engineering laboratory

Extending the Digital Thread to Manufacturing and Beyond!

Tom Hedberg and Allison Barnard Feeney

System Integration Division, Engineering Laboratory

MBE Summit 2014

Gaithersburg, Maryland

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

What is NIST up to in Manufacturing?

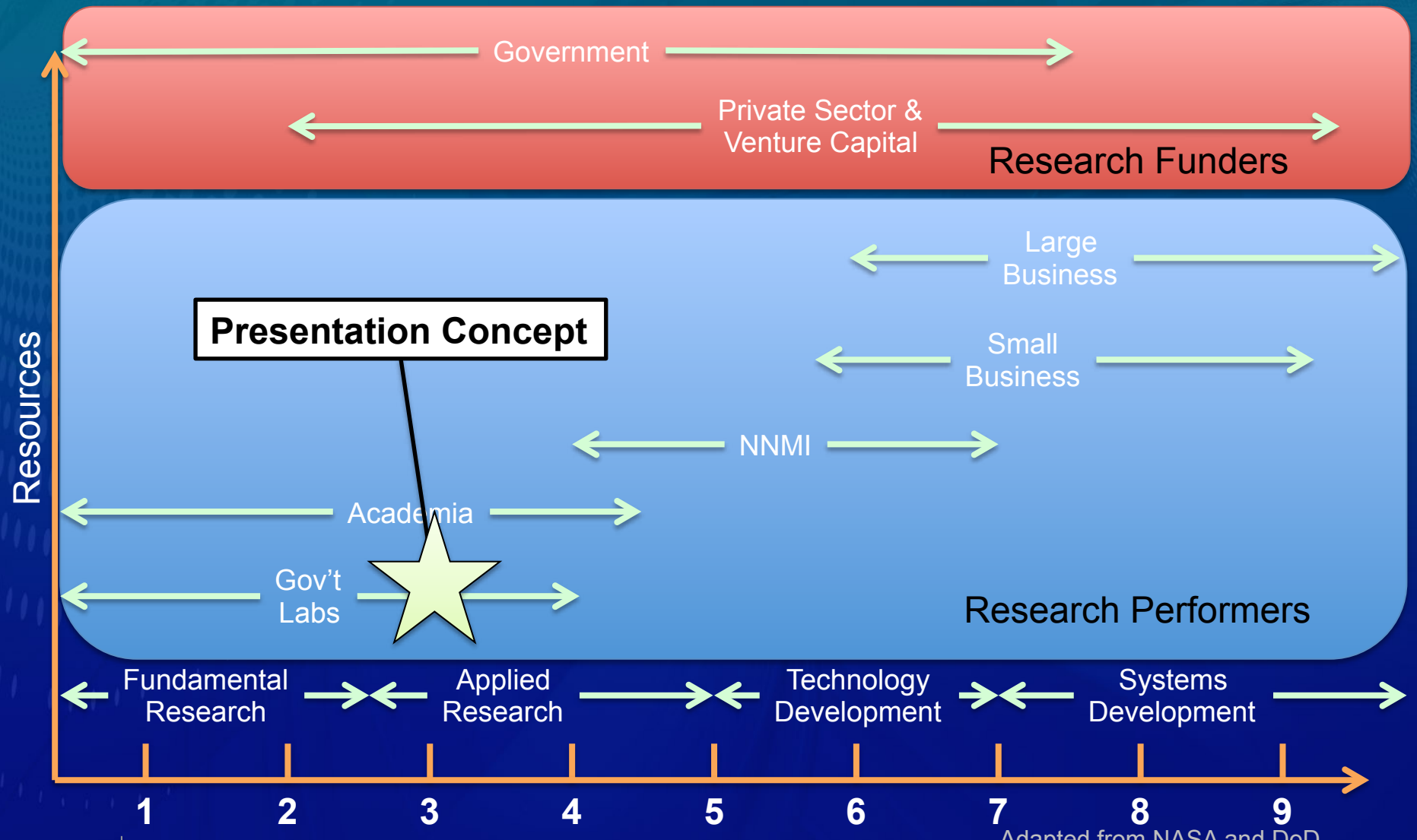
- Smart Manufacturing Operations Planning and Control (SMOPAC) Program
  - Program Manager: Allison Barnard Feeney
  - http://go.usa.gov/FXcT

- SMOPAC: Digital Thread for Smart Manufacturing Project
  - Project Leaders: Allison Barnard Feeney and Thomas Hedberg
  - http://go.usa.gov/Fg4B

➢ Enabling "Repurpose, Reuse, and Traceability of Information"

➢ Investigating the product lifecycle holistically to extend the digital thread of information with easy implementation into manufacturing systems

