Nathan Hartman

Director, Digital Enterprise Center Purdue University

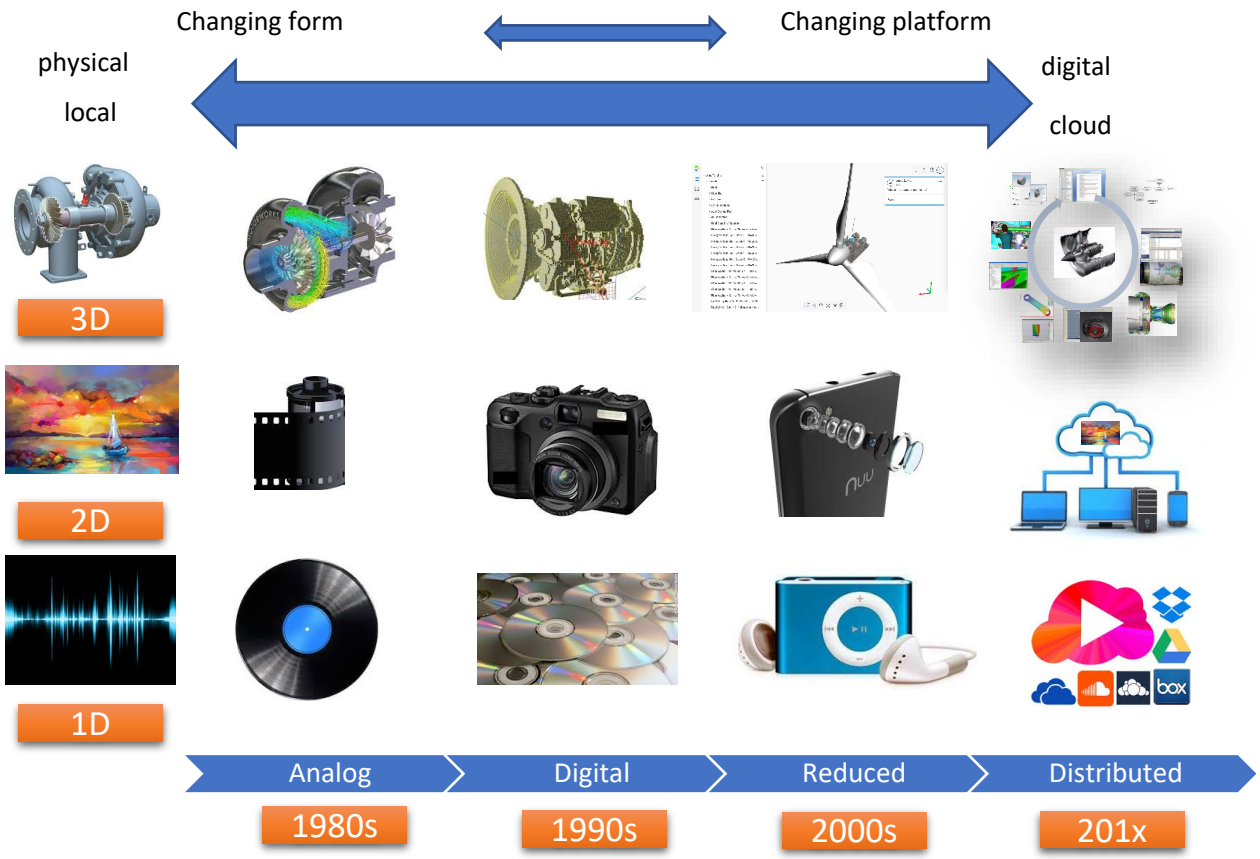
PURDUE UNIVERSITY®

Nathan W. Hartman, Ed.D.
Dauch Family Professor of Advanced Manufacturing and
Head of Computer Graphics Technology
Director, Digital Enterprise Center
Co-Executive Director, IN-MaC

