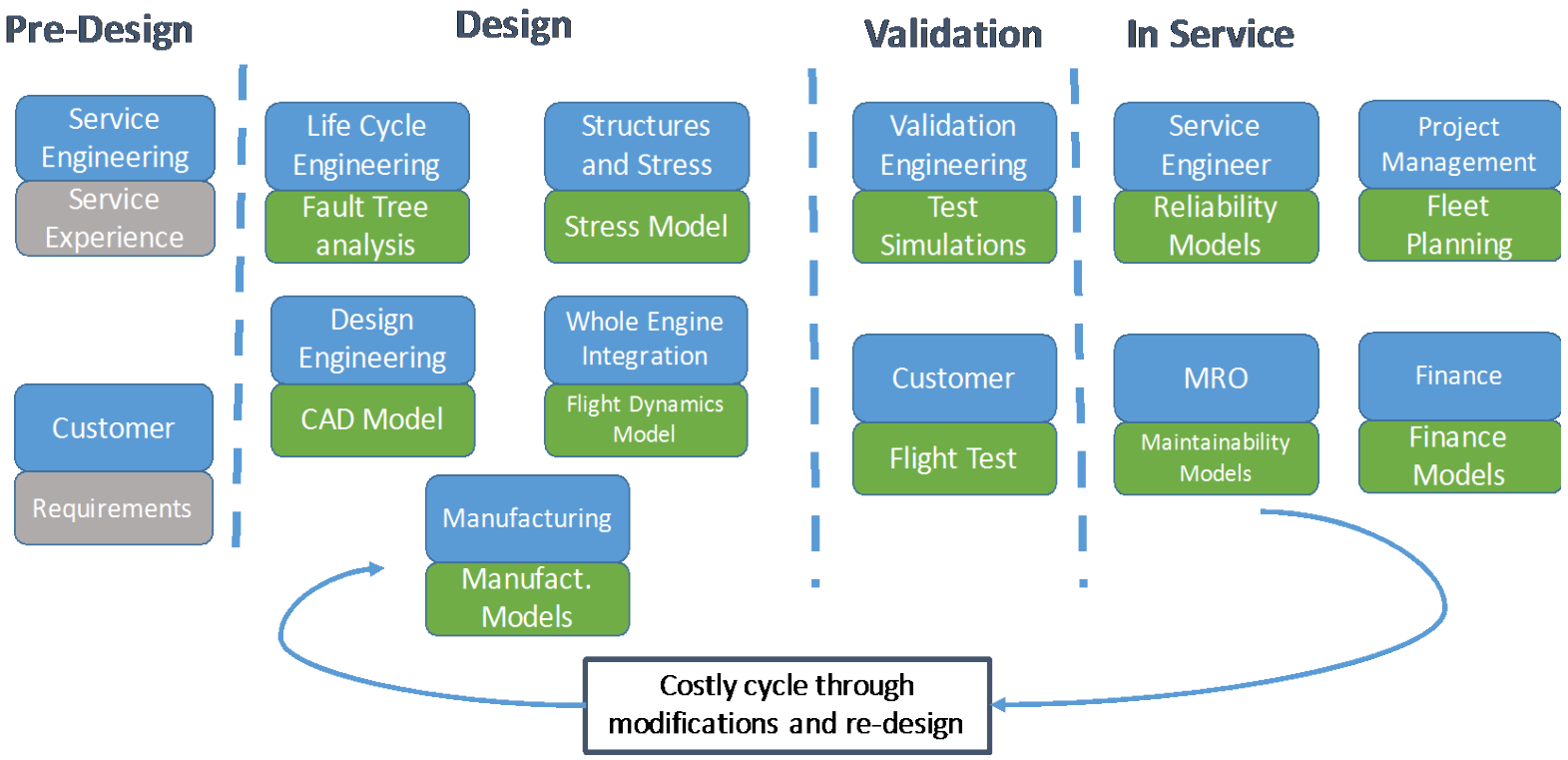
Perceived benefits of Digital twins



Enabling digital twins



Current models used during the lifecycle of a product



