Industry 4.0 Metrics and Standards
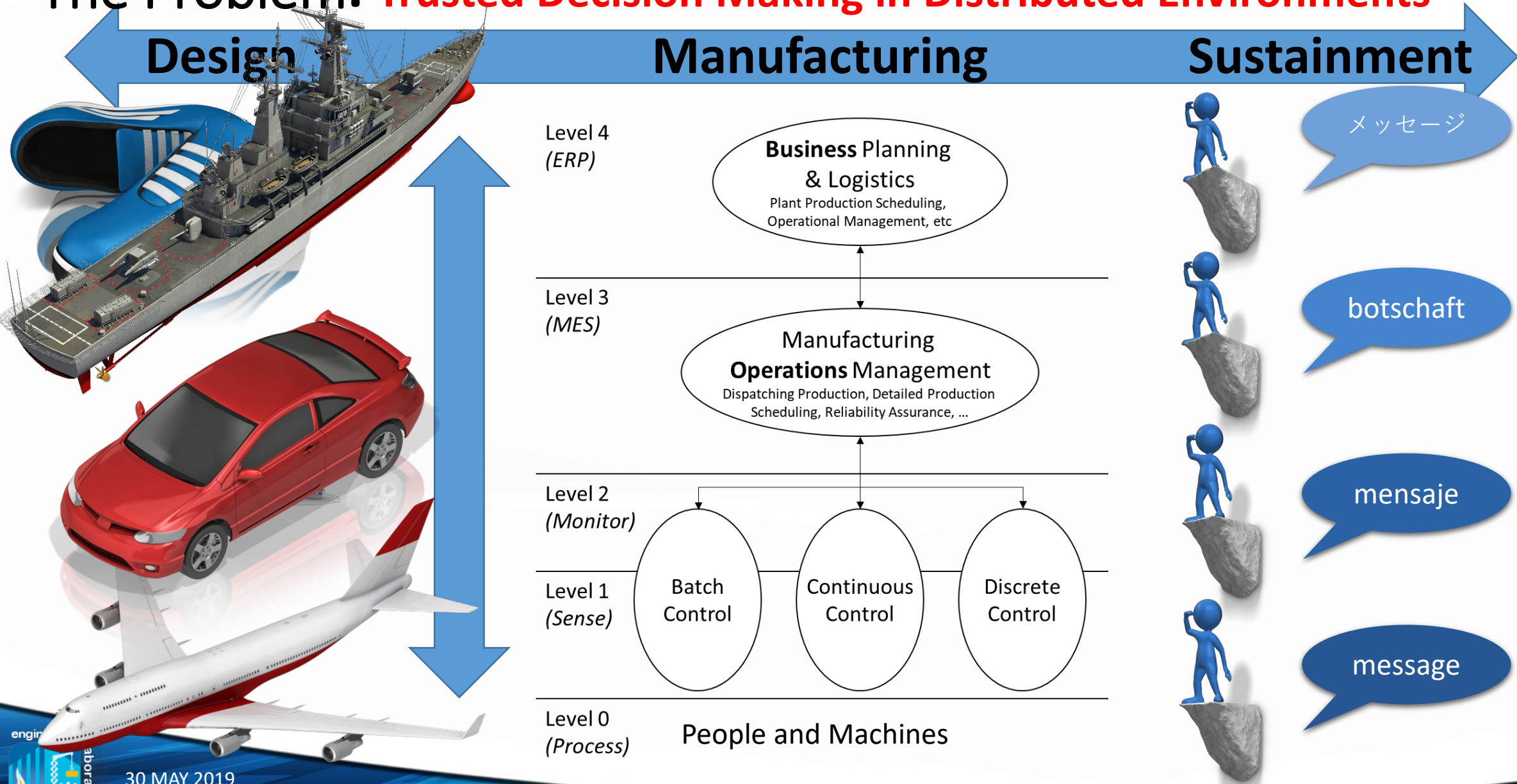
Thomas Hedberg, Jr., Ph.D., P.E.

