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High Value Manufacturing

(Composites) Perspectives on Transformation in Engineering

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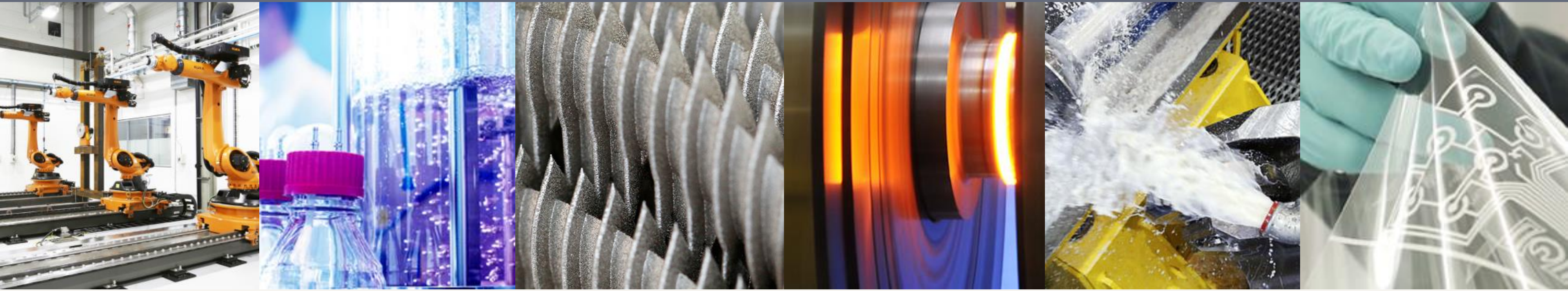

NMIS National Manufacturing Institute Scotland
AMRC Advanced Manufacturing Research Centre
cpi
mtc Manufacturing Technology Centre
National Composites Centre
Nuclear AMRC
WMG The University of Warwick

Manufacturing Mega Trends

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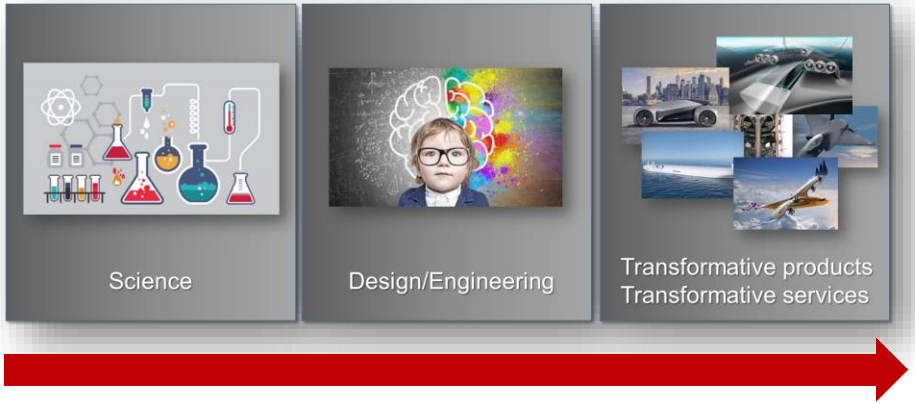
- Net Zero pressures will act as a major disruptor to global markets and to the provision of products/services to meet societal demand (major opportunity !)
- Supply Chain Resilience will play a key role in future actions (Gov't to Gov't, B2B et al)
- Growth of industrial capabilities in developing nations (BRIC ++) with supporting science and innovation capabilities (innovative manufacturing no longer restricted to the 'old world')
- Continued growth in size/numbers of global companies that may exceed the span/control of individual nations
- Rise in Intensive automation, autonomy and digitalisation (key to competitive edge in developed economies)

What is Engineering and why is it so influential?

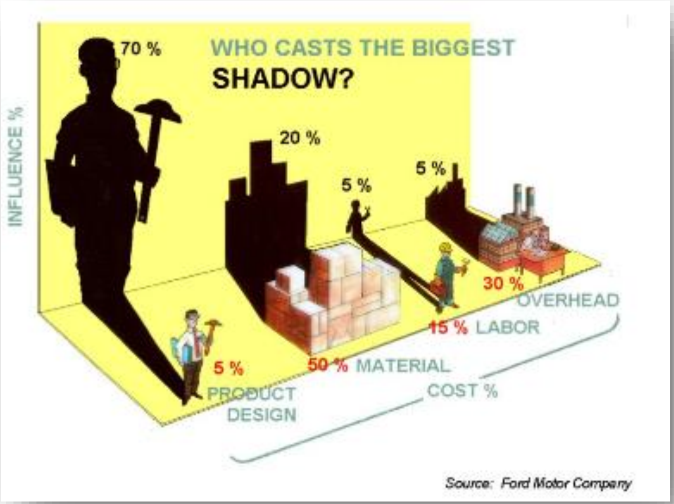
- Engineering is where science, ambition and imagination become a tangible, viable product
  - Combines analytical discipline with creativity and innovation
  - Enables the commercialisation of scientific outputs
  - Delivers practical solutions to society's greatest challenges



