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DEVELOPING MANUFACTURING CAPABILITY: RE-SHAPING THE ENTERPRISE

PURDUE
POLYTECHNIC

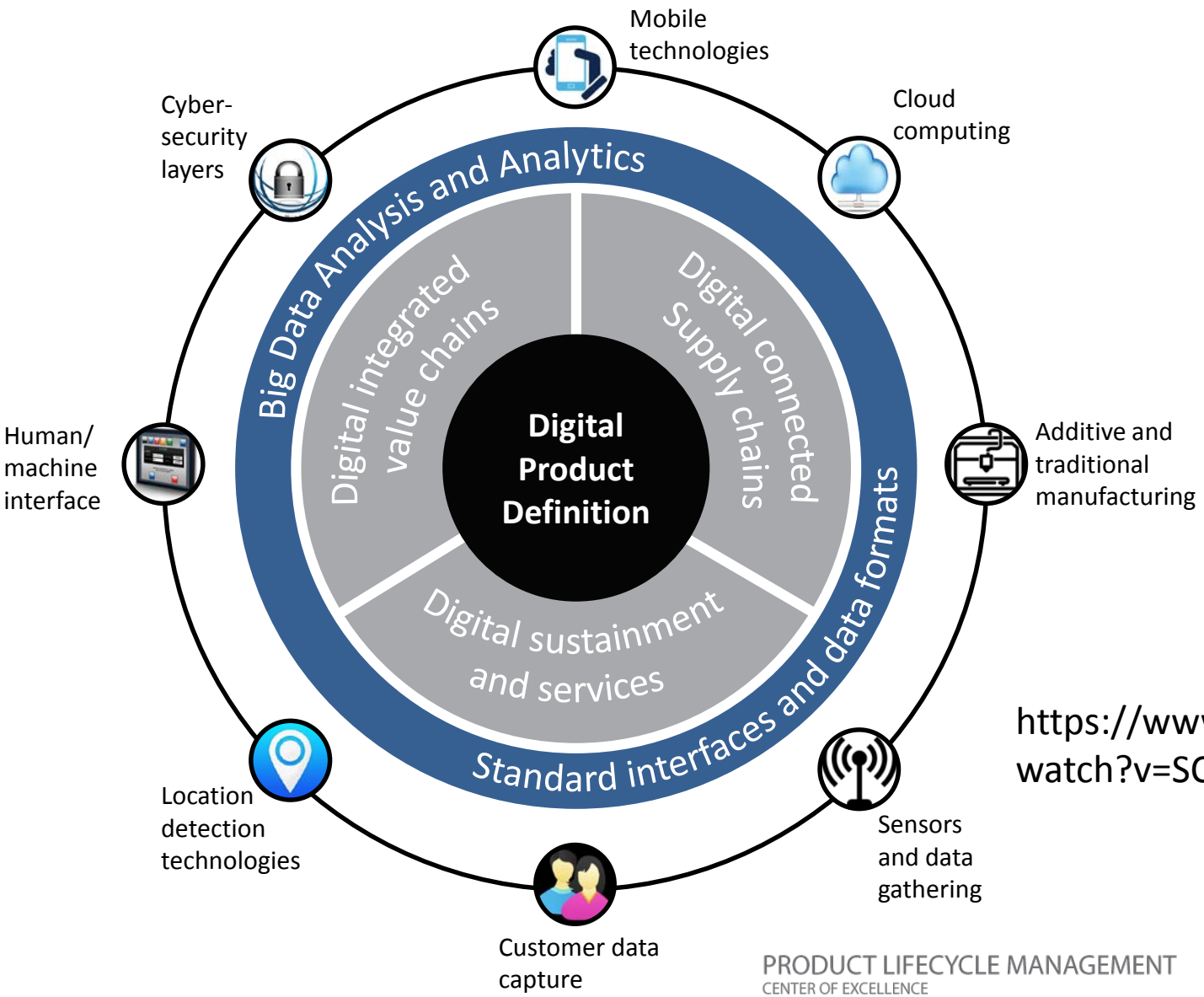
PLM
PURDUE
CENTER

What drives manufacturing competitiveness?

Tim Hanley, Deloitte

What is a digital enterprise?