Systems Integration Division, Engineering Laboratory
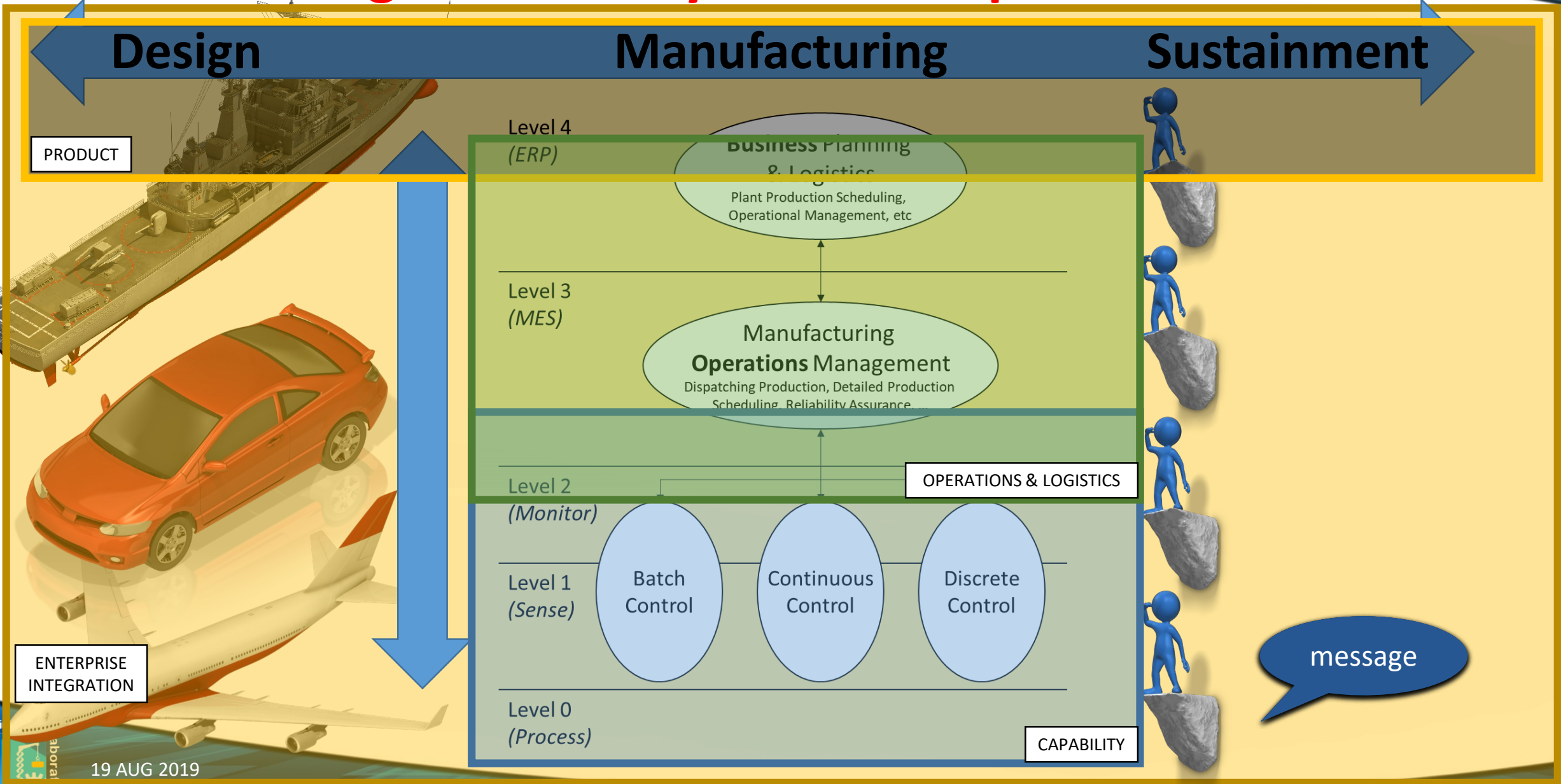
National Institute of Standards and Technology

Presented to the Fall 2019 Meeting of the Purdue Digital Enterprise Center

16 OCT 2019

The Problem: Trusted Decision Making in Distributed Environments
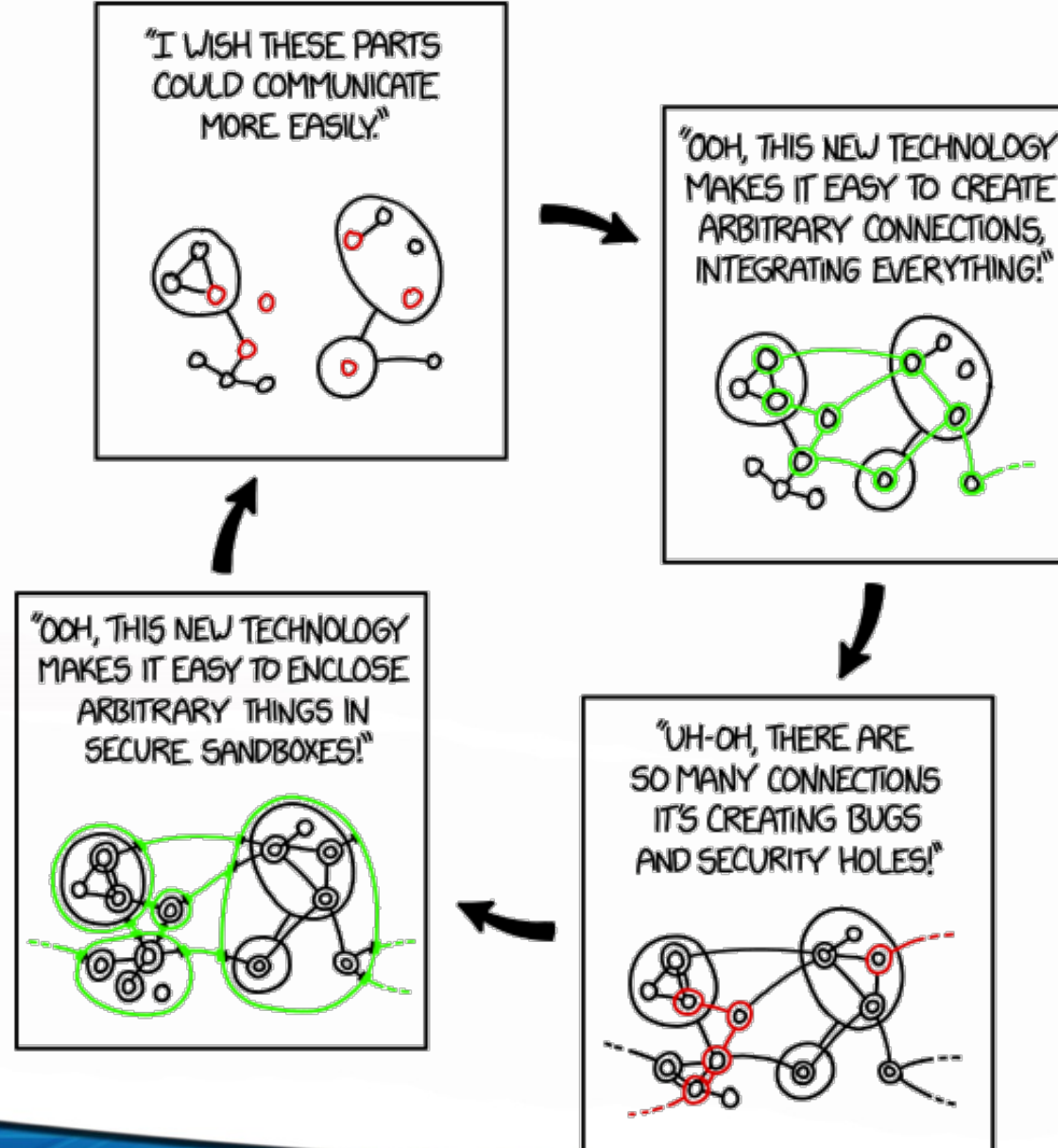
Design — Manufacturing — Sustainment