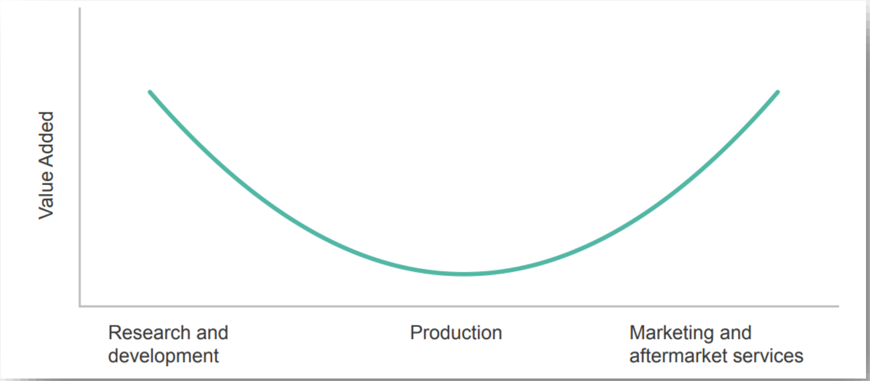
- Engineering leadership secures the control of the product architecture
  - Drives decisions on technologies, production and sourcing
  - Opens up new supply chain opportunities
  - Determines productivity and through-life performance

What is Engineering and why is it so influential?

- Engineering excellence is key to business competitiveness
  - >70% of lifecycle costs are "locked in" by design
  - Cost of rectifying in-service design problems can be considerable, even causing businesses to fail
  - Majority of value is added in the "design & engineering phase" of the product lifecycle