Setting Tech. Readiness Level Expectations



Adapted from NASA and DoD

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Presentation Overview

- Describe the problem
- Define the solution LIFT concept
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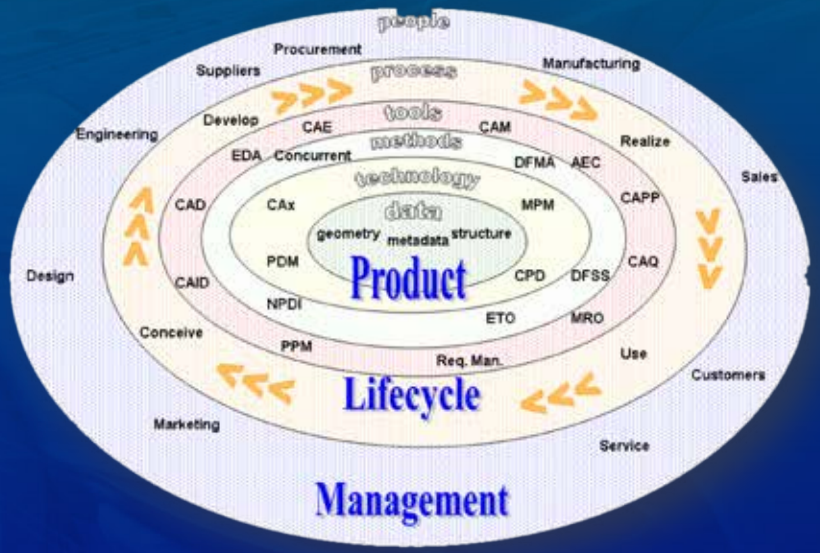
Data and Information Usage

- Putting lifecycle data into context for design decision is difficult
- Different data through out the lifecycle
- Data stored in different locations
- Different people (roles) using data in different ways
- Different contexts applied to data to form information differently

Components of the Product Lifecycle

1. Engineering
2. Commissioning (i.e. Supply Chain)
3. Operation
4. Technical Services
5. Modernization & Maintenance
6. Decommissioning



Freeformer, 2006, "Plm1.png," Wikipedia.

Dencovski, K., Löwen, U., Holm, T., Amberg, M., Maurmaier, M., and Göhner, P., 2010, "Production System's Life Cycle-Oriented Innovation of Industrial Information Systems," Factory Automation, pp. 389-410.

PLM: Popular vs. Theory

Populous View

- Conflated with product data management tools as a process for managing only CAD
- Can be implemented with only a single large enterprise tool
- Separate from ERP, MES, KM, Business Processes, etc.

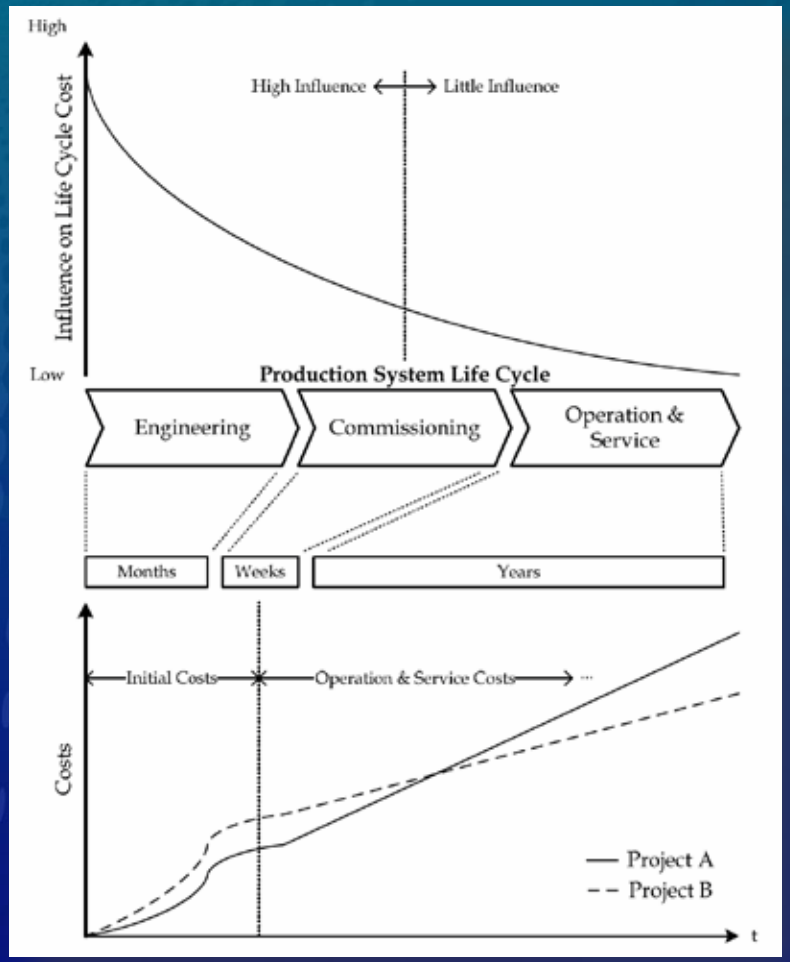
Theoretical View

- Considers many forms of product data, not only CAD and/or BOM data
- Integration of CAx, Mfg process management, PDM, and SysEn tools with methods, people, and processes❖
- Accounts for organizational, cultural, and human resource issues integrated with technology and data in a system of systems✚