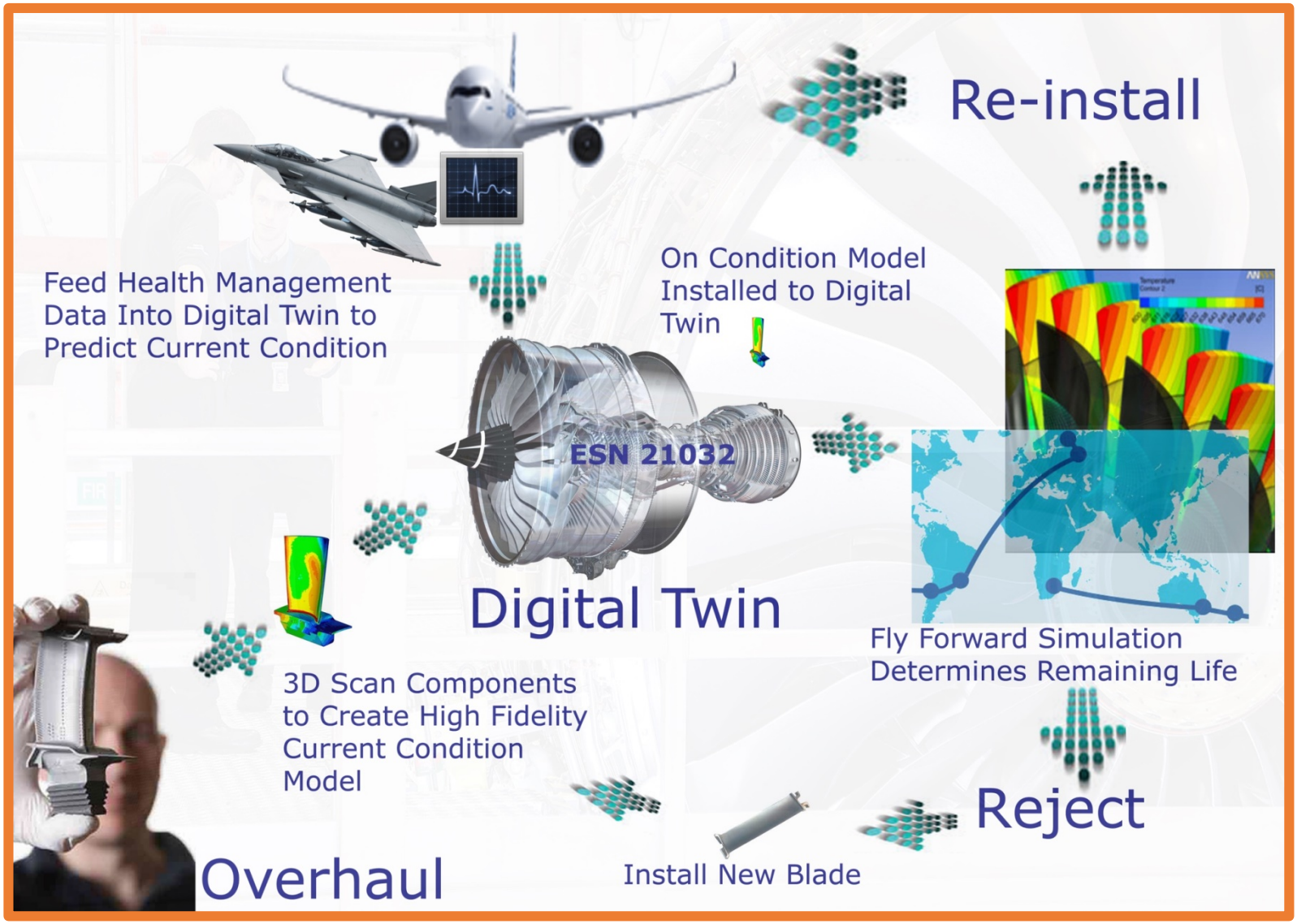
Digital twin concept

Integrated Technologies of a Digital Twin adapted from: (Glaessgen and Stargal, 2012, p.12)