Level 4 (ERP)
Business Planning & Logistics
Plant Production Scheduling, Operational Management, etc

Level 3 (MES)
Manufacturing **Operations** Management
Dispatching Production, Detailed Production Scheduling, Reliability Assurance, …

Level 2 (Monitor)

Level 1 (Sense)
Batch Control — Continuous Control — Discrete Control

Level 0 (Process)
People and Machines

メッセージ

botschaft

mensaje

message

30 MAY 2019

2

The Need: **Integrated Life Cycle of Viewpoints**

Design — **Manufacturing** — **Sustainment**

PRODUCT

ENTERPRISE INTEGRATION

OPERATIONS & LOGISTICS

CAPABILITY

Level 4
(ERP)

Business Planning
& Logistics

Plant Production Scheduling,
Operational Management, etc

Level 3
(MES)

Manufacturing
Operations Management

Dispatching Production, Detailed Production
Scheduling, Reliability Assurance...

Level 2
(Monitor)

Level 1
(Sense)

Batch
Control

Continuous
Control

Discrete
Control

Level 0
(Process)

message

"All I want is a secure system where it's easy to do anything I want. Is that so much to ask?"

https://xkcd.com/2044/

30 MAY 2019

4

Current Enterprise System Landscape
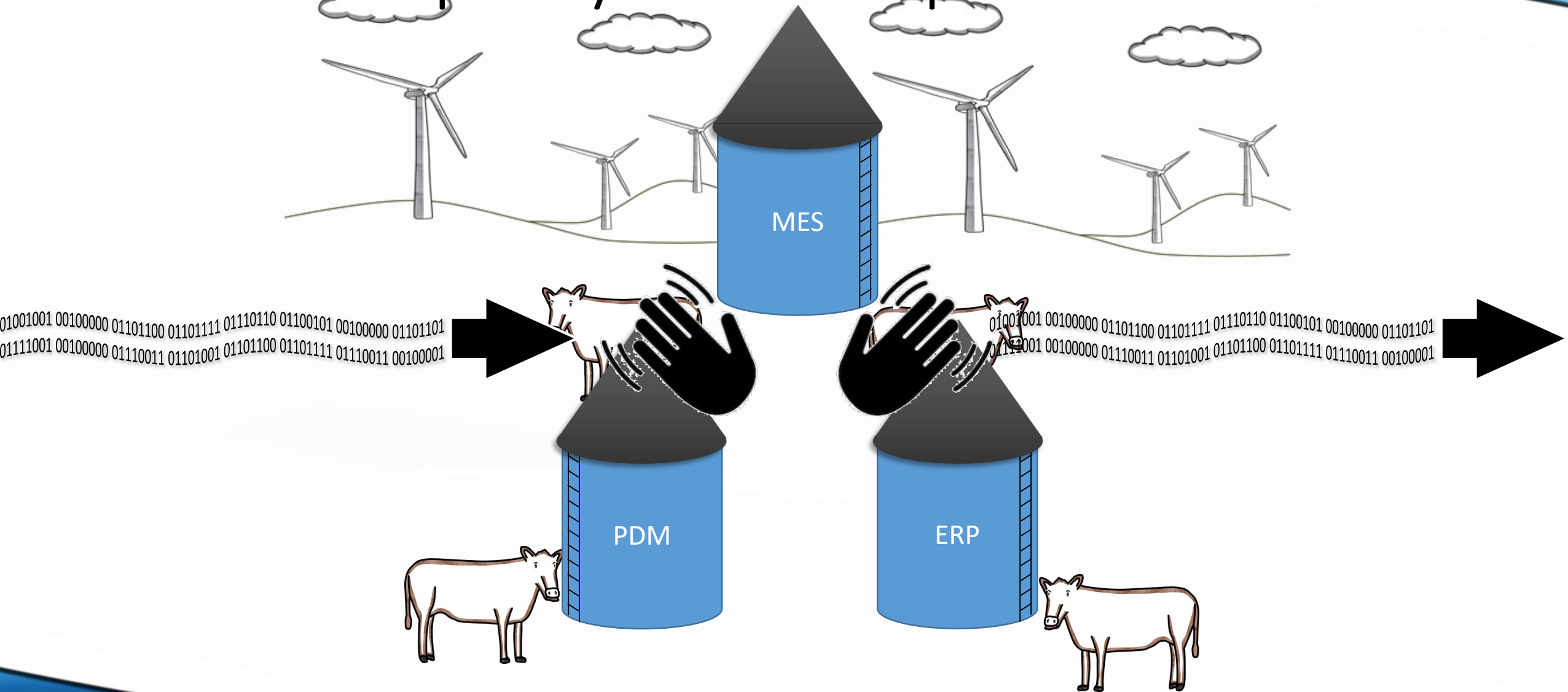
PLM: Current State of the Art

Option #1

Option #2
3rd Party Gateway System

User Database

API

File-based Exchange

API

User Database

Query
Get
Post
Update
Delete

User Request Handler

Access Control

Access Control

User Request Handler

Query
Get
Post
Update
Delete

Product Data Management (PDM)
(e.g., system used in design)