The digital twin and its role in manufacturing and supply chain

In collaboration with Dr. Michael Sangid and Dr. Dan Delaurentis

Digital Disruption

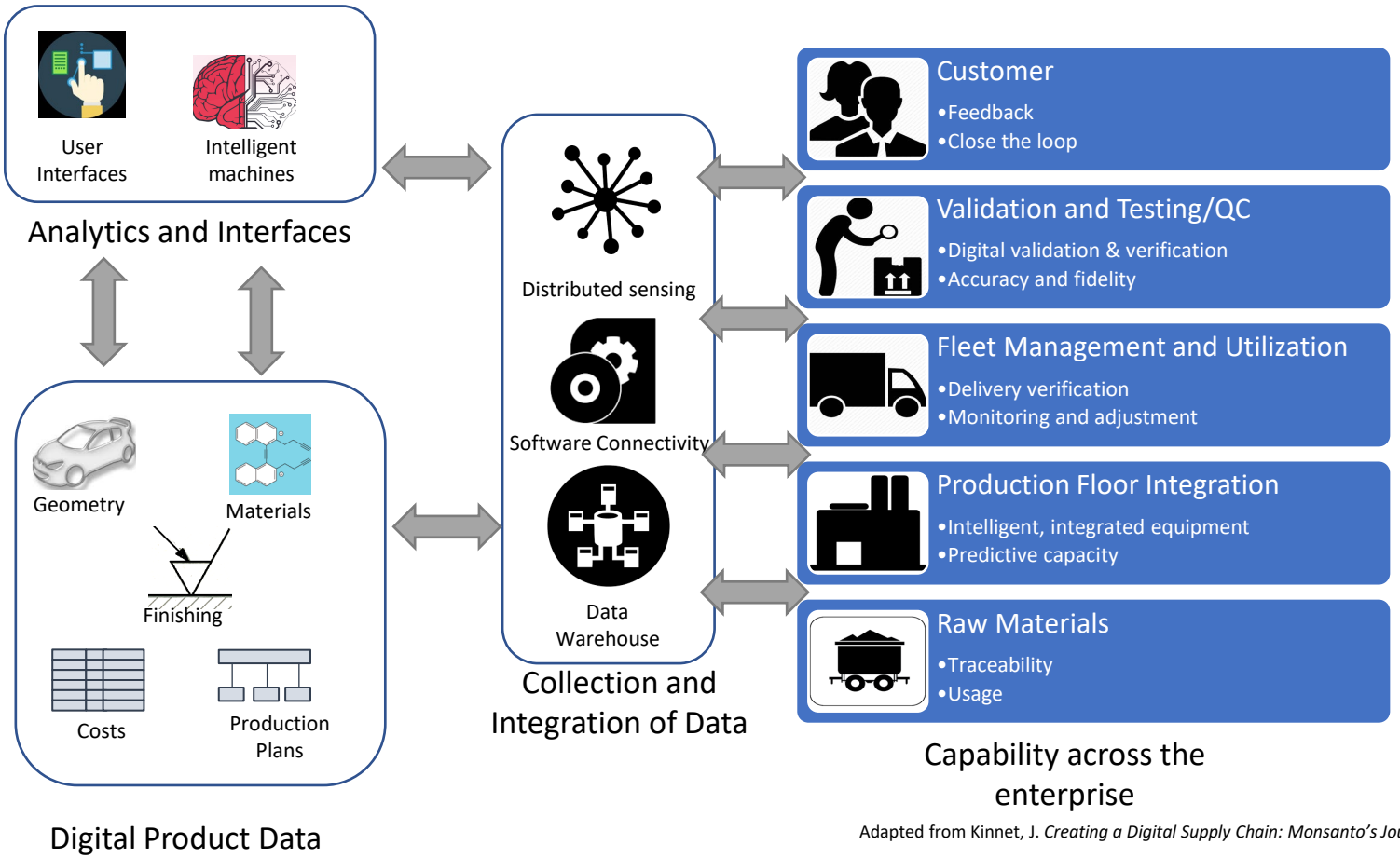


Digitalization allows for new business models to emerge:

- Mass customization
- Economic quantity: 1
- Product as a Service (PaaS)
- Product as a Platform
- Precision application of resources
- Intelligent support services

Adapted from Kurfess, T. (2015). *Advanced Manufacturing, Policy and Technology Opportunities for American Innovation*. 2015 University Turbine Systems Research Workshop.