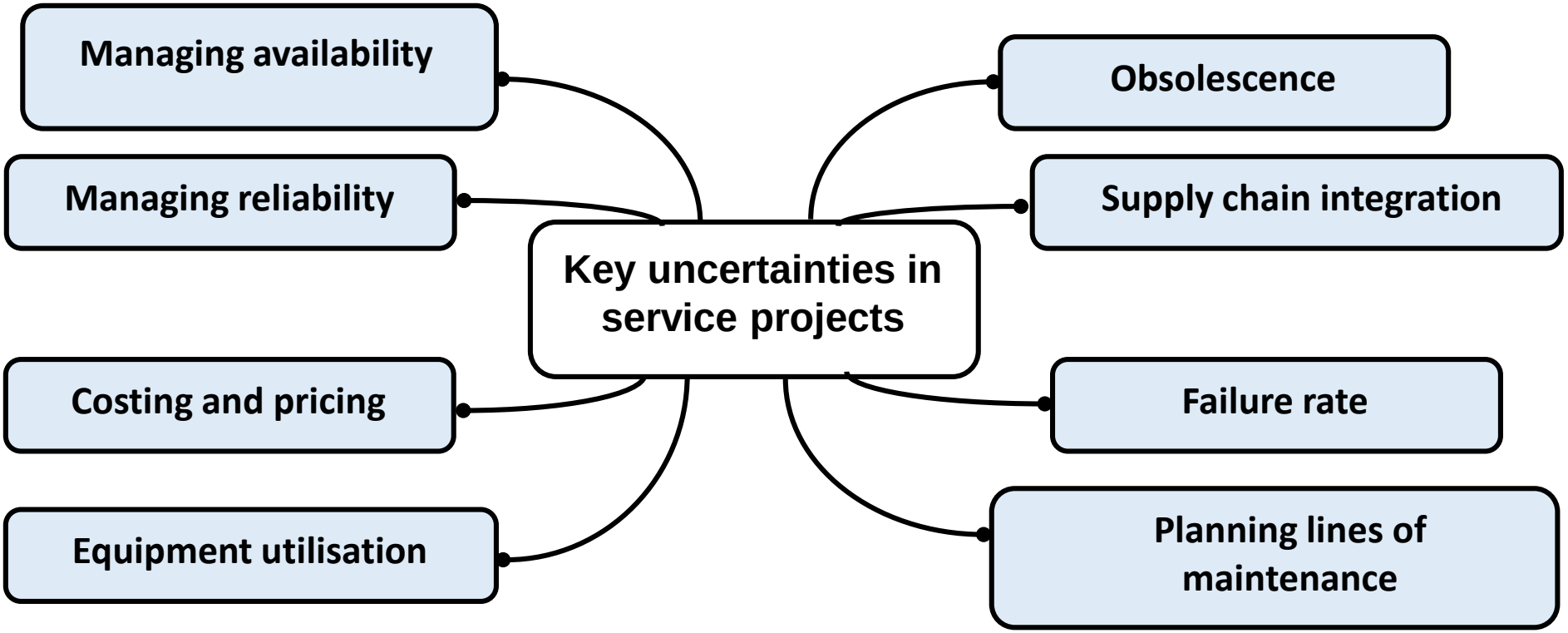
Benefits

- Tailored maintenance packages specific to Tail number or Engine serial number.
- Just in Time (JIT) spares provisioning reduces maintenance burden on spares with a ‘shelf life’.
- Potential to reduce costly range of Test Equipment (TE), user manuals, spares for TE, calibration requirements, facilities.
- Tailored Training Packages to train maintainers on ‘what will fail’ rather than ‘what might fail’.
- Ability to generate, capture, organise, and utilise relevant data & information to enable true Condition Based Maintenance
- Engineering Knowledge Management, Collaborative Environment and Repository for Engineering Knowledge in Support of Life Cycle.
- A virtual platform to record and update the as-maintained BOM of that particular serial numbered asset.