History of Lean Design, Munro & Associates, 1982

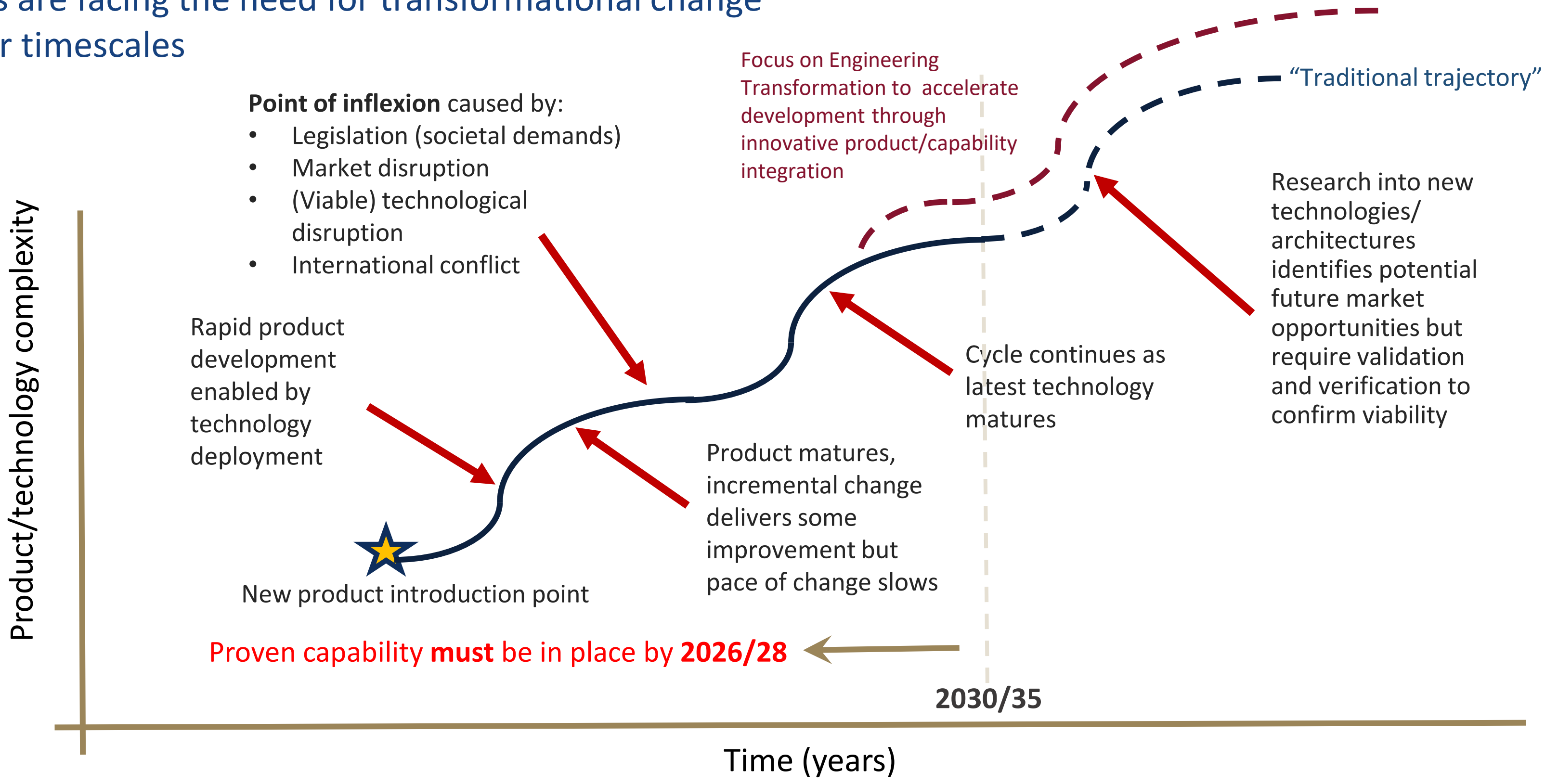


Smiling Curve Theory
Stan Shih 1992

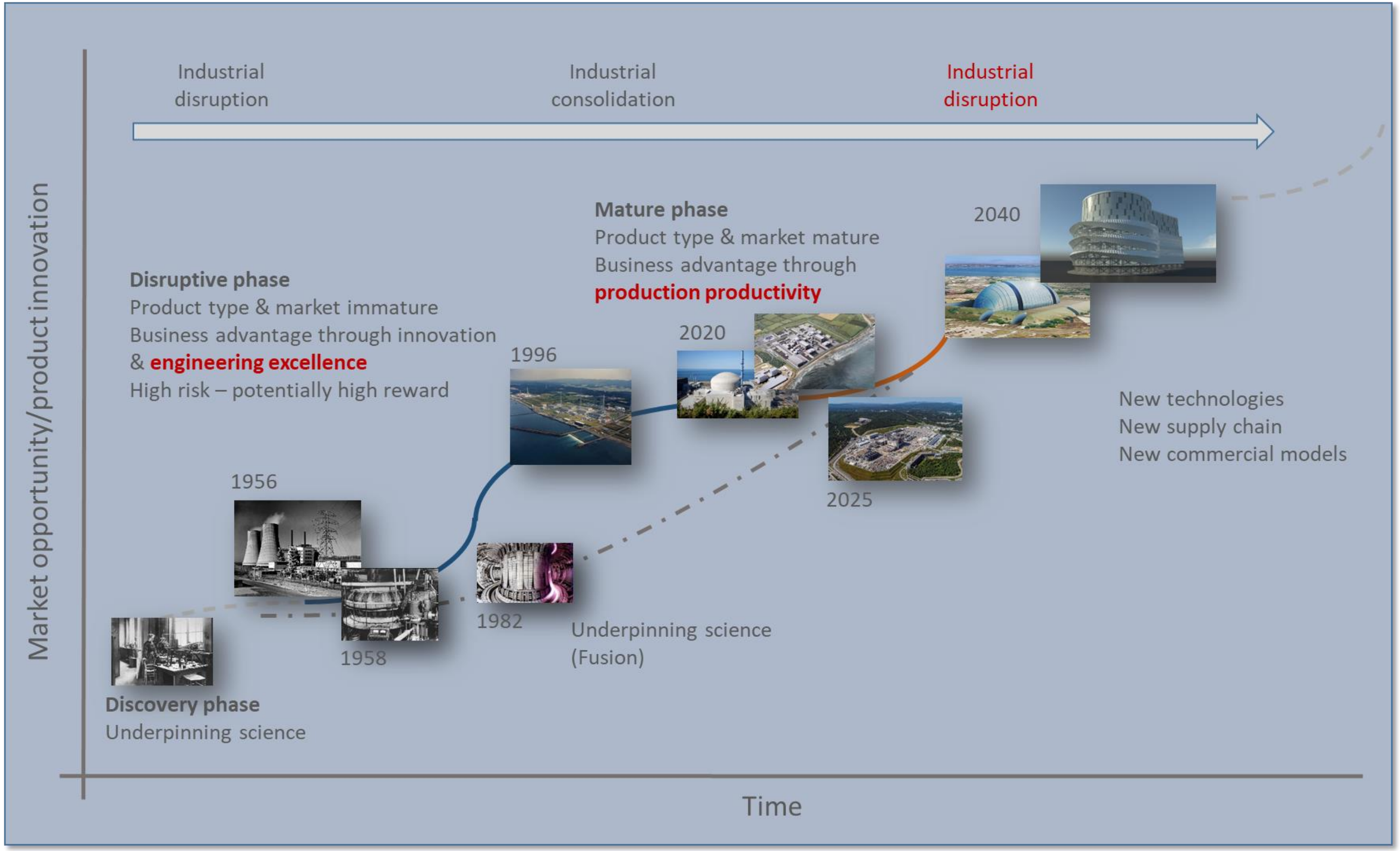
THE NEED FOR ENGINEERING TRANSFORMATION