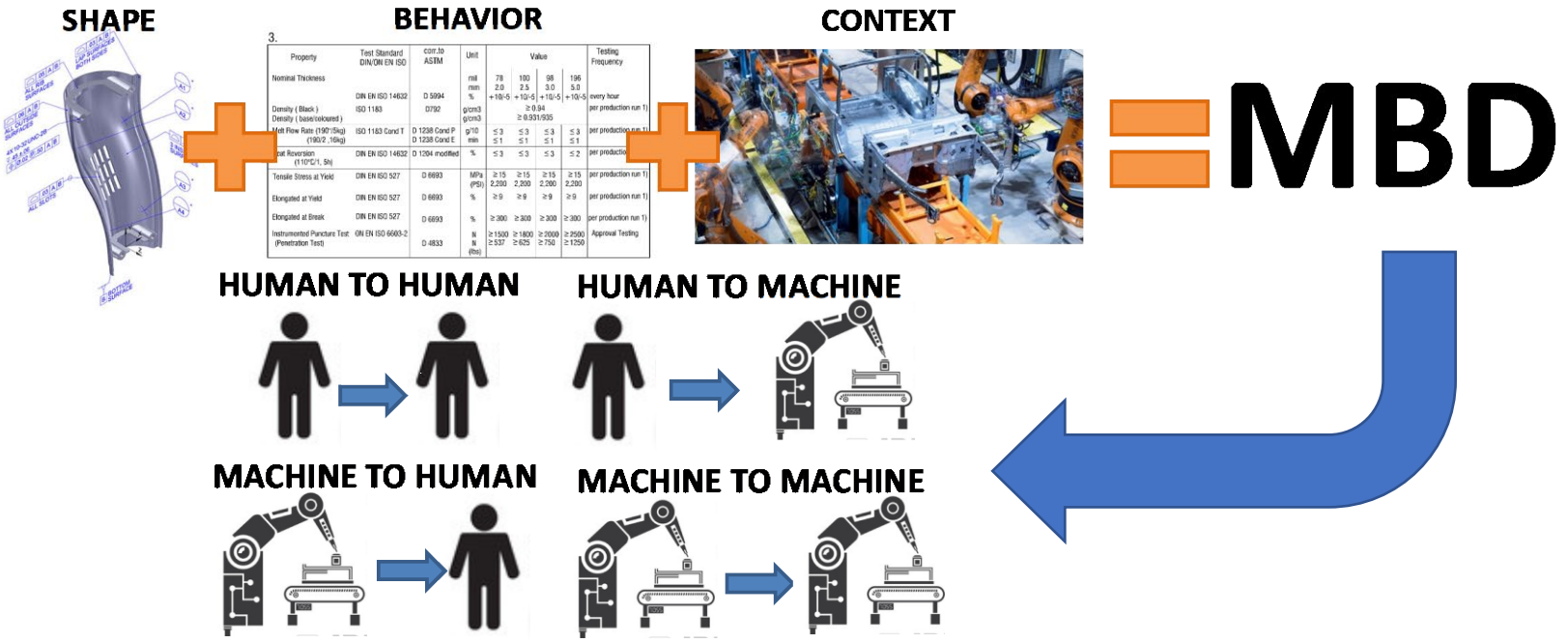
The Connected Supply Chain Allows for More Efficiency



Adapted from Kinnet, J. *Creating a Digital Supply Chain: Monsanto's Journey*, October 2015.