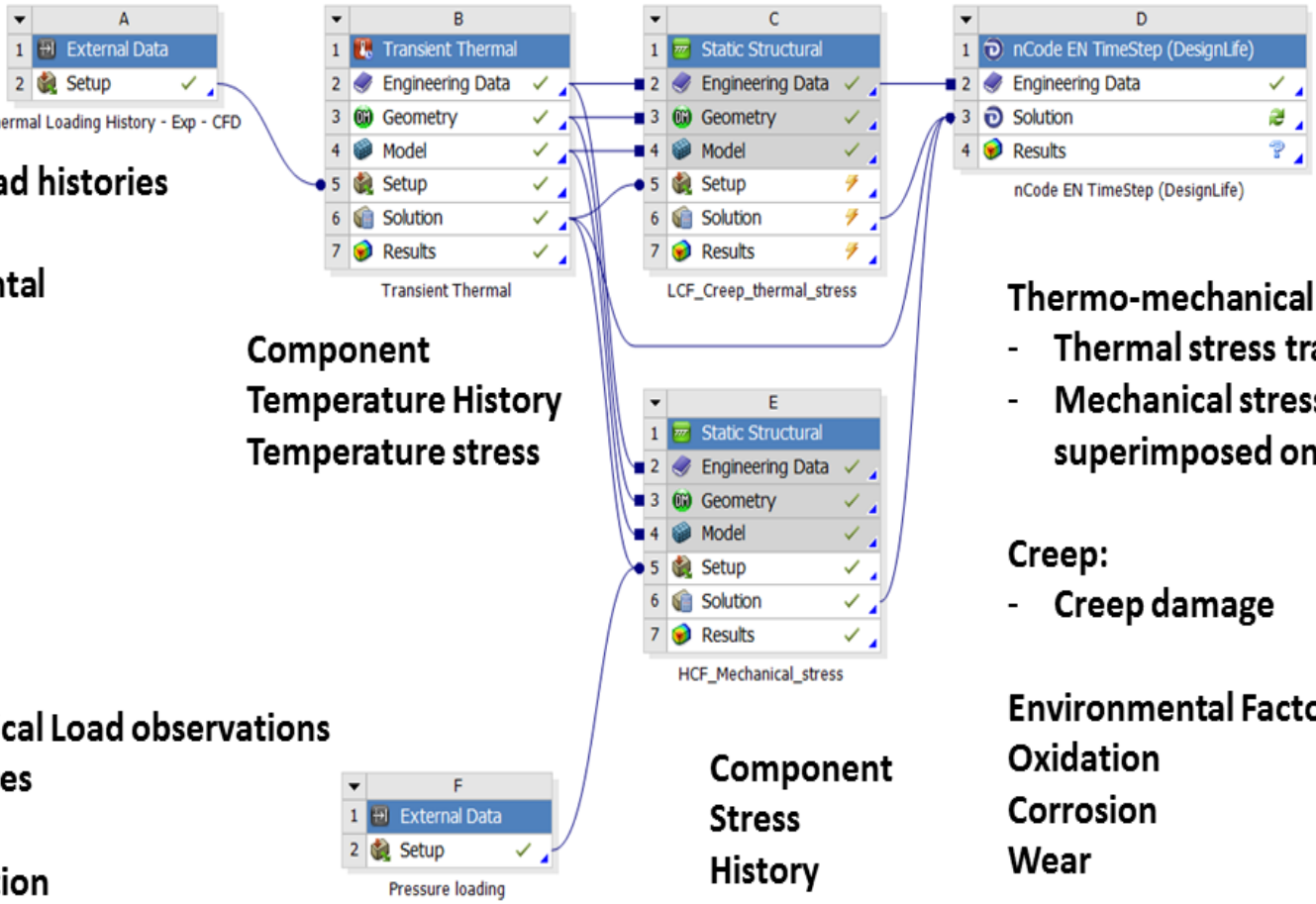
Concept


Re-install
Feed Health Management Data Into Digital Twin to Predict Current Condition
On Condition Model Installed to Digital Twin
ESN 21032
Digital Twin
Fly Forward Simulation Determines Remaining Life
3D Scan Components to Create High Fidelity Current Condition Model
Reject
Overhaul
Install New Blade

Key uncertainties in service projects



Concept



Thermal Load histories
- In service
- Experimental
- CFD

Component
Temperature History
Temperature stress

Thermo-mechanical fatigue:
- Thermal stress transient
- Mechanical stress varying – superimposed on thermal stress