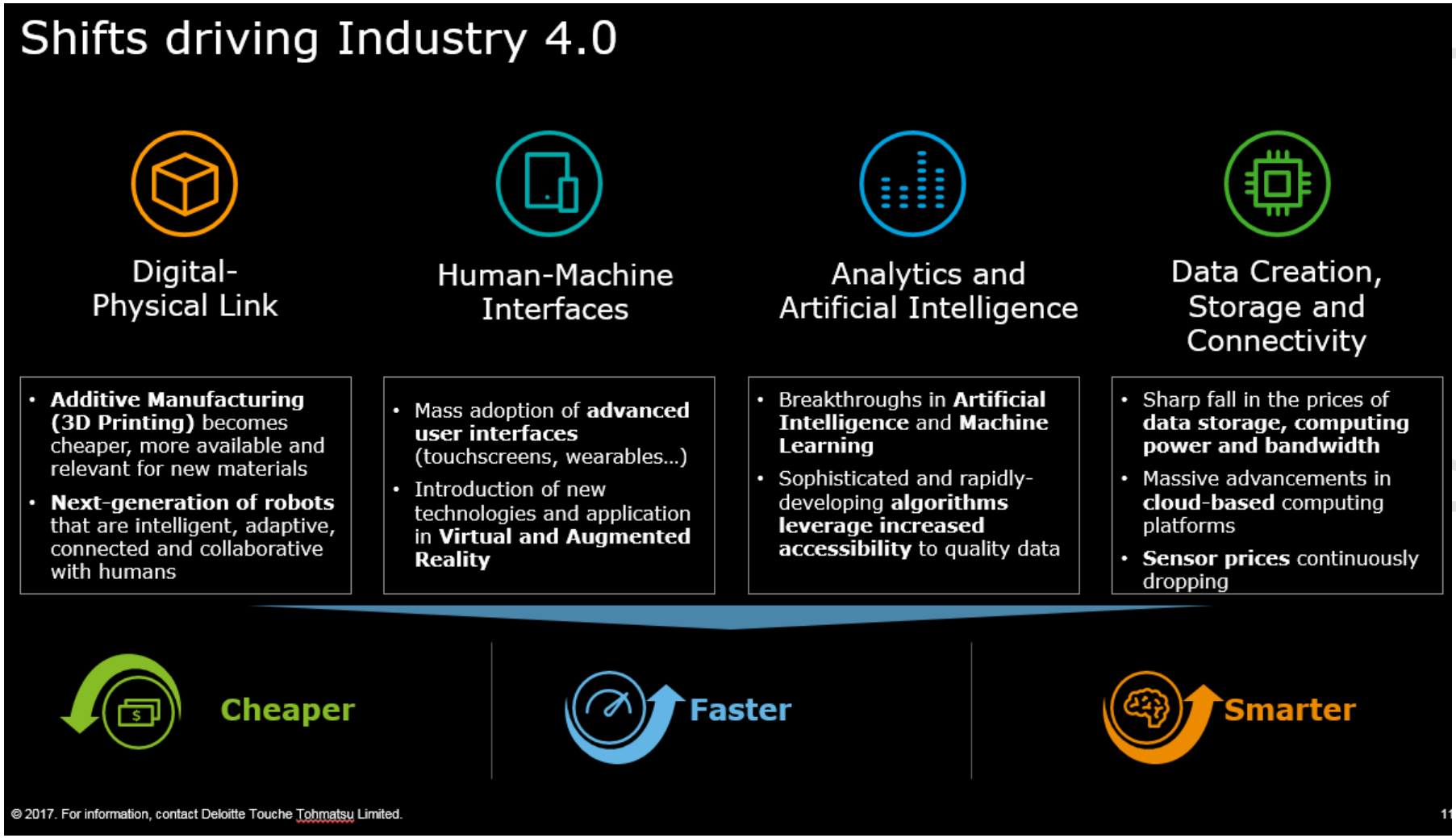
A digital enterprise changes the way people work and how they use information



https://www.youtube.com/watch?v=SCGV1tNBoeU

Technology moving forward…

Tim Hanley, Deloitte

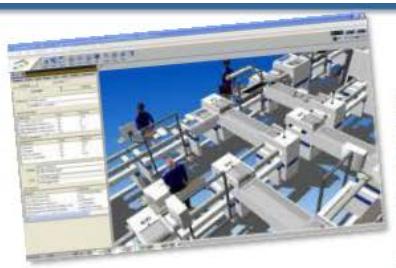


Digital Manufacturing Technology Trends

Mike Molnar, NIST

- **Digital Technologies**
  - Internet of Things/Ubiquitous Sensing
  - Digital Twin and Digital Thread
  - Big data & advanced analytics
  - Cloud computing
  - Mobile computing/apps
  - Security technologies