Why now? - Product transformation points

- Many sectors are facing the need for transformational change within similar timescales



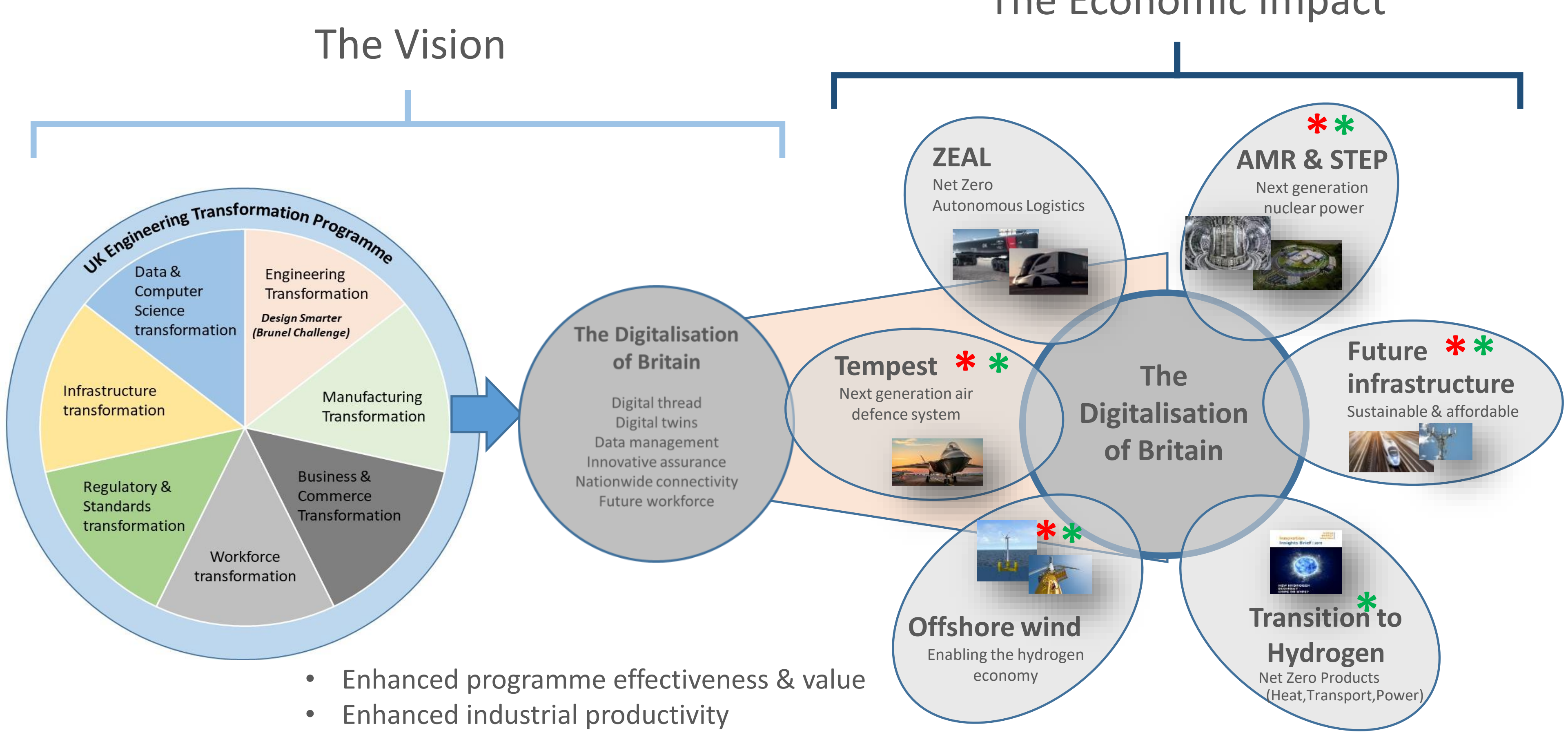
Industry is entering an exciting new age