Manufacturing Execution System (MES)
(e.g., system used in production)

sync

sync

Gateway Database

Solutions are a one-to-one <u>copy</u> of data between systems

Hedberg and Barnard Feeney

Digital Threads in a Model-Based Enterprise

Digital Thread, *noun*

A connected information flow between standard interfaces for activities across the product lifecycle

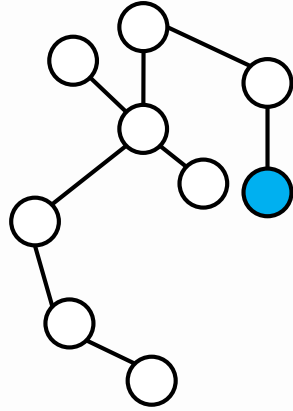# Don't copy the data. Link to it.
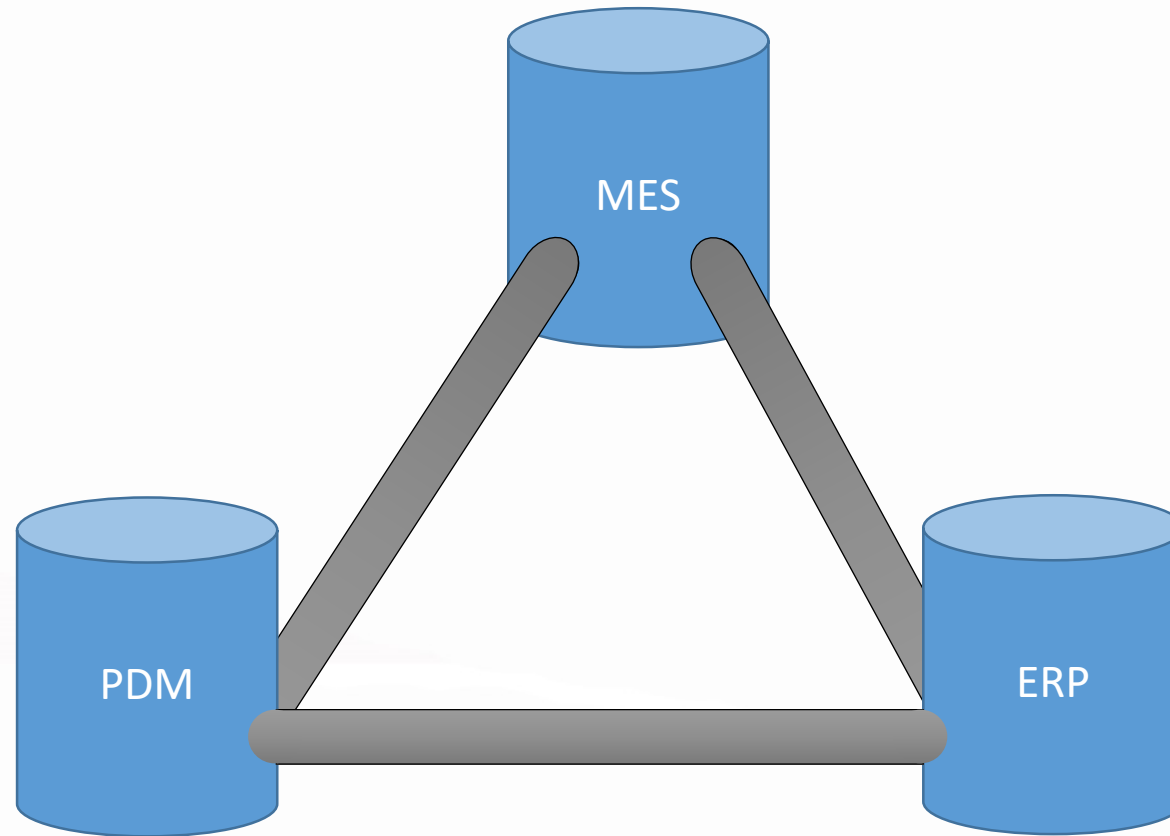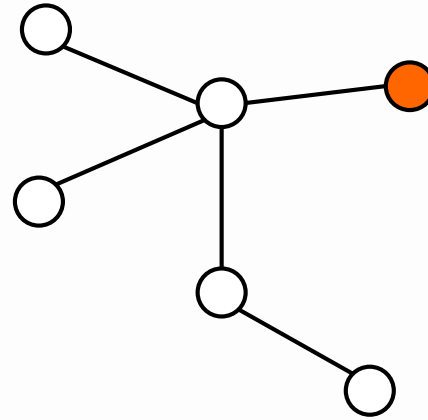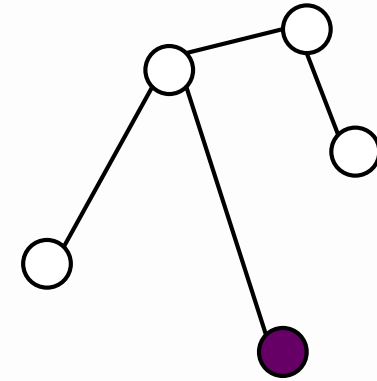
Dynamic Information Models
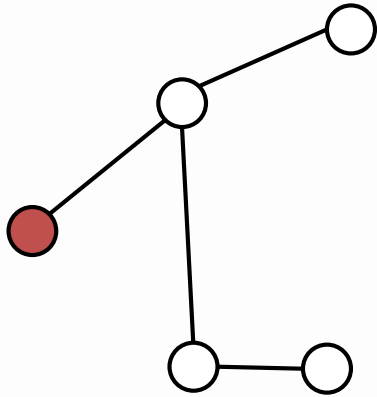
Design
Information Model