- **Advanced Manufacturing Capabilities**
  - Advances in additive processes/3D printing
  - Advances in robotics
  - Model-based everything
  - Complex systems engineering
  - Advances in materials

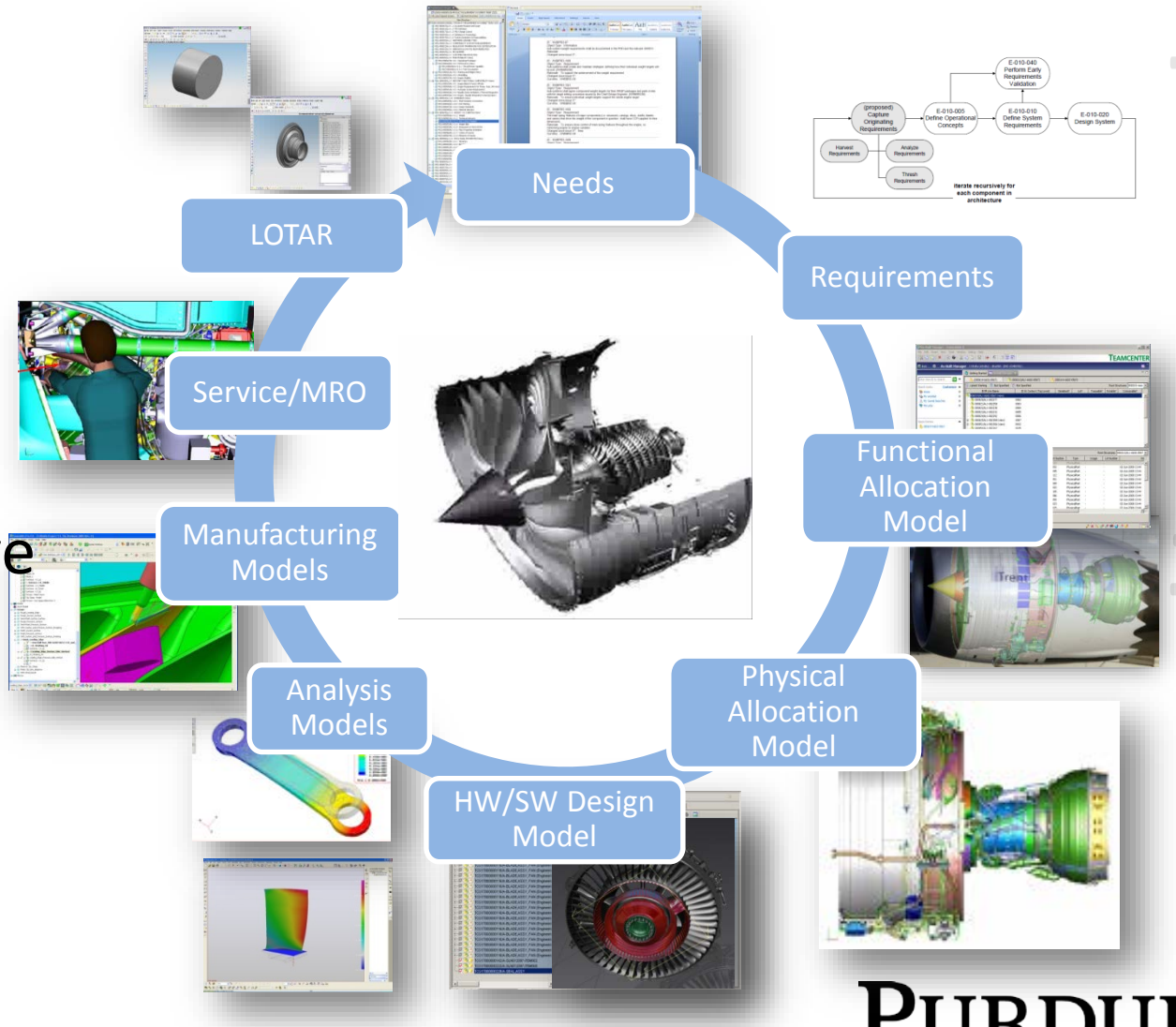


NIST
National Institute of Standards and Technology
U.S. Department of Commerce

PLM – a key element to digital enterprise

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

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



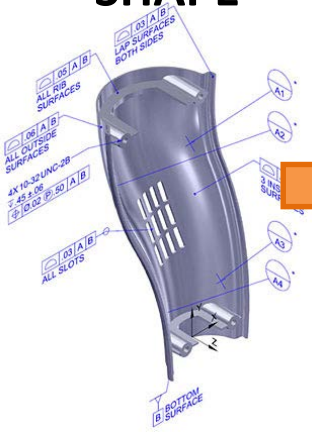
PRODUCT LIFECYCLE MANAGEMENT
CENTER OF EXCELLENCE

PURDUE POLYTECHNIC

The communications spectrum…

A complete MBD supports lifecycle communication

SHAPE

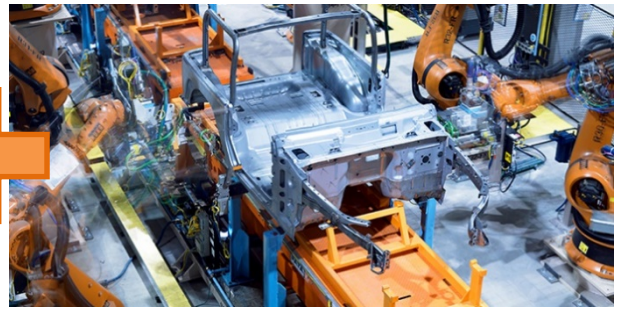


BEHAVIOR

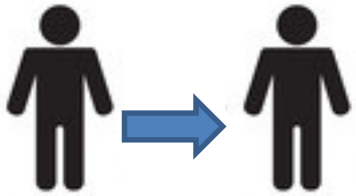
3.

Property	Test Standard DIN/ON EN ISO	corr.to ASTM	Unit	Value				Testing Frequency
Nominal Thickness			mil	78	100	98	196	