Industry is entering an exciting new age

- Many industrial sectors are entering a period of major technological and commercial revolution following an extended period of evolution
  - Risks must be managed more effectively to allow for technical innovation & disruption
  - Government capital programmes require enhanced agility, affordability and in-service delivery
- Delivering reliable & competitive product solutions will require transformational technological & cultural change in the product development and assurance process
  - Not all of today's product knowledge & skills base will be relevant to future product applications
  - New technologies, materials and production processes need to "work first time"
  - New regulatory frameworks will be required
  - Assurance costs and timescales need to be reduced significantly
  - Greater product integration will require democratisation of capability across the supply base
- Engineering capability will define industrial competitiveness for decades to come

Industry is entering an exciting new age

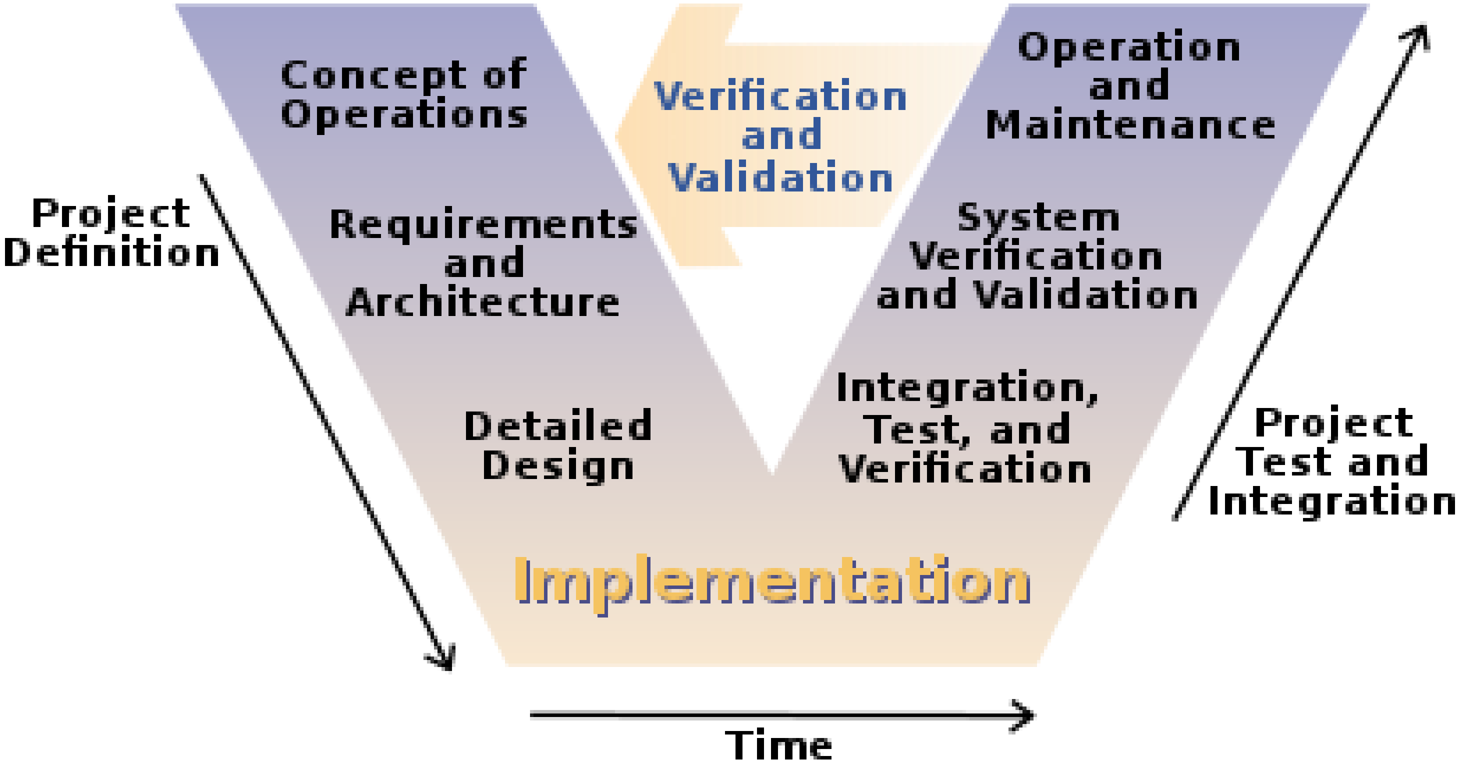


- Enhanced programme effectiveness & value
- Enhanced industrial productivity

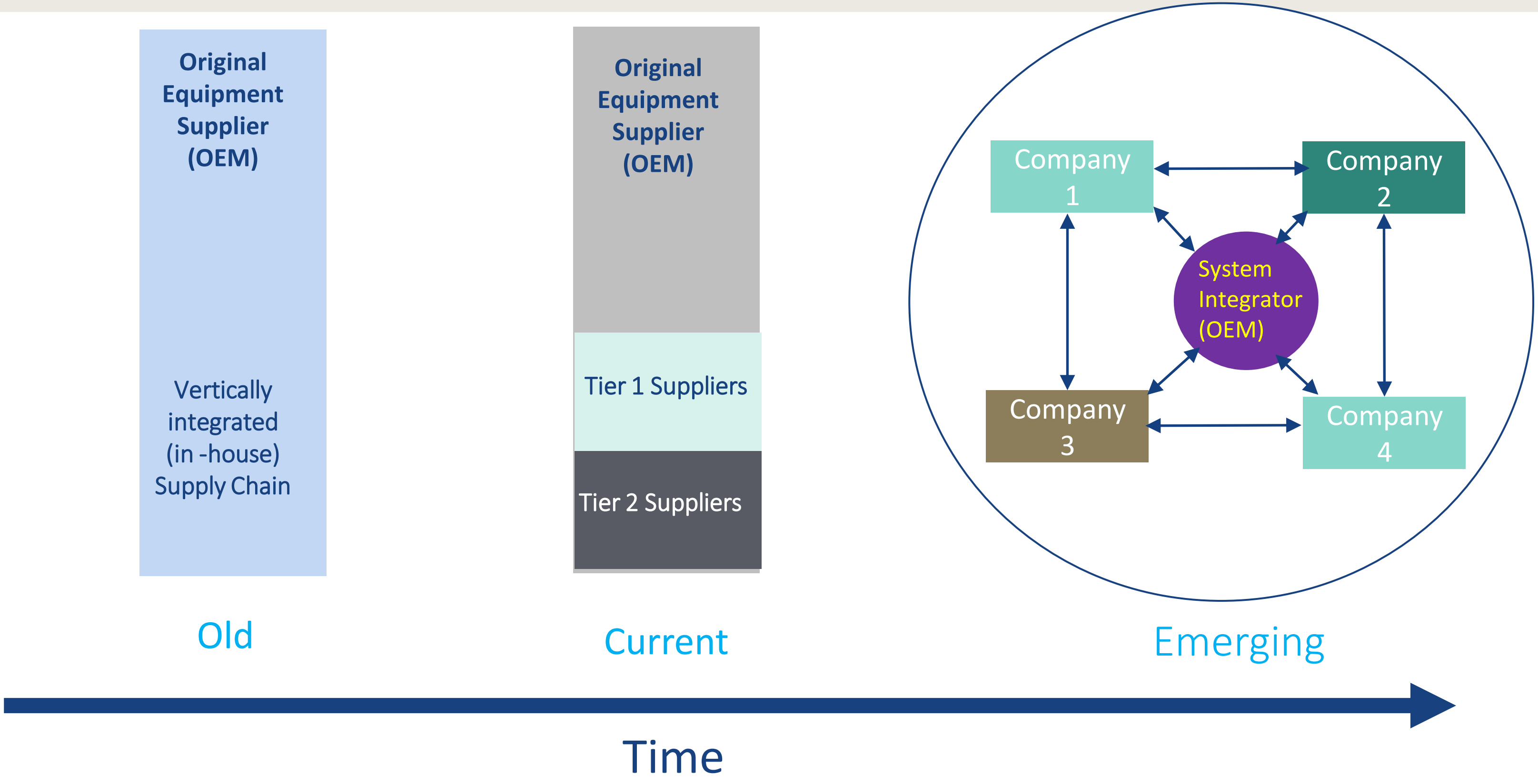
* UK Gov't funded/controlled programmes

* Part of 2021 Spending Review announcement

How we do things currently – the systems engineering 'Vee'



Changing the Enterprise



The need to move beyond the systems engineering 'Vee'