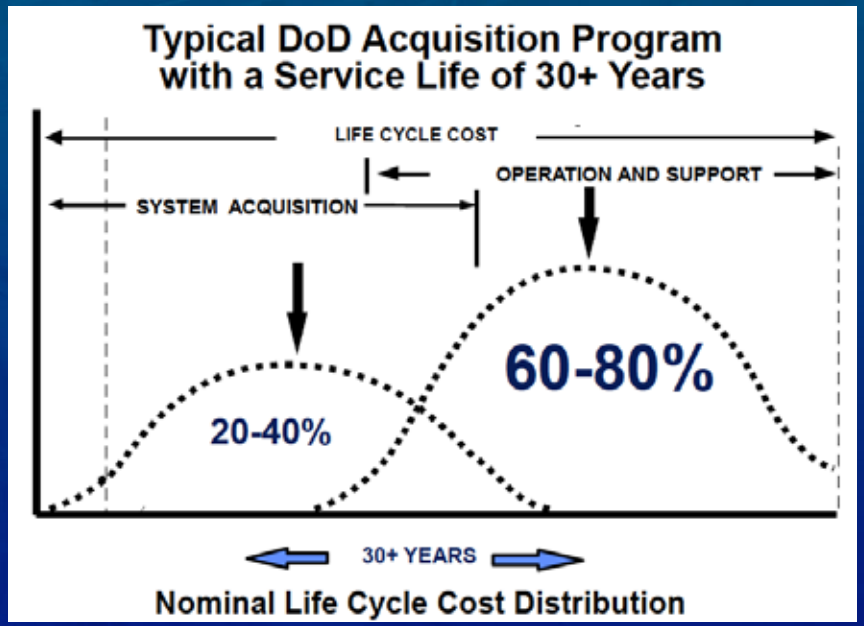
❖ Teresko, J., 2004, "The PLM Revolution," IndustryWeek, Penton.

✚ Stark, J., 2005, Product Lifecycle Management, Springer London.

Product Lifecycle: Costs vs. Influence



Dencovski, K., et al., 2010, "Production System's Life Cycle-Oriented Innovation of Industrial Information Systems," Factory Automation, pp. 389-410.



2011, "DoD Life Cycle Management (LCM) & Product Support Manager (PSM) Rapid Deployment Training," Defense Acquisition University.

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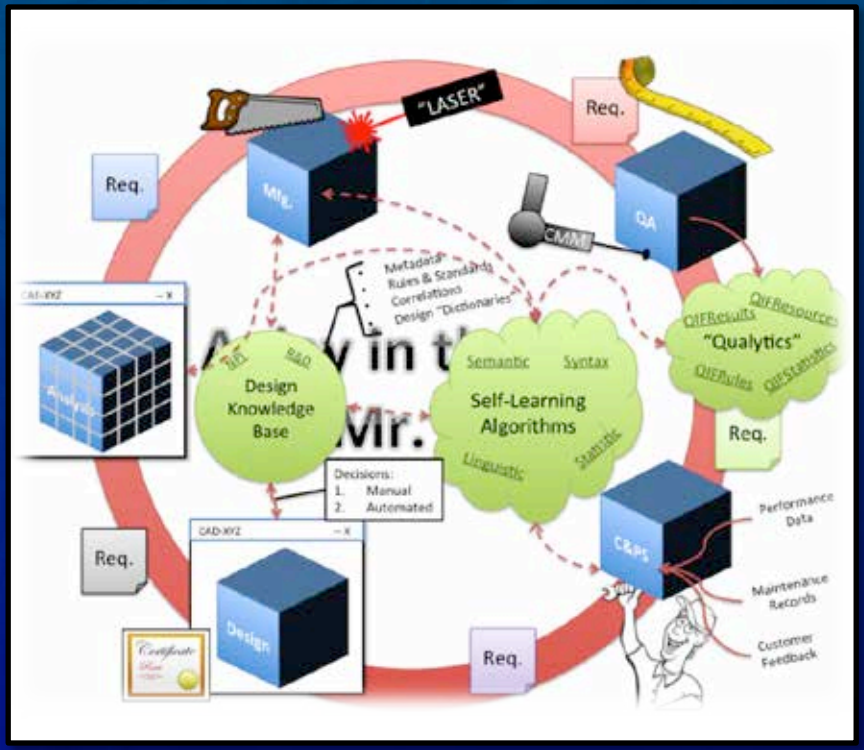
Proposing a Solution with an Infographic

- Develop / integrate technology and standards to enable straightforward PLM theory implementation
- Stretch / replace current product lifecycle paradigms with innovative processes
- Create the “Google” for engineering data to support information cultivation