			mm	2.0	2.5	3.0	5.0	
	DIN EN ISO 14632	D 5994	%	+10/-5	+10/-5	+10/-5	+10/-5	every hour
Density (Black)	ISO 1183	D792	g/cm3	≥ 0.94				per production run 1)
Density (base/coloured)			g/cm3	≥ 0.931/935				
Melt Flow Rate (190°/5kg)	ISO 1183 Cond T	D 1238 Cond P	g/10	≤ 3	≤ 3	≤ 3	≤ 3	per production run 1)
(190/2 ,16kg)		D 1238 Cond E	min	≤ 1	≤ 1	≤ 1	≤ 1	
Heat Reversion (110°C/1, 5h)	DIN EN ISO 14632	D 1204 modified	%	≤ 3	≤ 3	≤ 3	≤ 2	per productio
Tensile Stress at Yield	DIN EN ISO 527	D 6693	MPa (PSI)	≥ 15 2,200	≥ 15 2,200	≥ 15 2,200	≥ 15 2,200	per production run 1)
Elongated at Yield	DIN EN ISO 527	D 6693	%	≥ 9	≥ 9	≥ 9	≥ 9	per production run 1)
Elongated at Break	DIN EN ISO 527	D 6693	%	≥ 300	≥ 300	≥ 300	≥ 300	per production run 1)
Instrumented Puncture Test (Penetration Test)	ON EN ISO 6603-2	D 4833	N N (lbs)	≥ 1500 ≥ 337	≥ 1800 ≥ 625	≥ 2000 ≥ 750	≥ 2500 ≥ 1250	Approval Testing

