ESTABLISHING A LEXICON FOR THE MODEL-BASED ENTERPRISE

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A new world...

By 2018, 20% of all business content will be authored by machines.

By 2018, more than 3 million workers globally will be supervised by a "roboboss".

By 2020, more than 35 billion things will be connected to the Internet.

The growing range of 3D-printable materials will drive a compound annual growth rate of 64.1% by 2019.

Source: Gartner Analysis
Ongoing industrial challenges

- Driving product lifecycle data with high fidelity representations
- Increasing product complexity
- Securing digital product and process data through the enterprise
- Global competition
- Product knowledge stored with people or artifacts?
- Funding priorities for education focus on jobs that are not there
- Design/make vs. make to print (model)? → supply chain transformation
- Mobility, Collaboration, and Interfaces → the social psychology of expertise
- Difficult to hire new workers with requisite knowledge

PURDUE POLYTECHNIC
The next industrial revolution

Mechanization, mass production, automation, digitalization

Four Industrial Revolutions

Industry 1.0
End of 18th Century
Use of manual labor, water and steam power to run machines and facilities.

Industry 2.0
Beginning of 20th Century
Electrical power generation and use of electricity to enable longer running machines and mass production.

Industry 3.0
Middle of the 20th Century
Use of electronics and basic computing to automate production. Menial, repetitive tasks began to be replaced by machines.

Industry 4.0
Today and beyond
Use of IT infrastructure to connect machines and humans in a digital environment. Automated processes with active machine monitoring and analysis.
The collaboration journey...

Yesterday

Communications often in serial fashion

You trusted the data because you trusted the person that generated the data

Collaboration meant face-to-face communication
The old communications medium

The paper thread
What is a digital enterprise?

A digital enterprise changes the way people work and how they use information.
The communications spectrum...

A complete MBD supports lifecycle communication
The product lifecycle and the 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
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, 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.
What is the model-based definition?

Singular representation vs. multiple, connected representations

Singular Representation

- Context
- Behavior
- Shape

Multiple Connected Representations

- Shape
  - geometry
  - topology
  - logic
  - constraints
- Behavior
  - materials
  - process
  - dim./tol.
  - physics
- Context
  - assembly
  - machining
  - in use
  - retirement

OR
Shape definition and visual clarity

Many people simply use annotated CAD models as a proxy for a drawing

- Geometry definition
- Dimensional information
- Design intent clarity
Behavior and MBD

Reduce the need for trial-and-error approaches

Models and analysis replace costly experimental iterations to optimize the manufacturing process and component performance

As Is - Today

Behavior and MBD

Reduce the need for trial-and-error approaches

Models and analysis replace costly experimental iterations to optimize the manufacturing process and component performance

To Be – Goal

Application of physics-based modeling tools can reduce overall cost and time to complete system design

Context and MBD

The evolution of representations

Next step for PLM

Evolution of PLM to date

Context

Behavior

Geometry

Virtual environment based

MBx based

CAD based

Drawing based

Next step for SE

Evolution of SE to date

Specifications

Interface requirements

System design

Analysis & Trade-off

Test plans

Behavior

Structure

Requirements

Diagram based

Document based
MBD, Systems engineering, and big data decision making

- Big Data and Data Analytics
  - State-of-art methods to help make sense of generated data
  - In line with INCOSE SE Vision 2025* vision of “Leveraging Technology for SE Tools”
  - Current parametric solvers limited in scope and application** to potential bigger SE picture
- Can we exploit state-of-art in analytics to aid in turning large volume of MBSE outputs into useful information?

*INCOSE Systems Engineering Vision 2025 June 2014
**Approximation Analytics for Model-Based Systems Engineering – Vitech Corporation 2014 Insigh Webinar
Evolution of a model-based product representation

MBD relevance is often a matter of whether you are an **author** or a **consumer**.

- **Geometry**
- **Behavior**
- **Context**
- **Lifecycle based**
- **Virtual environment based**
- **MBx based**
- **CAD based**
- **Drawing based**

Increased sophistication in digital representations and their fidelity to the physical world.
MBD and the Digital Twin

MODEL-BASED DEFINITION
Multiple Connected Representations

Context
Behavior
Shape

Future
Today

Shape
- geometry
- topology
- logic
- constraints

Behavior
- materials
- process
- dim./tol.
- physics

Context
- assembly
- machining
- in use
- retirement

DIGITAL TWIN

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

Temporal, lifecycle-based
levels of a model-based
definition

DIGITAL THREAD
MBD + IT architecture + Connectivity

Interfaces
Standards
Requirements
Enabling 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 or to develop predictive modeling and validation schemes for existing products.
... and the accompanying educational revolution

Craft, tools, practice, and design

1. Apprenticeship
   Up through the early 19th Century. Characterized by studying the Master, and focused on specific customer needs. Difficult to reproduce.

2. Manual Arts
   Through the 19th and beginning of the 20th centuries. Focused on work and tools of the day. Discussion of a formal discipline began.

3. Industrial Arts
   Beginning to middle of the 20th centuries. Included a focus on breadth of topics to develop technological literacy, but clinging to its vocational roots. Focused on putting students to work.

4. Design, Make, Sustain
   MBD, MBx, and MBE should be a formal element of the curriculum. The design process and its use as a problem solving method is central to understanding the lifecycle.

Regardless of the era, the educational revolution connected to manufacturing has always had a focus on the tools and techniques of the day, and on the making of something. However, the incumbent workforce was left unattended in this model.
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