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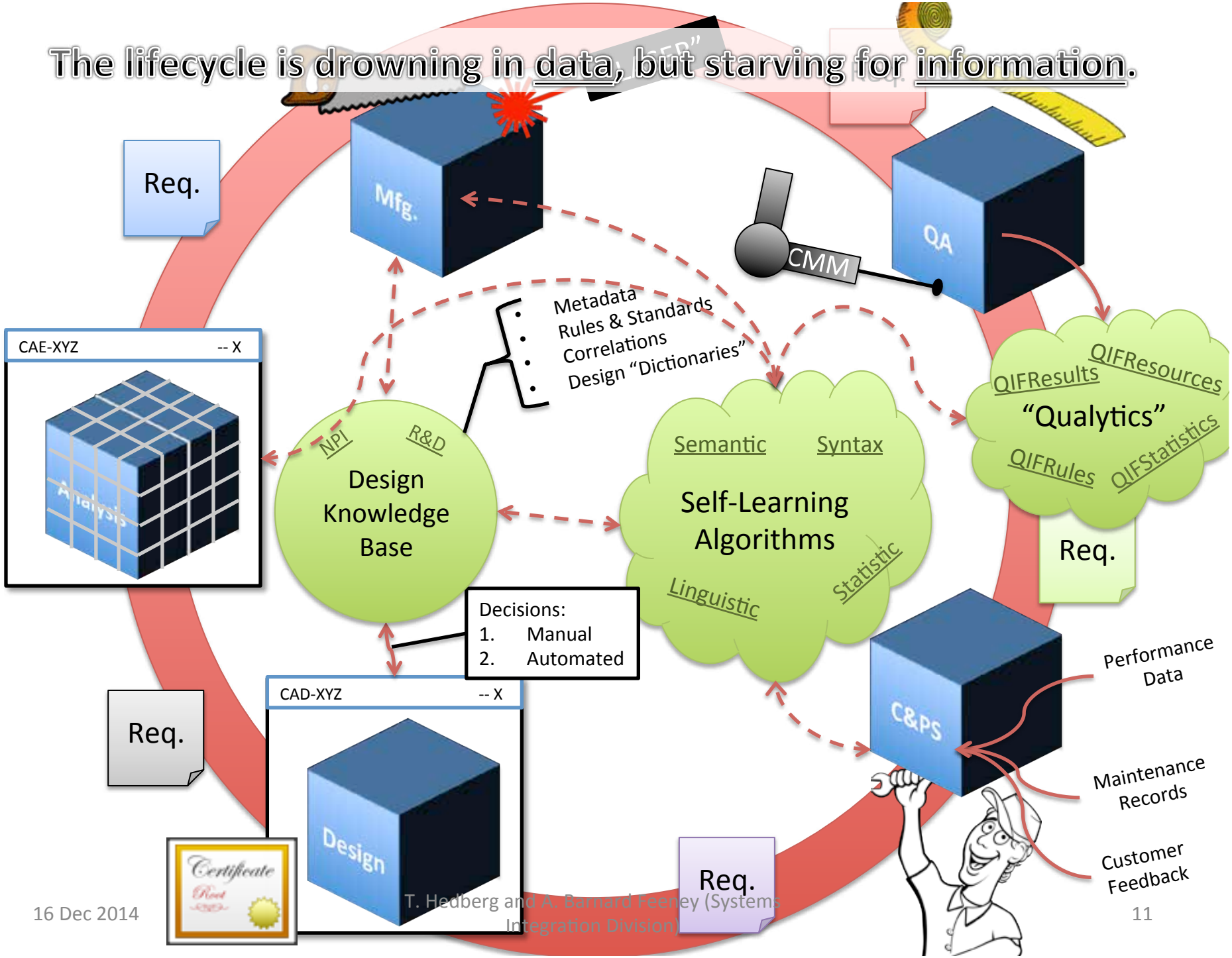
The lifecycle is drowning in data, but starving for information.