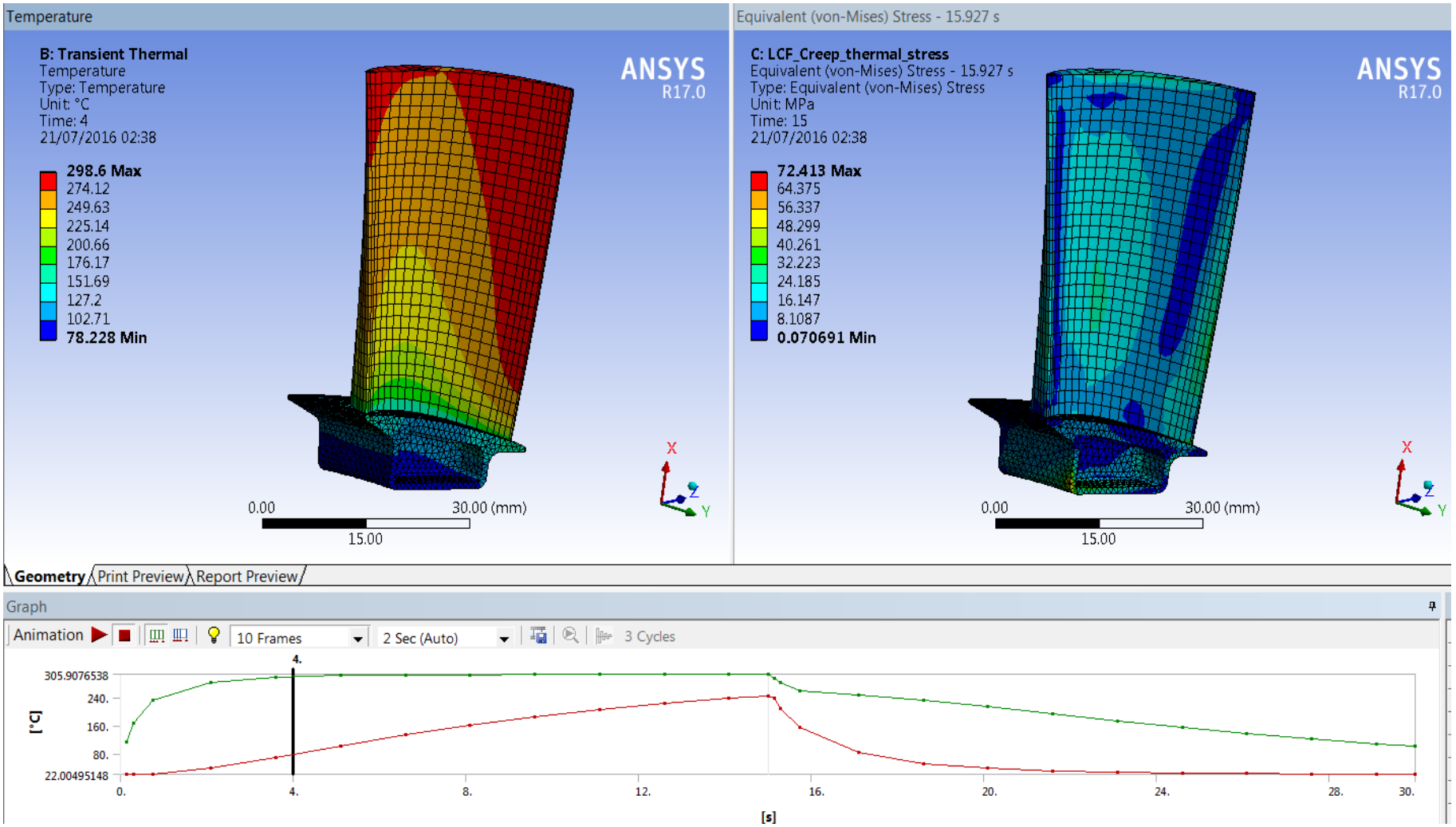
Creep:
- Creep damage

Environmental Factors:
Oxidation
Corrosion
Wear

Mechanical Load observations
- Pressures
- RPM
- vibration

Component
Stress
History

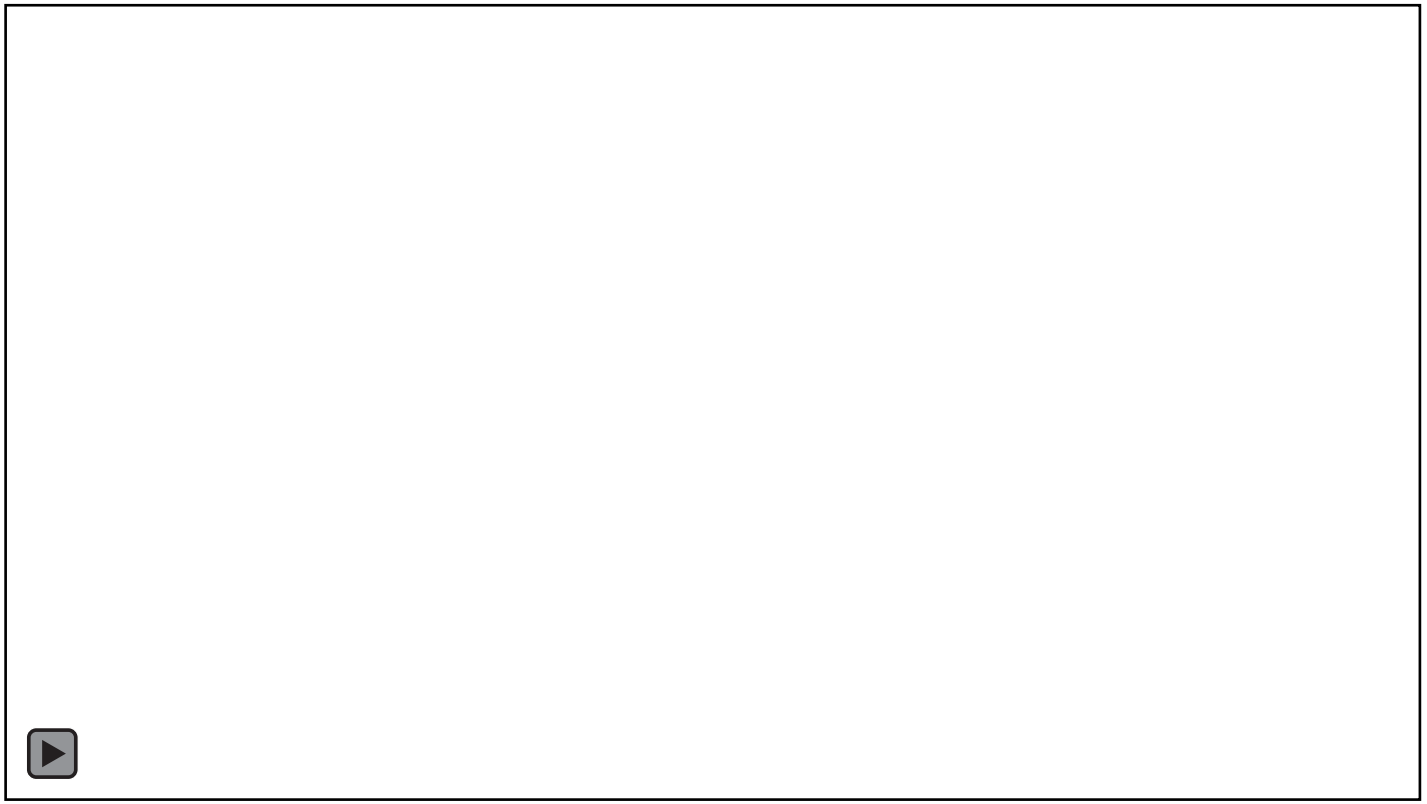
Concept


Temperature
B: Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 4
21/07/2016 02:38
298.6 Max
274.12
249.63
225.14
200.66
176.17
151.69
127.2
102.71
78.228 Min
ANSYS
R17.0
0.00
30.00 (mm)
15.00
X
Z
Y
Equivalent (von-Mises) Stress - 15.927 s
C: LCF_Creep_thermal_stress
Equivalent (von-Mises) Stress - 15.927 s
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 15
21/07/2016 02:38
72.413 Max
64.375
56.337
48.299
40.261
32.223
24.185
16.147
8.1087
0.070691 Min
ANSYS
R17.0
0.00
30.00 (mm)
15.00
X
Z
Y
Geometry
Print Preview
Report Preview
Graph
Animation
10 Frames
2 Sec (Auto)
3 Cycles
305.9076538
240.
160.
80.
22.00495148
[°C]
4.
0.
4.
8.
12.
16.
20.
24.
28.
30.
[s]