Material
Information Model

Manufacturing
Information Model

Quality
Information Model

Dynamic Information Models

Design
Information Model

Material
Information Model

Manufacturing
Information Model

Quality
Information Model

Dynamic Information Model
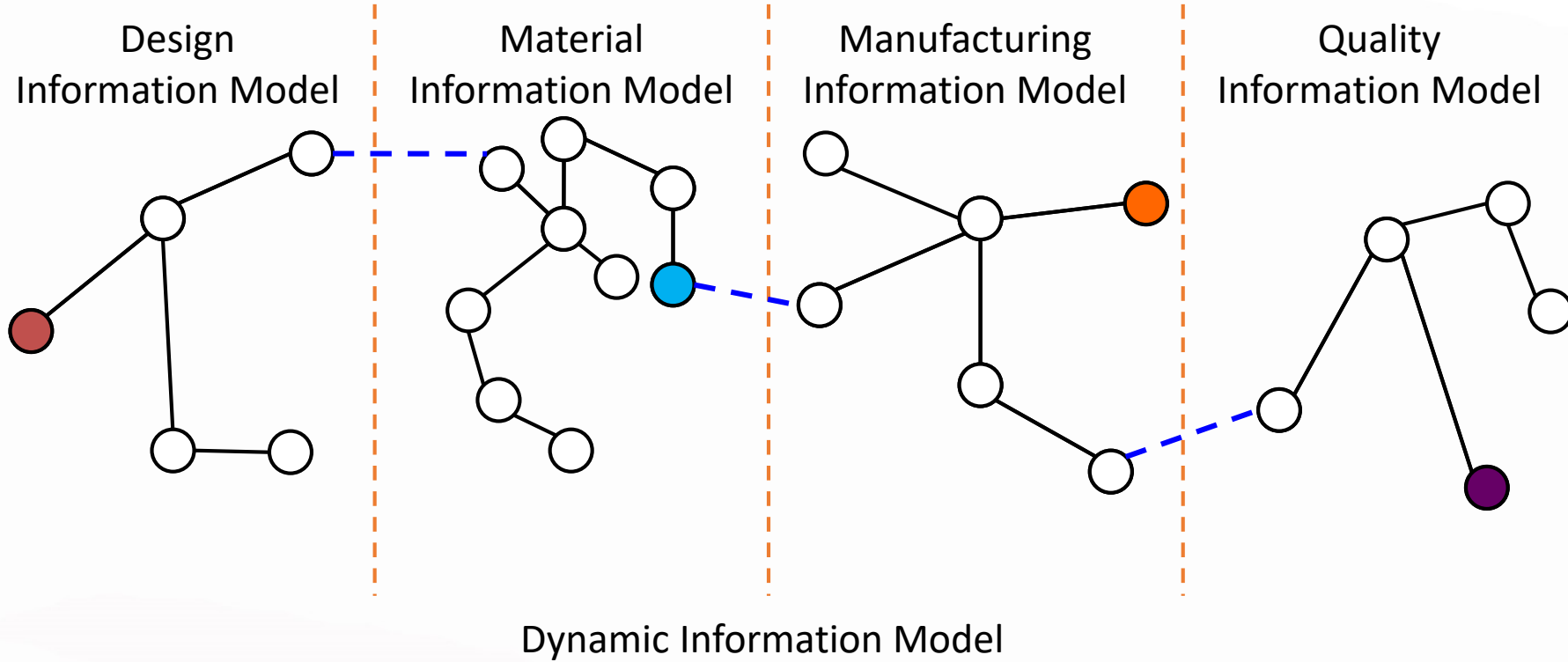
OAG Integration Specification (OAGIS) for Messaging Services

- Specifies message definitions (BODs) for integrations of business and engineering applications (***manufacturing services***)

- Supports many industries
  - Automotive, Aerospace, Defense, Process Manufacturing, Electronic Manufacturing, Construction, etc.