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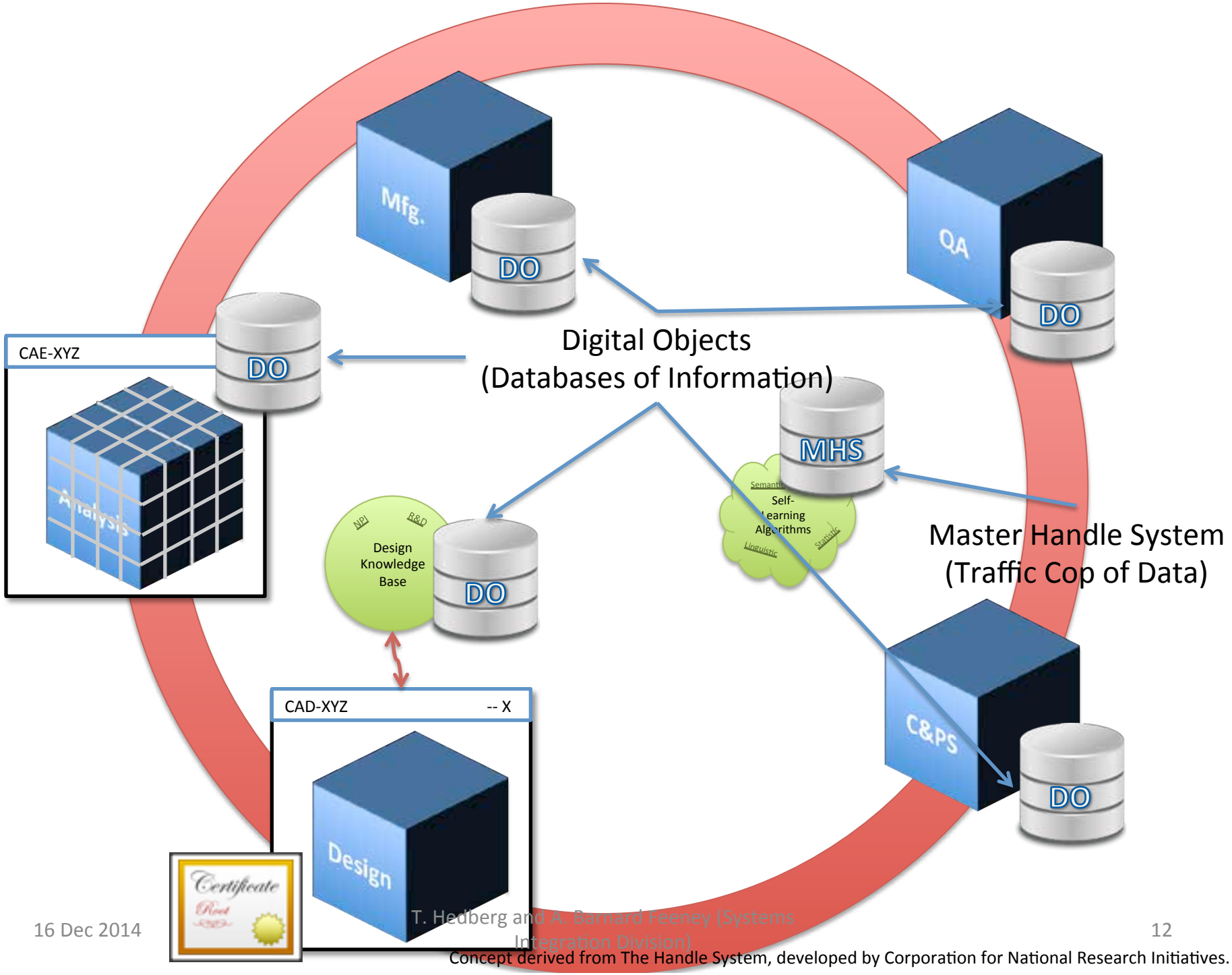

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Concept derived from The Handle System, developed by Corporation for National Research Initiatives.

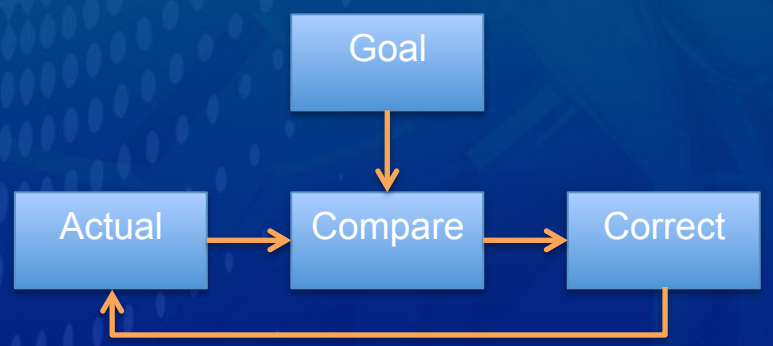
Support for Organizational Learning

- People have *mental maps* with regard to how to act in situations
- Involves the way people plan, implement, and review their actions
- The maps guide people's actions rather than the theories they explicitly espouse causing a split between theory and actions

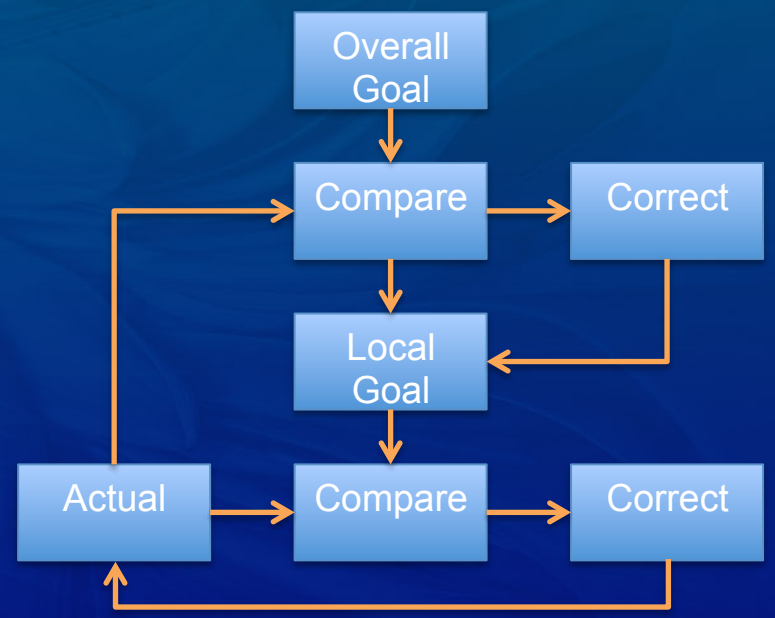
Argyris, C., and Schön, D. A., 1978, Organizational learning, Addison-Wesley Pub. Co., Reading, Mass.
Argyris, C., 2008, Teaching smart people how to learn, Harvard Business Press, Boston, Mass.