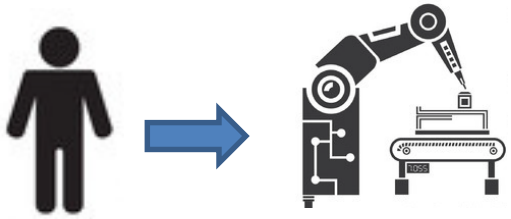
CONTEXT



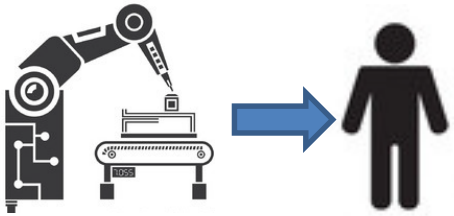
HUMAN TO HUMAN



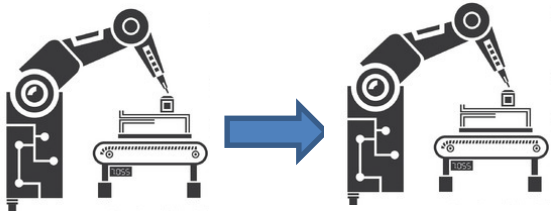
HUMAN TO MACHINE



MACHINE TO HUMAN



MACHINE TO MACHINE



MBD and Systems Engineering

The evolution of representations

Evolution of PLM to date

Next step for PLM

Drawing based

CAD based

MBx based

Virtual environment based

Lifecycle based

Diagram based

Document based

Behavior
Structure
Requirements

Specifications
Interface requirements
System design
Analysis & Trade-off
Test plans

Evolution of SE to date

Next step for SE

MBD and Materials & Process Characterization

Physics-based modeling

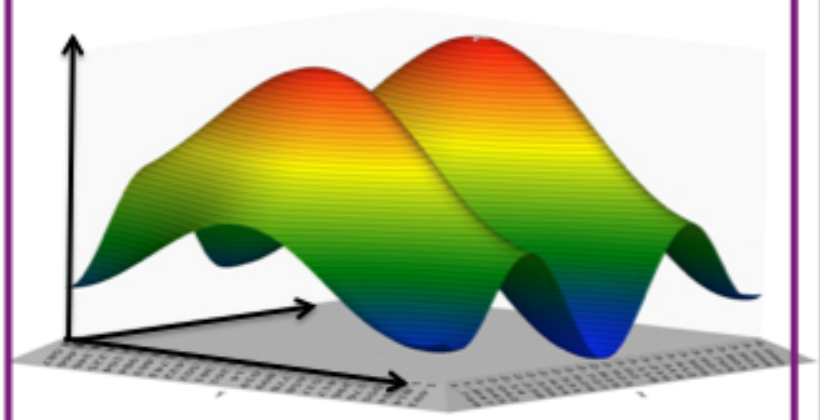
- Through surrogate meta-models create tools that can be used to inform decisions, in real time, for shop floor use.

Input
- Geometry (CAD)
- Workpiece Material
- Tool Information
- Process Parameters

Machining Model
- Third Wave

Output
- End Geometry (CAD)
- Residual Stresses / Material Info
- Tolerances / Surface Finish