- Supports nearly all operational areas of a manufacturing enterprise
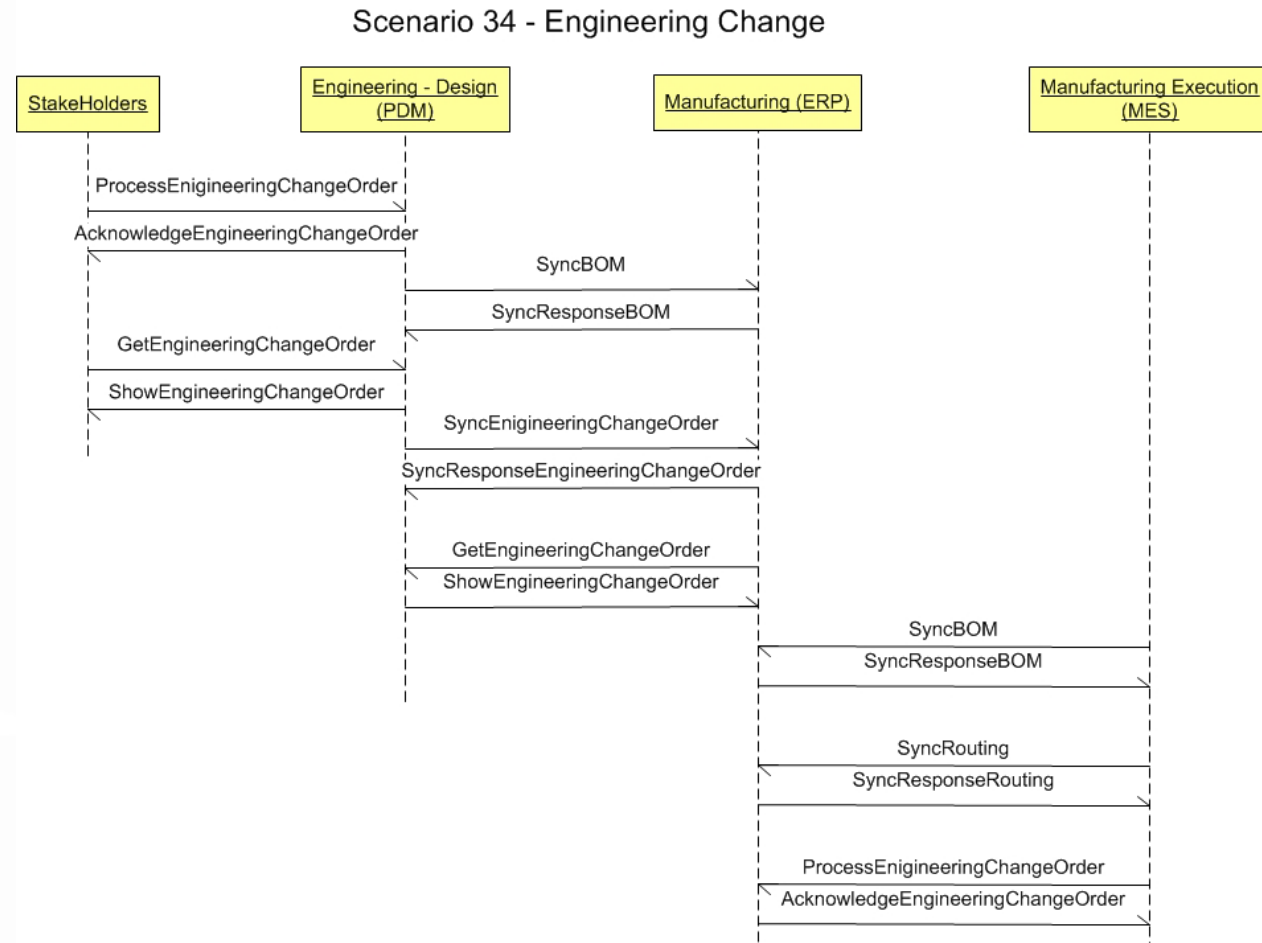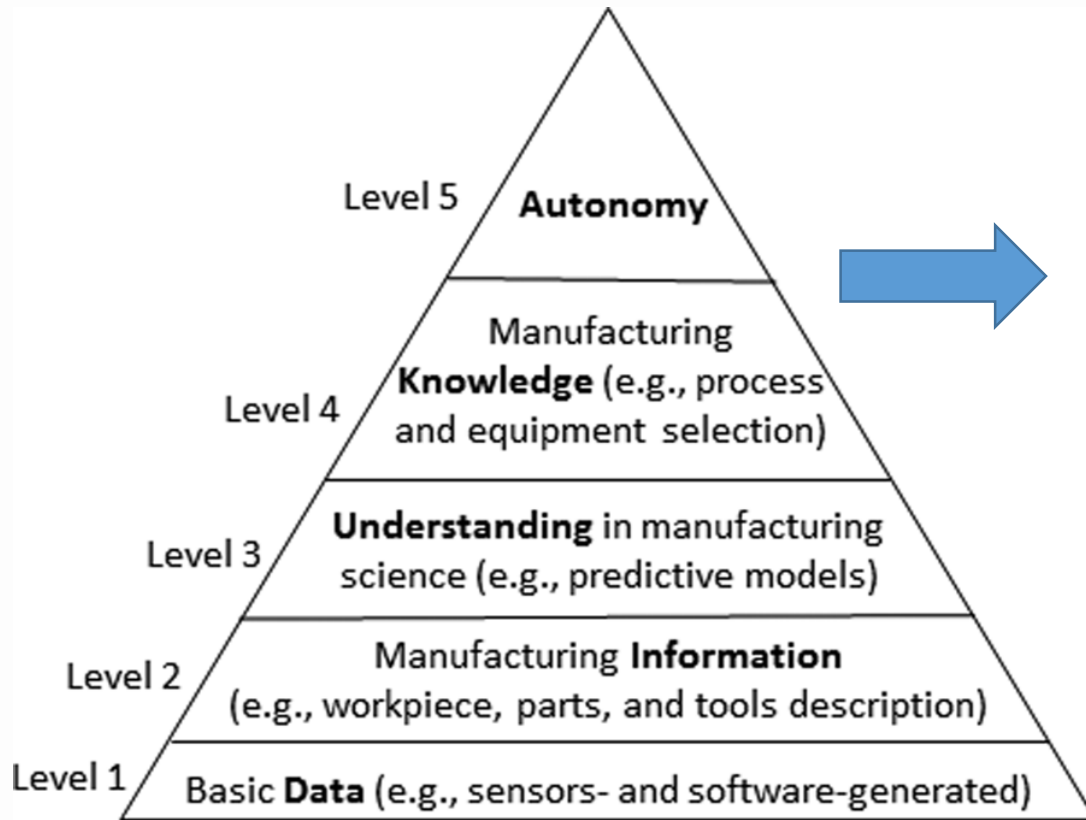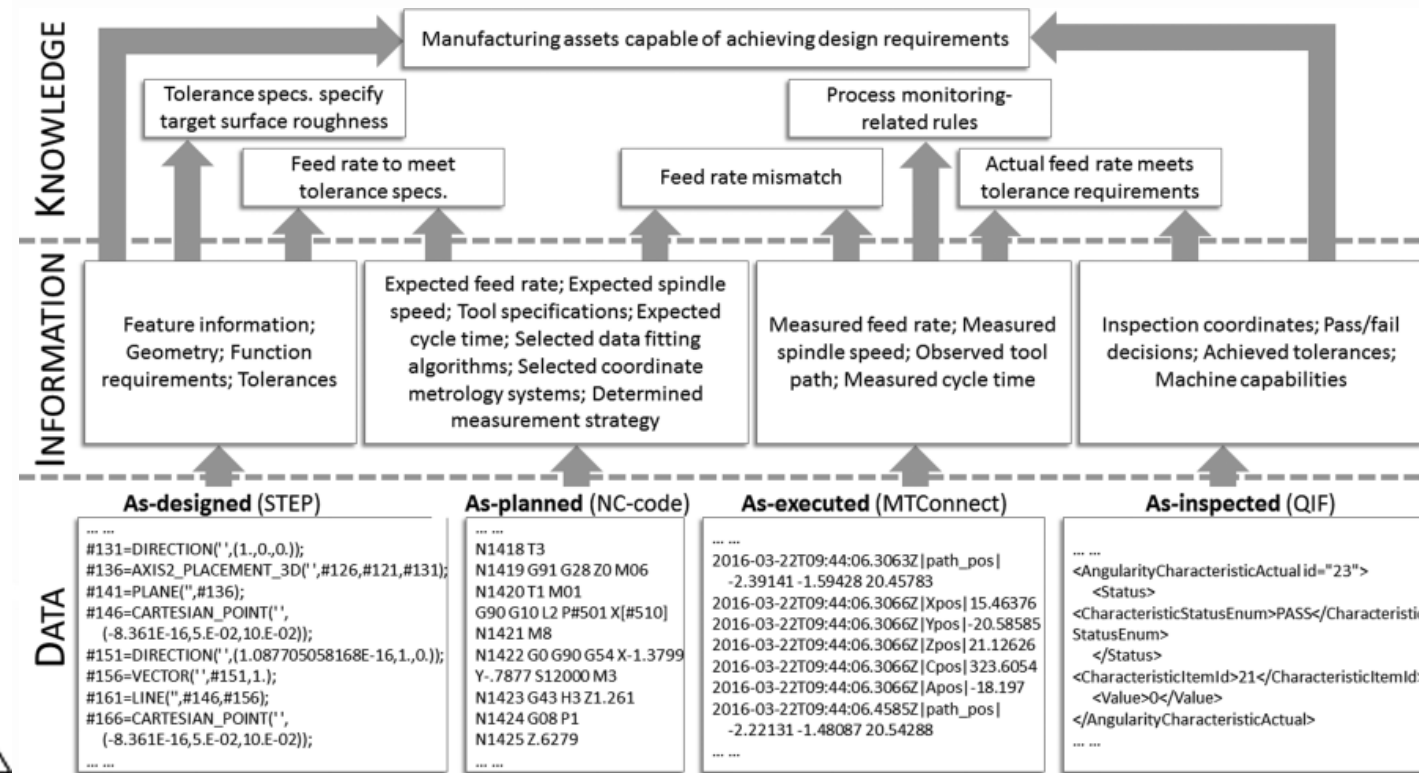 - Sales, manufacturing, supply, and financials