Moving Away from Paper Environments…

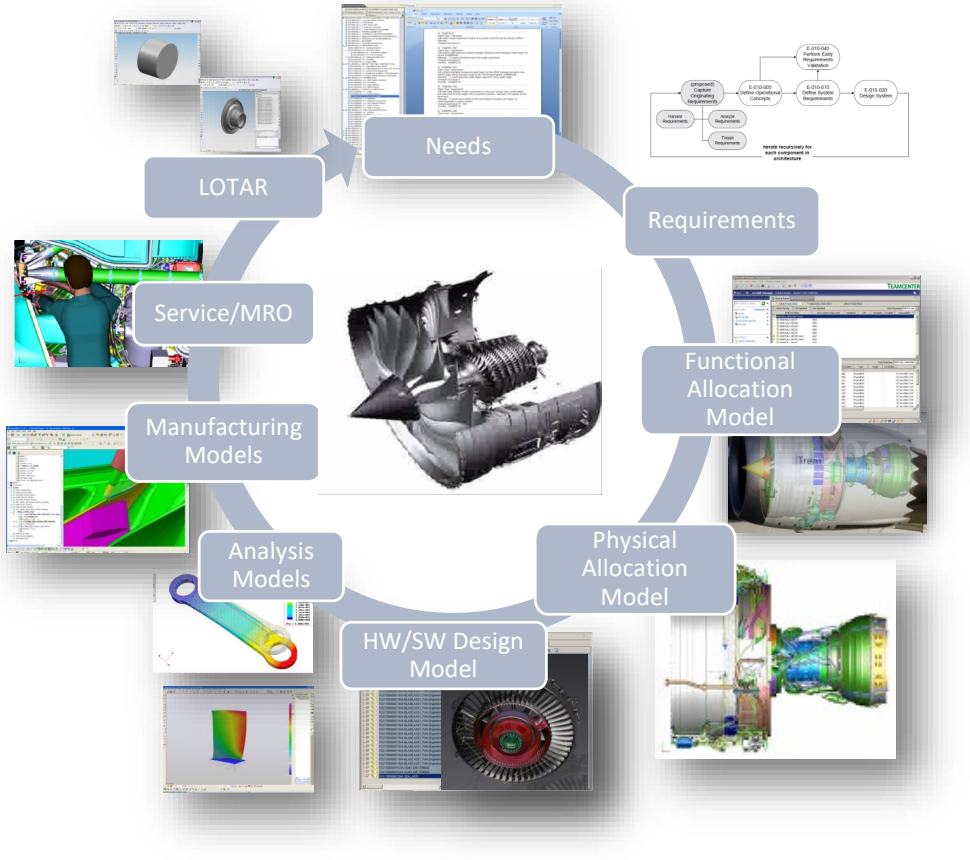
Model-based definitions (MBDs) aim to create digital product definitions using 3D CAD models as a form of baseline to disseminate lifecycle information across design, manufacturing, and sustainment. MBDs are desired to eliminate error-prone information exchange associated with traditional paper-based drawings and to improve the fidelity of component details, captured using 3D CAD models.



…Towards an Integrated Product (and data) Lifecycle

The digital product definition forms the core of how product information is moved through this sociotechnical system.

- However, it is often still sequential
- Dynamic model re-purposing still lacking
- MBD must move beyond shape
- Lifecycle loop still not connected