Two Ways of Learning

Single Loop Learning / Control



Double Loop Learning / Control

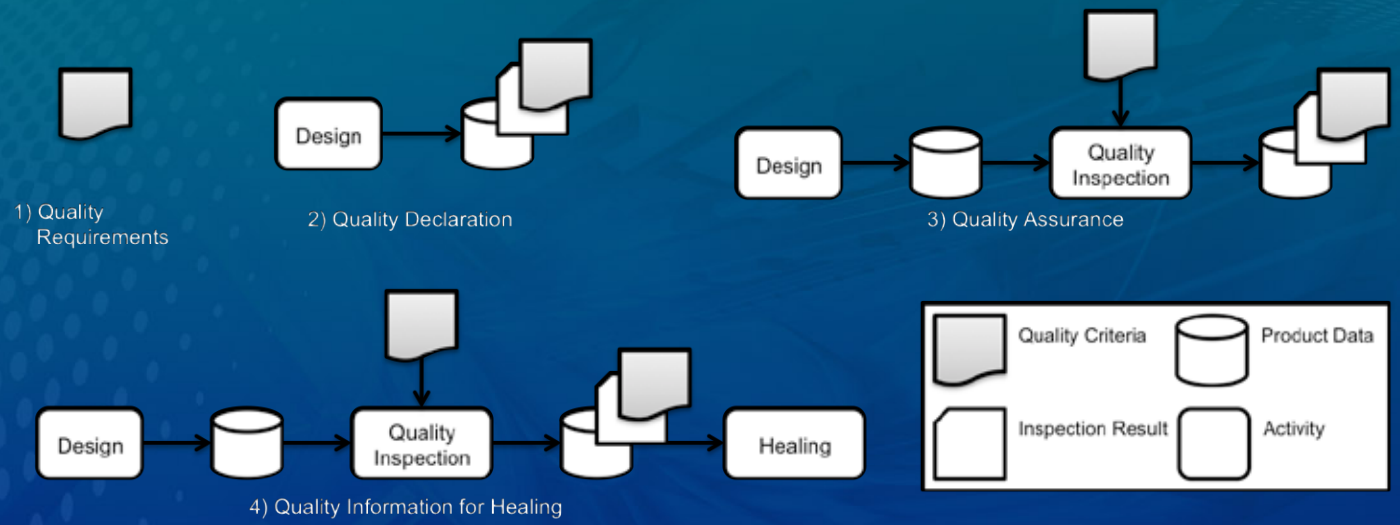


Double-loop learning breaks the pattern of,
"This is the way we've always done it"

Argyris, C., and Schön, D. A., 1978, Organizational learning, Addison-Wesley Pub. Co., Reading, Mass.

D. G. Reinertsen, *Managing the design factory : a product developer's toolkit*. New York: Free Press, 1997.

The Product Data Quality (PDQ) Process



1. Product data requirements used to define and communicate the PDQ criterion with related tolerance and accuracy

2. PDQ declaration for the model data (e.g. Concept model)

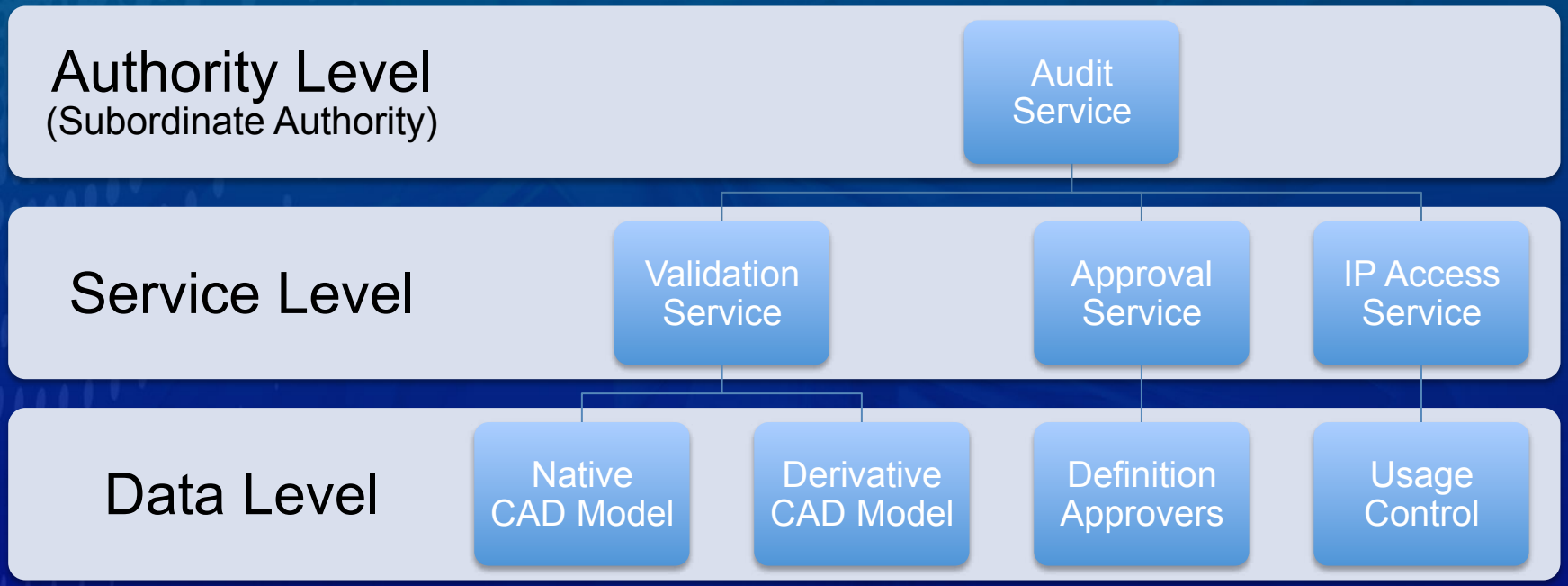
3. PDQ verification and validation results (e.g. 3rd Party model V&V tool)