- Contains 1000+ BODs

Fig. An example scenario covered by OAGIS

https://oagi.org/DownloadsResources/tabid/143/Default.aspx

Knowledge Generation

**Levels in smart manufacturing knowledge management**

Engineering is Decision Making
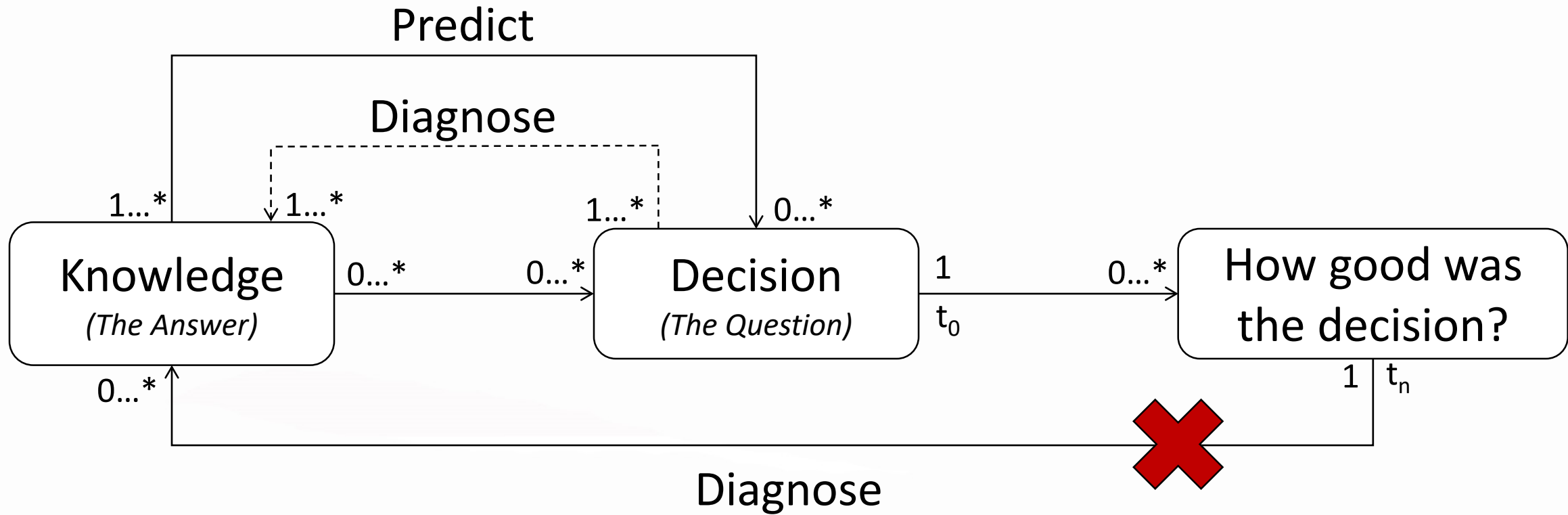
Hedberg, T., Barnard Feeney, A., & Camelio, J. (2018). Toward a Diagnostic and Prognostic Method for Knowledge-Driven Decision-Making in Smart Manufacturing Technologies. In A. M. Madni, B. Boehm, R. G. Ghanem, D. Erwin, & M. J. Wheaton (Eds.), *Disciplinary Convergence in Systems Engineering Research* (pp. 859–873). doi: 10.1007/978-3-319-62217-0_60