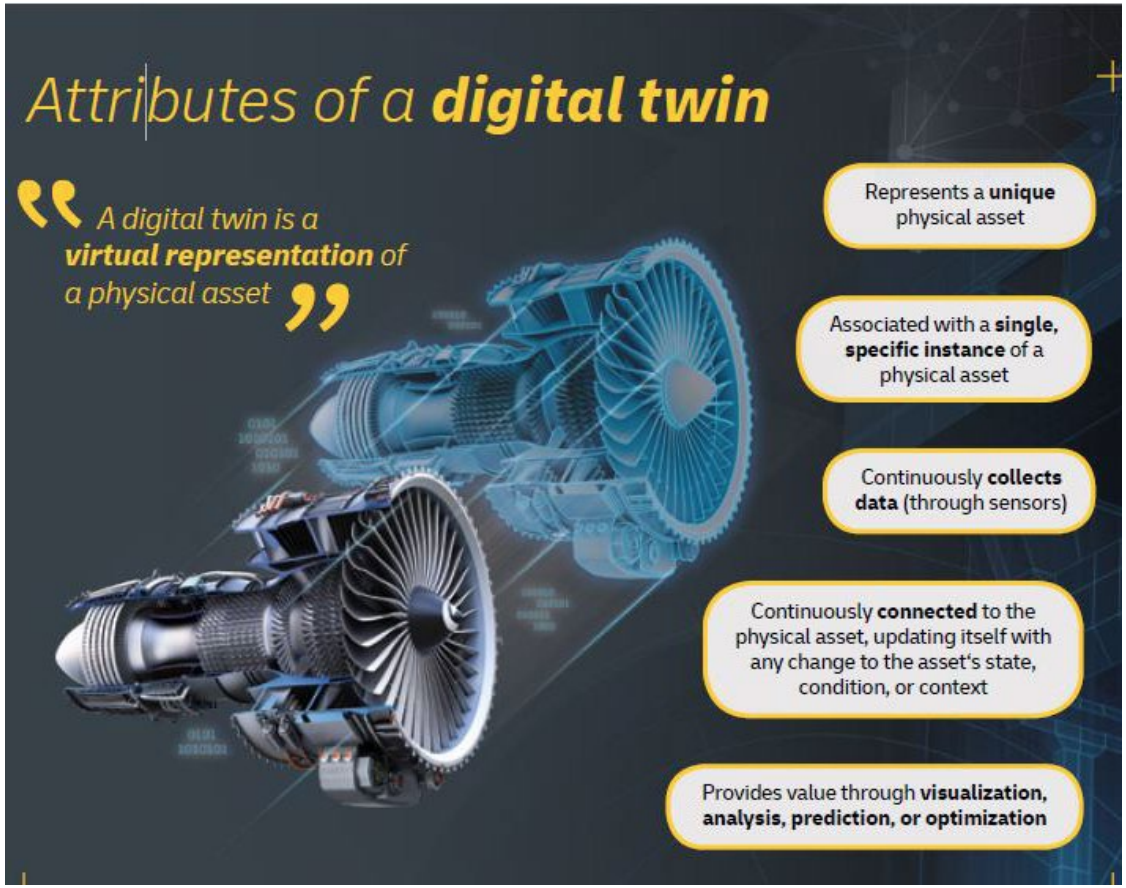
Key Elements of digital twins

What do we need to make this work?

- Ubiquitous connectivity
- Big data acquisition and aggregation
- Analytics and visualization
- Artificial intelligence/Machine learning
- Alignment between capacity monitoring and demand prediction