4. PDQ defect information including healing (e.g. what is off nominal)

Hedberg, T., 2012 "Model Based Enterprise and Enabling Quality Inter-operable Data Exchange," Proc. Global Product Data Interoperability Summit.

Building a Product Lifecycle of Trust (PLOT)

A concept inline with X.509 Private Key Infrastructure and Privilege Management Infrastructure as an all-in-one solution



A system based on Authorization with embedded Authentication.

Who does what to whom?

Authority Level

Authority level vets the Service level and signs the solutions

Service Level

Service level licenses Authority signed solutions to end users

Data Level

End user runs V&V on Data level and signs the Data with embedded attributes from the Service level

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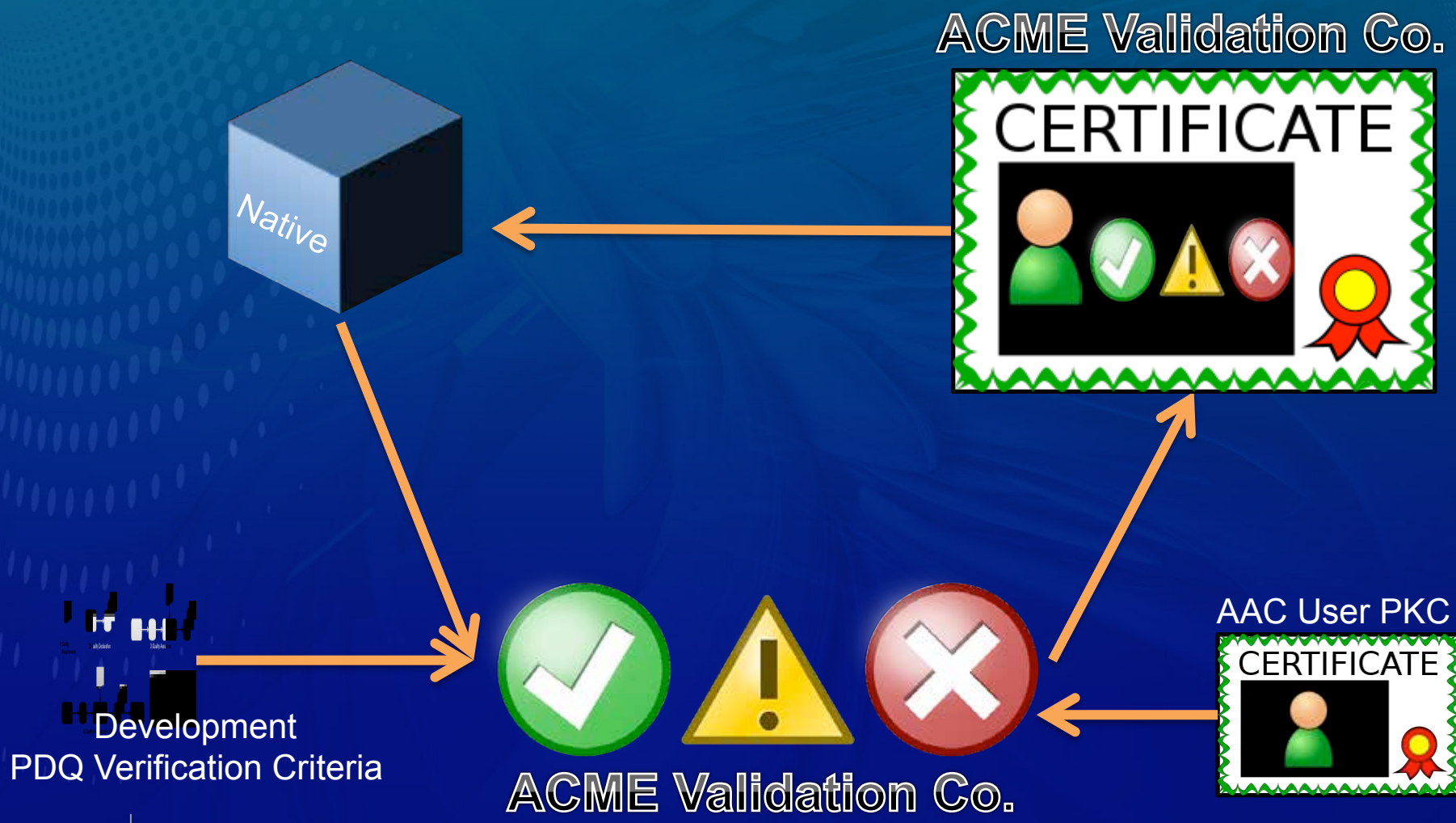
Building Trust: Verify the model meets the criteria