Summary

- I4.0 and MBE involve trusted decision making in distributed environments

- Deploying digital thread via standard interfaces between "things" using consensus-based, voluntary, open standards will enable rapid data exploration, knowledge extraction, and model generation

- Conservatively, $100 Billion annual savings* is available to industry through the adoption of open-standards, model-based methods
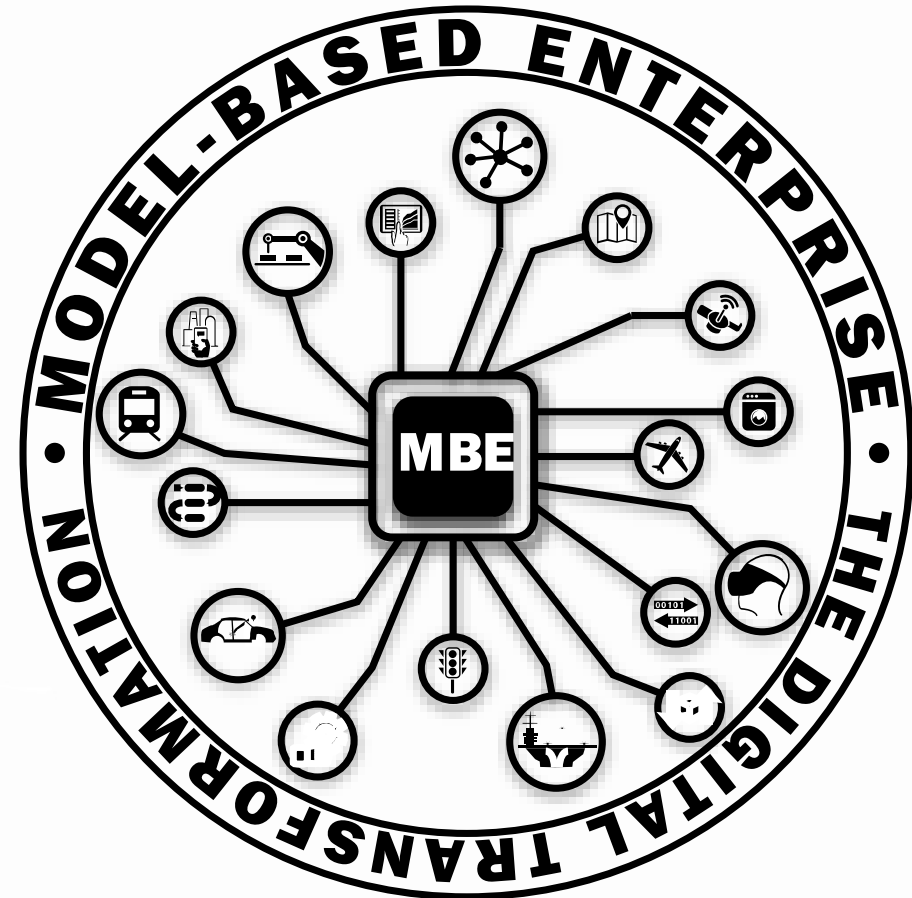
* Anderson, G. (2016). *The Economic Impact of Technology Infrastructure for Advanced Manufacturing: An Overview* (NIST Economic Analysis Briefs 1).
Retrieved from Gaithersburg MD: http://nvlpubs.nist.gov/nistpubs/eab/NIST.EAB.1.pdf

Questions?

Thank you for your kind attention!

Thomas Hedberg
thomas.hedberg@nist.gov

MBE Program: https://go.usa.gov/xPzGU

SMS Test Bed: https://smstestbed.nist.gov

My Publications: https://go.usa.gov/xnf3w

"The 95% confidence interval suggests Rexthor's dog could also be a cat, or possibly a teapot."

R²=0.06

REXTHOR, THE DOG-BEARER
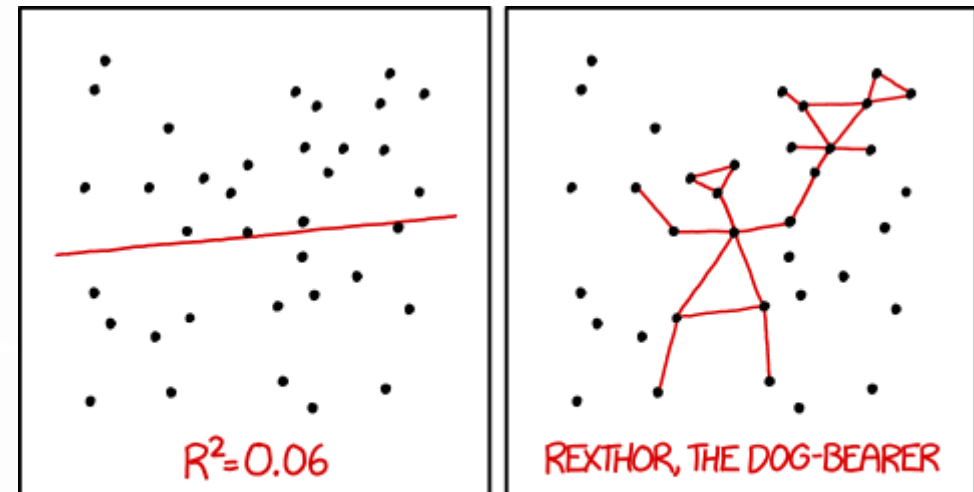
I DON'T TRUST LINEAR REGRESSIONS WHEN IT'S HARDER TO GUESS THE DIRECTION OF THE CORRELATION FROM THE SCATTER PLOT THAN TO FIND NEW CONSTELLATIONS ON IT.

https://xkcd.com/1725/

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