Digital twin examples

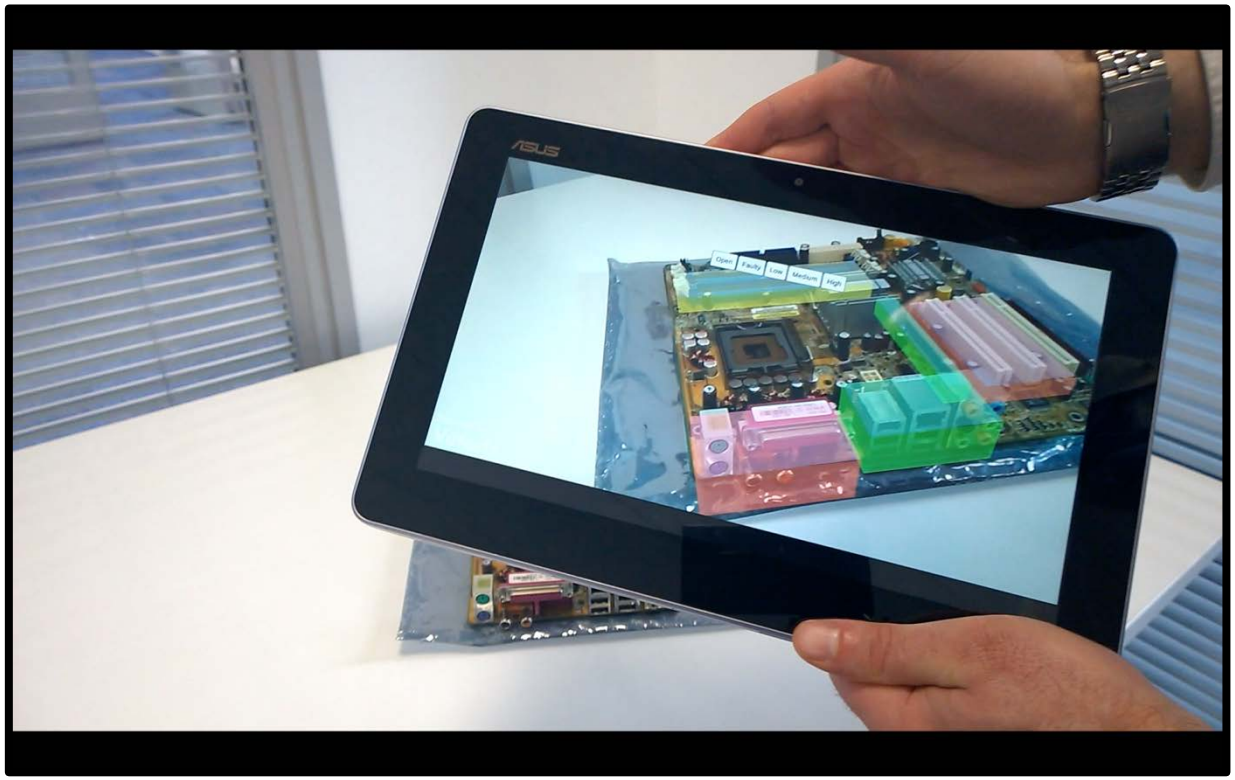
Example 1: Remote collaboration

- Physical attributes
- Predicting cost
- Real time data about equipment health
- Verify and validate



Digital twin examples

Example 2: Obsolescence



- Real time data overlay
- Flexibility to light conditions
- Remote collaboration

Design for through-life performance

Scientific challenges in digital twins

- Predicting how a physical product behaves and performs in the future in a range of alternative scenarios and environments
- Developing algorithms to predict fatigue life, corrosion and delamination for metallic and composite components
- Developing a link between the design and manufacturing attributes to the in-service degradation
- Continuous data management of failures or damage for developing real-time continuous digital twin at component and system level

Roadmap

Timescale	Level of Digital Twin	Benefits	Requirements
CURRENT STATE	**Concept of a Digital Twin** • Disjointed set of capabilities (Simulation and Analytics) • Access to large amounts of raw data • Digital design	• Identified benefits to different stakeholders/industries	• Academic and industry research
SHORT TERM	**Component Level Digital Twin** • Requirements based creation • Defined connections between requirements • Data sharing	• Financial savings on high risk components • Enable feedback to design in lifecycle • Advance part sentencing	• Validated simulation accuracy Set Digital Twin format standards • De-compartmentalised Culture • Prediction capability (uncertainty models) • FMEA tool connectivity • Accurate to real life analytics