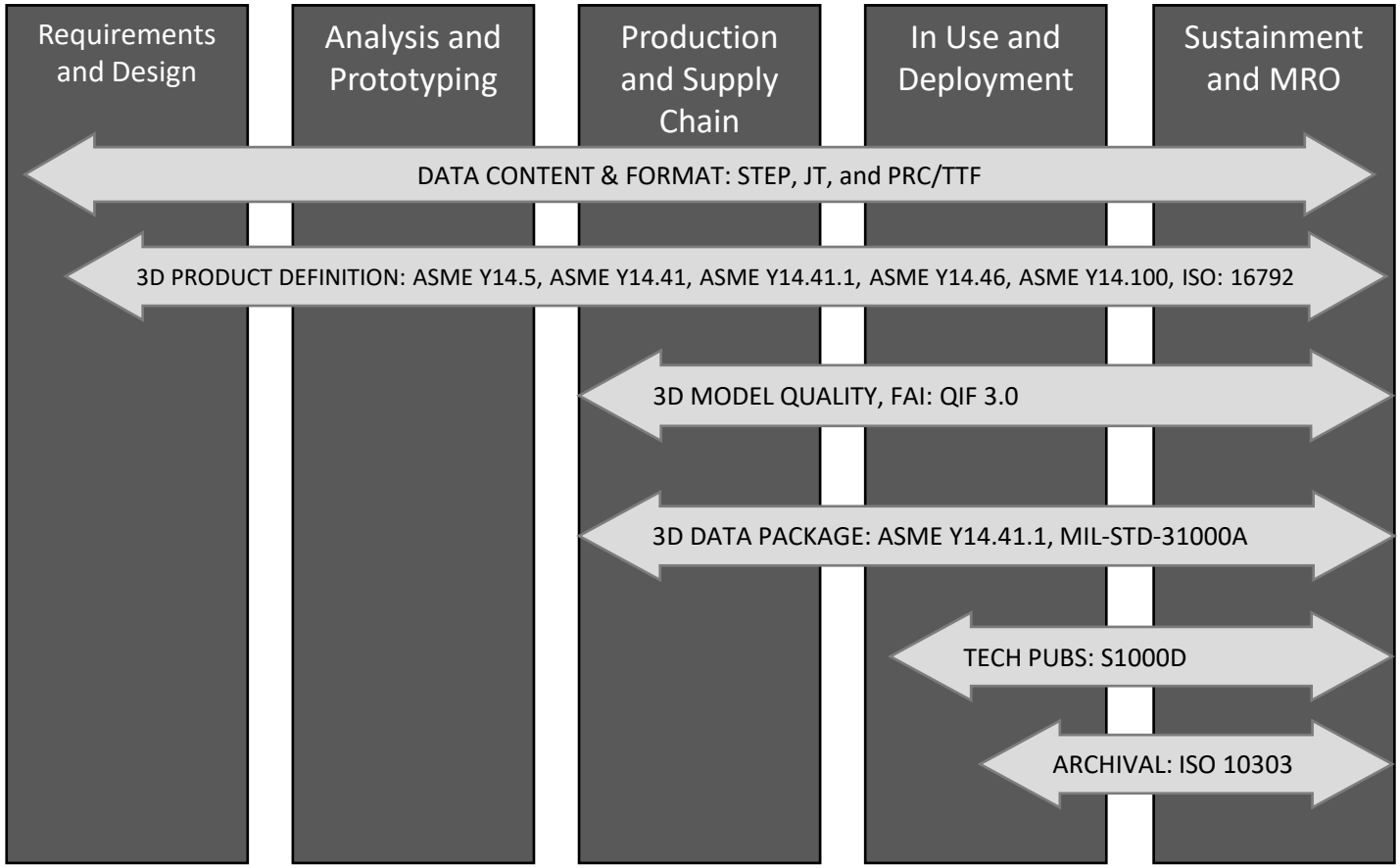
How does that happen?

- Digital data and models to represent product, process, behavior, and context
- IT architecture to gather, analyze, and disseminate data
- A sensor infrastructure connected to key elements above
- Interfaces and standards to allow information to move through the enterprise.