Component

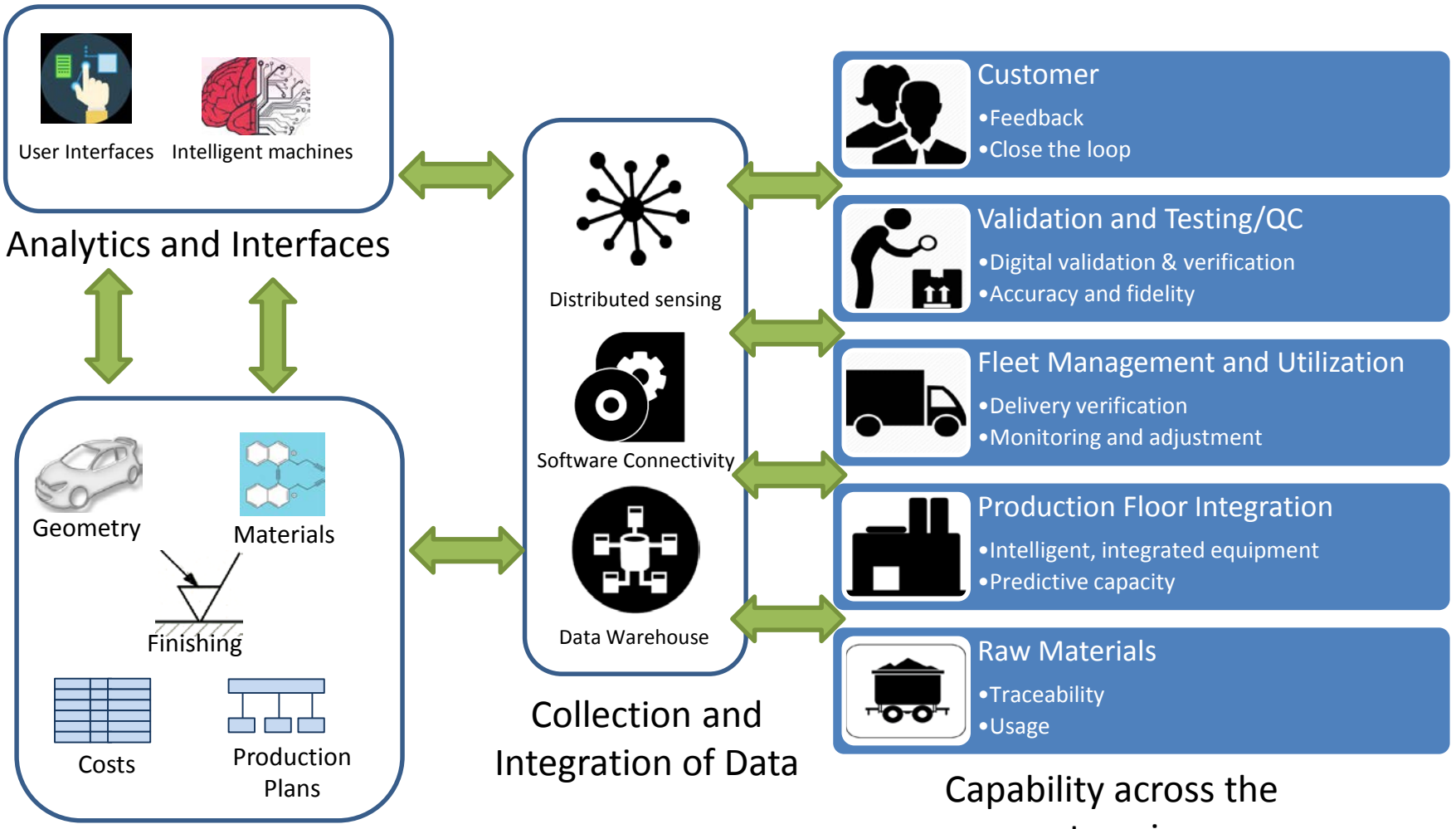


- Parametric Design of Experiments
- Database offline
- Metamodel

Approach
- Third wave inaccuracies
- Function form inaccuracies
- Validation of model predictions
- Extrapolation for geometry variants