MEDIUM TERM	**System Level Digital Twin** • Integrated culture • Produce ROMs for whole system for speed • Incorporate FMEA information to simulation • Validated system level simulation accuracy • Enable feedback to design in lifecycle	• Determination of more accurate overhaul workscopes • Increased reliability, and efficiency	• Increased measurements/data acquisition • Proven cases to regulatory bodies
LONG TERM	**Full Scale Platform Digital Twin** • Service management • Customer usage • Artificial intelligence and learning	• Optimal decision making • Visibility of predicted current condition • Ability to predict issues and manage product accordingly • Digital certification • Substantially reduce physical testing	• Industrial collaboration • Crowdsourcing of twin development • Accessibility and security

Conclusions

- Elements of Digital Twin technology available but has not been integrated together to create a full Digital Twin.
- The Digital Twin will require collaboration between partner companies across industry, including hardware and software companies.
- Future development of the Digital Twin will require standardisation to ensure this collaboration can be fully exploited.
- The Digital Twin applications will require detailed cost/benefit analysis.
- Computational power and storage will always be limited so the Digital Twin will require intelligent use of data to achieve the most efficient results.
- The Digital Twin could change the way we work as Engineers and will require consideration in the initial product requirements to ensure that products are designed to exploit the full benefits of digitally enabled services.

Further Work

- Create a comprehensive working prototype
- Verify accuracy between Digital Twin Simulation and physical components
- Develop a Business Case
- Set an industry standard for Digital Twins

Thank you! Any questions?

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