Left Image Source: https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf

Enabling Model-based Data from Here to There



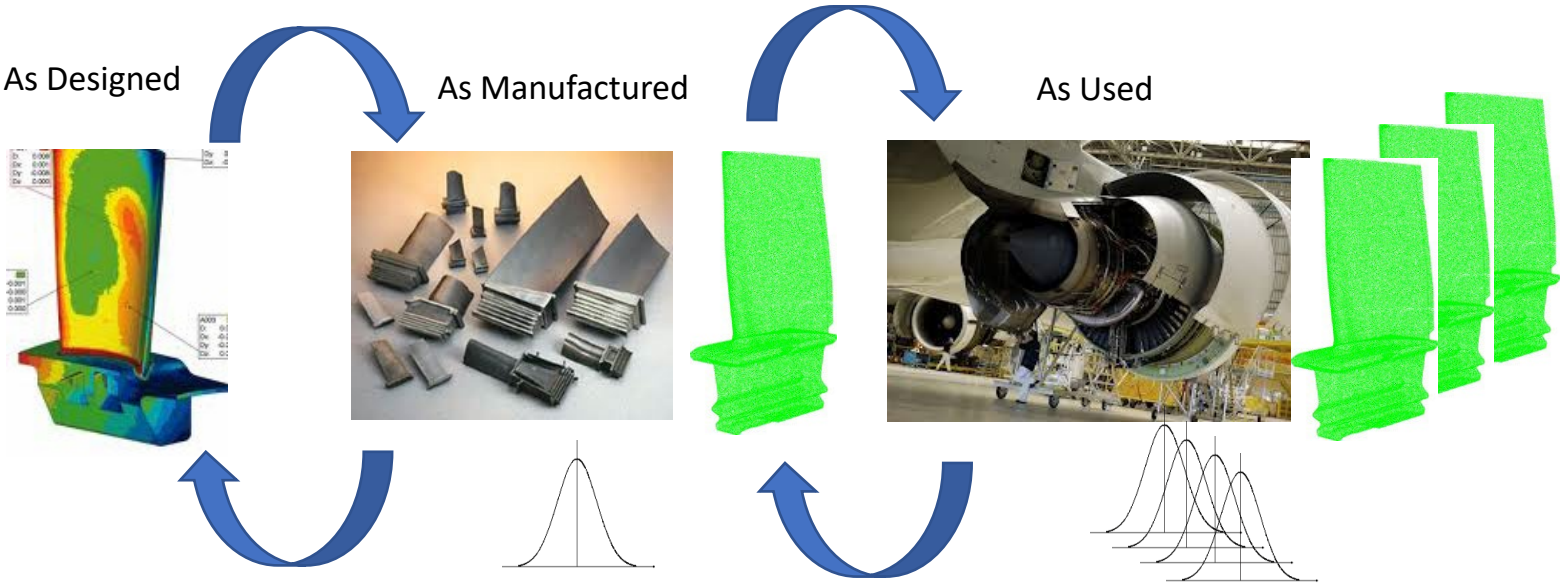
Adapted from Jennifer Herron, Action Engineering

Common product and process data standards associated with product lifecycle stages.

While these standards typically deal with product and process data, several are evolving to include data forms which exist at domain intersections.

Getting value from a digital twin

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.



Digital Twins Should Scale to the Product Platform

- Decisions on integration exist at multiple levels (e.g., material-components-engine-aircraft-Sys-of-Sys)
  - Outcome: Setting the right requirements in the right place
  - Outcome: Identifying opportunities for innovation in face of uncertainty; overcome binding constraints via adaptive arch.
- Dependencies propagate within and across multiple levels
  - Outcome: Assessing the impact of cascading dependencies to inform good integration strategies
  - Outcome: Assessing and tracking technology maturity (TRL) to prevent poor integration strategies
- Leveraging digital domain models/simulation with model-based methods are critical:
  - Outcome: Continuously test integration hypotheses and develop library of evaluated integration strategies that can be interrogated
  - Outcome: Compute sensitivities that link initial requirements to relevant metrics