The digital enterprise supply chain

Leveraging supplier and process data to ensure capacity

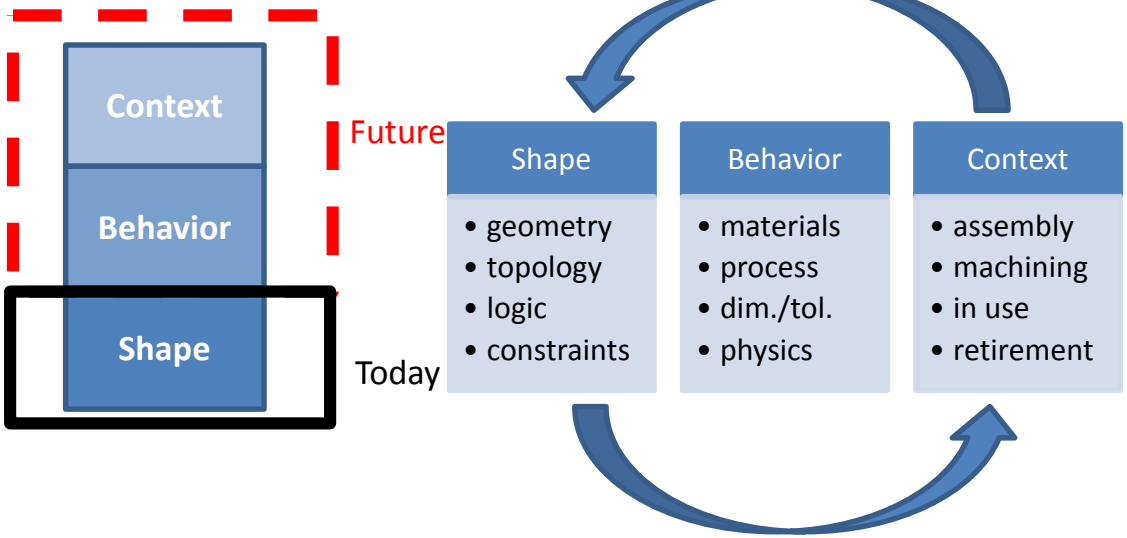


Adapted from Kinnet, J. *Creating a Digital Supply Chain: Monsanto's Journey*, October 2015.

MBE and the Digital Twin

MODEL-BASED DEFINITION

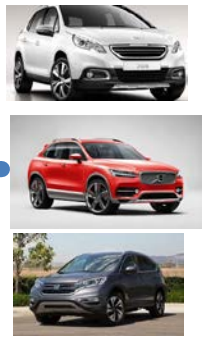
Multiple Connected Representations



DIGITAL TWIN

Interfaces
Standards
Requirements

- Product Line
- Model 1
  Model 2
  Model N
- Subsystem
- Component



Temporal, lifecycle-based representations

DIGITAL THREAD

MBD + IT architecture + Connectivity

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.

Clearing up some vocabulary…

- A ***model-based enterprise*** (MBE) is an **environment**. It is an organization that has transformed itself to leverage model-based information in its various activities and decision-making processes. In this environment, the model serves as a dynamic artifact that used by various authors and consumers of information for their respective tasks. The MBE embraces feedback from the various lifecycle stages to improve the model representation for the creation of subsequent products and product iterations. People working within the enterprise have an enlightened view of digital product information that can be leveraged in their daily work.

- ***Model-based*** _____ (MBx) Model-based engineering (MBe), model-based manufacturing (MBm), model-based sustainment (MBs), and any other model-based [fill in the blank] (MBx) are categories of **activity** within the model-based enterprise. Any of these activities (and the people in them) use digital product data to represent shape, behavioral, and contextual information carried by the model-based definition to execute their functional role. Model-based activities are conducted by relying on the predictive and archival capabilities of the model, by replying on its high levels of fidelity to physical object or system.

- A ***model-based definition*** (MBD) is a **thing**. It is a digital representation (artifact) of an object or system. It is representative of the physical object or system and all of its attributes, and is used to communicate information within various MBx activities in a model-based enterprise. The MBD is rich in information – shape, behavior, and context – and it travels the information architecture within an enterprise (including its extended supply chain and customers), providing input to the various authors and consumers who need it. The model-based definition is analogous to the *digital twin*, although most people today do not think of it in such broad view. And the *digital thread* is the combination of the MBD and the IT architecture that connects the various functional areas of the model-based enterprise.

A changing workforce…

Tim Hanley, Deloitte

Advanced technologies will increase the skillsets required

…and potentially drive companies to explore different talent models

As Skill Requirements Increase, More Manufacturing Jobs Go Unfilled

(WSJ, Sep 2016)

New Manufacturing Jobs Require New Manufacturing Skills—It's That Simple

(AutoDesk, May 2017)

Automation Will Lead To Collaboration Between Man And Machine

(Forbes, Jul 2017)

A Robot Can Be a Warehouse Worker's Best Friend

Companies are racing to develop 'collaborative' robots, which are relatively cheap and can boost employees' productivity

(WSJ, Aug 2017)

Trends

- Aging population
- Shortage of manufacturing talent
- Exponential technologies
- Gig economy / open talent
- Rapid product cycles

This next industrial revolution is about the combination of man & machine, not the replacement of one for the other.

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