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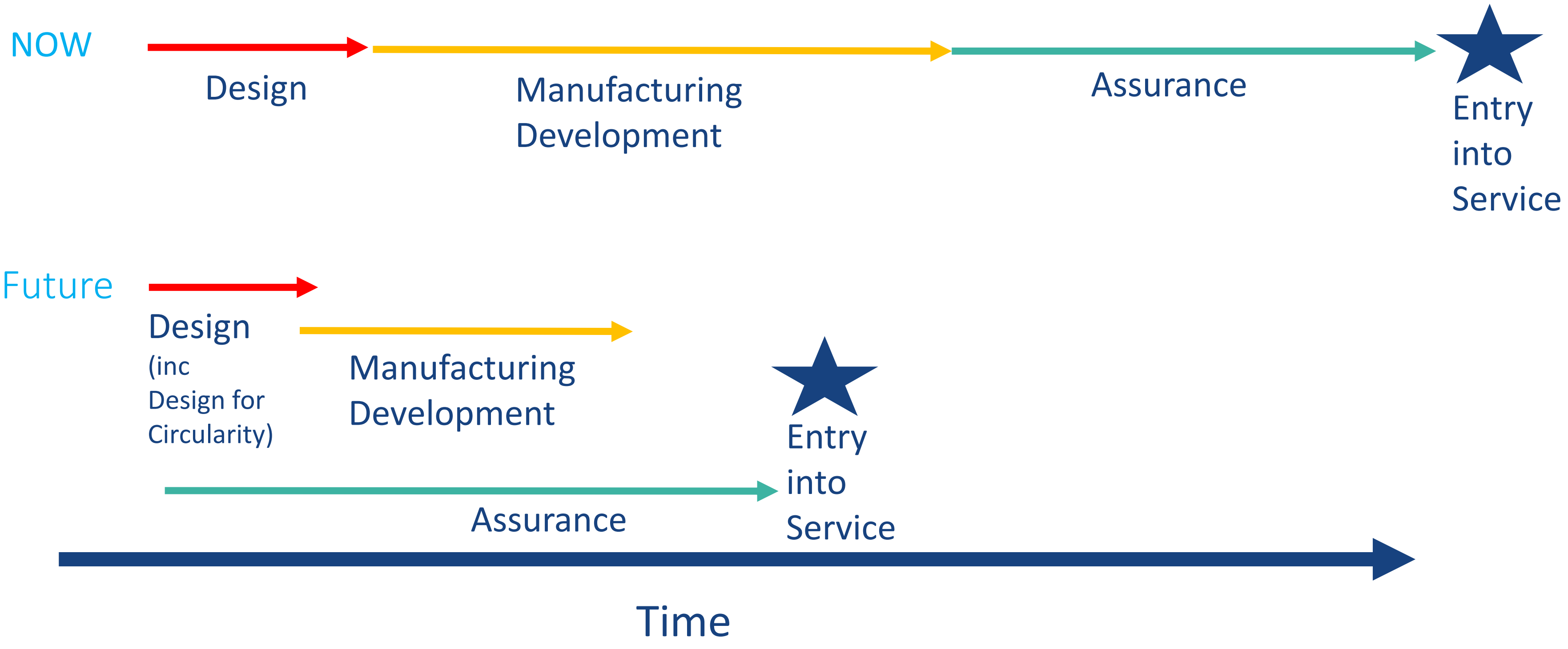

The path towards engineering transformation

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1. Digital engineering environment

Optimising product performance from inception to disposal and enhancing manufacturability through transformation in engineering productivity

- Delivering capabilities and techniques to digitally replicate real-life product characteristics
- Expanding the use of artificial intelligence capabilities to capture human know-how and support robust decision-making
- Maximising the exploitation of current and emerging computing platforms
- Enabling full lifecycle simulation through the use of integrated, variable fidelity simulation and innovative analysis processes
- Understanding user psychology and transforming the user interface

2. Enterprise integration & co-creation

Right first time, complex product solutions, embracing new technologies, processes & services

- Supporting growth throughout the enterprise ecosystem through participation in collaborative development challenges
- Increasing digital enablement within the supply chain
- Adoption of innovative approaches to IP management to encourage engagement of the wider enterprise ecosystem
- Influencing the definition and harmonisation of data standards throughout engineering

3. Transformative engineering culture & skills

Ensuring continued business competitiveness and success

- Delivering the future Engineer – combining digital and data science skills with in-depth understanding of physics within engineering
- Providing opportunities to gather proven experience through realistic product and process development challenges
- Embracing cultural and societal evolution
- Maximising the benefits of artificial intelligence capabilities

4. Validation, certification & assurance

Accelerating business improvement and managing risk

- Developing capabilities and processes to facilitate virtual product assurance
- Developing test techniques and enabling infrastructure to validate numerical simulation tools and processes
- Delivering the route to certification through simulation
- Developing techniques to manage risk and uncertainty associated with generational change