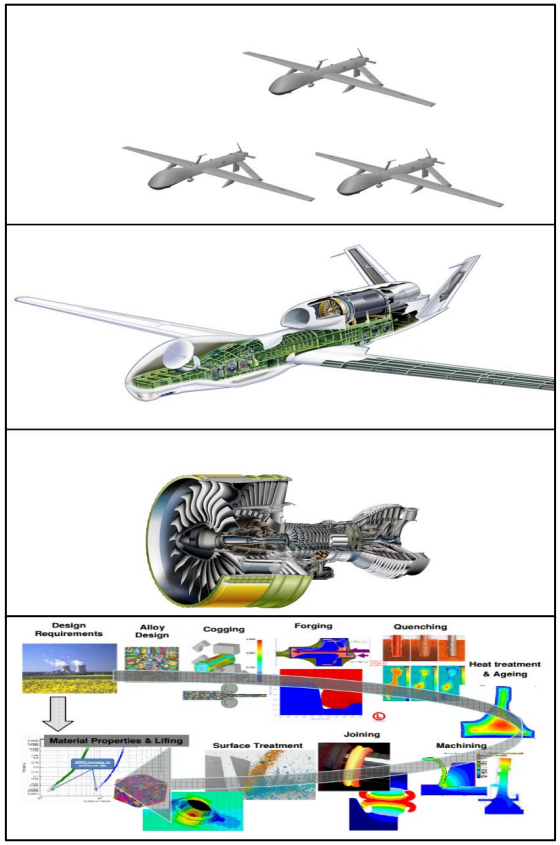
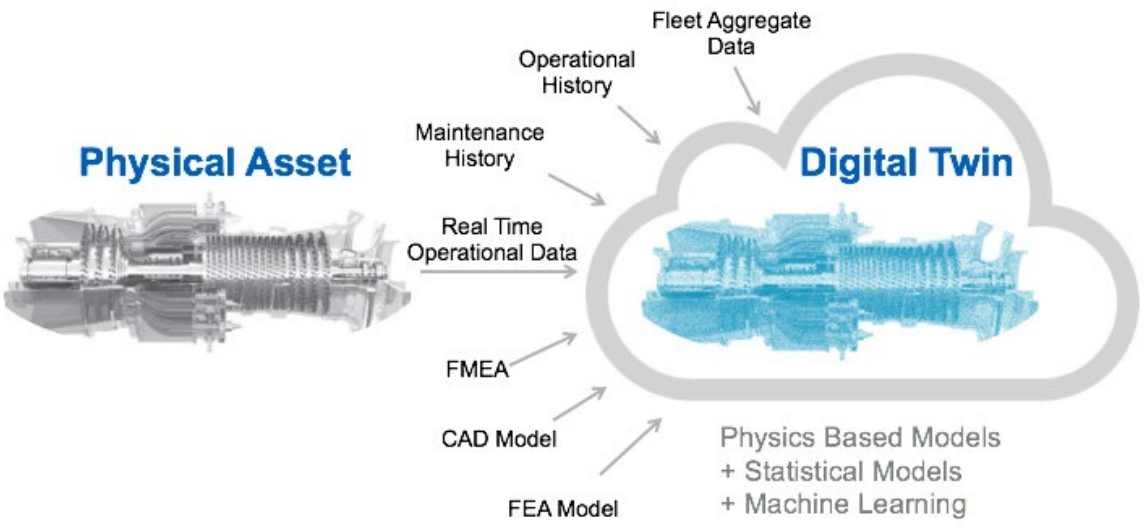


Image Source: "Application of ICME to Turbine Engine Component Design Optimization" http://arc.aiaa.org/doi/abs/10.2514/6.2011-1738

Ultimately, The Digital Twin Allows for Better Decisions

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.



A digital twin is not just a simulation; it is a closed-loop **predictive representation** of a product or a system.

By comparing product specifications, behavior, and context data to the physical object, variation can be analyzed to **inform** design of future products, to **diagnose** and solve problems that occur, and to **predictive** viability and performance of future states through more robust **validation and verification**.

Right Image Source: https://www.vizexperts.com/blog/digital-twin-and-its-impact-on-industry-4-0

Nathan W. Hartman, Ed.D.
Dauch Family Professor of Advanced Manufacturing and
Head of Computer Graphics Technology
Director, Digital Enterprise Center
Co-Executive Director, IN-MaC

The digital twin and its role in manufacturing and supply chain

In collaboration with Dr. Michael Sangid and Dr. Dan Delaurentis