Initial "proof of concept" projects to accelerate engineering transformation

- **Secure enterprise integration and co-creation**
  - Accelerated and enhanced product concept development through co-creation across the supply base
  - Integrated design reduces risk, accelerates innovation and controls costs
  - Requires research into information exchange, trust & provenance, affordability and security
- **Set-based design**
  - Allows for parallel definition and evaluation of multiple solution concepts
  - Enhances lifecycle optimisation and "future proofs" capability
  - Provides means to analyse effects of requirements variation and delays need for down-selection decision
  - Requires research into requirements management, rapid analysis methods and uncertainty quantification
- **Digital Thread**
  - Extracting full benefit from the "thread of knowledge" delivered by digital design
  - Providing seamless integration of information across the lifecycle, providing a lasting record of analyses and decisions
  - Requires research into application integration, context capture and automated information management
- **Innovative assurance and regulation**
  - Exploiting advances in mathematics and data science to accelerate assurance and reduce costs
  - Unlocking opportunities for secure validation of technology applications and operational models
  - Requires research into applicational of mathematical methods, long term data retention and smart testing methodologies
- **Authoritative Digital Twin**
  - Creating authoritative, predictive and certifiable outputs from digital twins
  - Integrating digital twin technologies into complex product development and lifecycle management processes

Towards Product Certification by Analysis (CbA)

Work Package 1 – Assessment Methodology and Roadmap Definition

Certification by Analysis Work Package Breakdown

WP 1 Assessment Methodology and Roadmap Definition

- To develop a 'Certification by Analysis' assessment methodology/readiness scale, state-of-the-art mapping of product certification processes and derivation of a roadmap for future state

WP 2 Use Case Development

- To conduct investigation into state-of-the-art techniques (case studies), explore boundaries for application and future development as well as feasibility of methodology proposed in WP1 and support to a wide-reaching roadmap

WP 3 Engineering IT Environment

- To establish an Engineering IT environment to host research activity and deliver compute capacity, as well as preliminary research into requirements for effective collaboration and traceability of data, knowledge and decisions across certification ecosystems

WP 4 Skills Foresighting

- To conduct foresighting activities to map skills and competencies of a workforce able to deliver future state as well as reviewing current training content, identifying gaps and assessing supply chain ability to fulfil training needs

Work Package 1 – Approach

- The purpose of this work package is to define a methodology for the assessment of a product/process in terms of suitability for 'Certification by Analysis' (focusing on regulatory compliance).

- By applying this approach to several examples/case studies we expect to identify quick wins and a roadmap for future development; to inform further research activities and engagement with stakeholders including industry and representatives from the appropriate regulatory bodies.

- In addition, there are 'attributes' against which the assessment should take place. These include practical and commercial considerations such as the cost and sustainability impact of testing vs analysis, timescales for completion, quality of the outputs/results, the risk associated with the approach and the level of trust that can be placed on the information generated to support the compliance process

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Indicative Readiness Level Methodology

- Level 0 – Proof testing
- Level 1 – Production sampling
- Level 2 – Product sample / prototype-based certification
- Level 3 – Hybrid certification
- Level 4 – Smart testing virtual certification
- Level 5 – Virtual certification

CbA Levels

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Level 0 – Proof testing

Every product is tested before use against defined operational criteria.

Level 1 – Production sampling

No dedicated prototyping.

Regulation compliance demonstrated via product sampling taken from production line.

Compliance via physical testing of production items against defined measured performance criteria.

Level 2 – Product sample / prototype-based certification

Compliance demonstrated based on prototypes / physical testing alone.

Physical testing covers components, sub-assemblies and complete product, with compliance demonstrated against defined product performance criteria.

No numerical simulation data used within the regulation / compliance process.

Level 3 – Hybrid certification

Compliance demonstrated via combination of numerical simulation and physical testing of sub-scale models, components, sub-assemblies or complete product.

Numerical simulation compliance demonstrated by suitability and user quality assessment, physical testing of sub-scale models and full-scale components / sub-assemblies.

Compliance demonstration of non-safety critical components possible via numerical simulation.

Level 4 – Smart testing virtual certification

Compliance demonstrated via numerical analysis (simulation, uncertainty quantification, etc.) with simulation methods/processes validated via smart testing – i.e., design methods validated rather than the product.

Design integration based on validated numerical models of individual components and sub-assemblies.

Ongoing calibration of simulation/uncertainty methods via in-service experience.

Ongoing development of smart testing techniques based on feedback from in-service experience.

Compliance demonstrated against quality of smart testing processes, methods application (suitability and user quality) and suitability and performance against specified criteria.

Level 5 – Virtual certification

No physical testing within the design compliance process. Compliance demonstrated via numerical analysis (simulation, uncertainty quantification, etc.) against defined regulatory criteria.

Design integration based on validated numerical models of individual components and sub-assemblies.

Ongoing calibration of simulation/uncertainty methods via in-service experience.

Compliance demonstrated against methods application (suitability and user quality) and suitability and performance against specified criteria.

Production quality compliance based on numerical simulation and targeted process validation via smart testing.

Operation into service based on complete product-related simulation compliance.

Thank you

Questions ?