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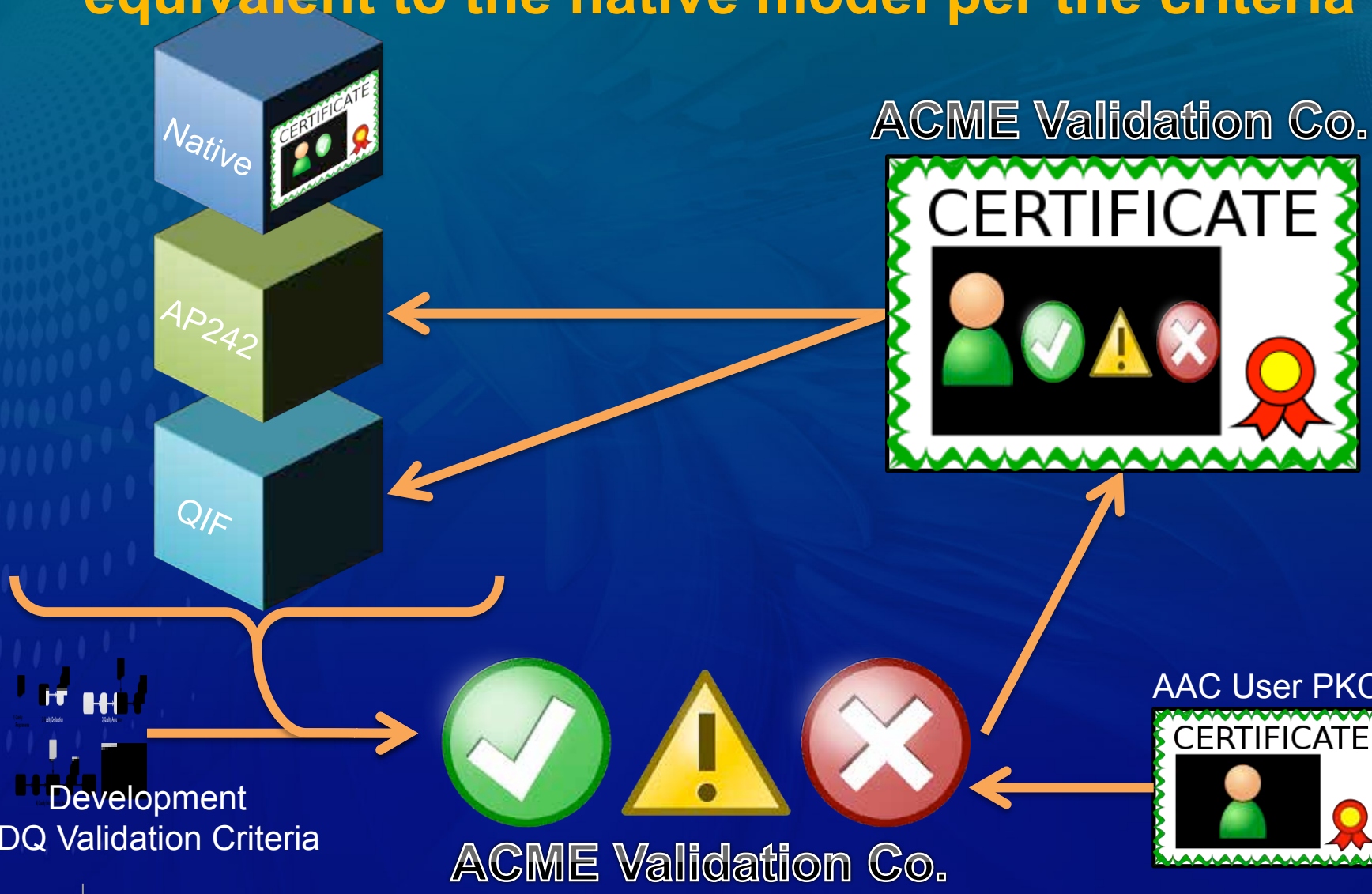
Building Trust: Validate the derivatives are equivalent to the native model per the criteria



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Scenario

1. The capture of quality information and intelligent engineering change request (ECR) system

.:: Scenario One::.

THE CAPTURE OF QUALITY INFORMATION AND INTELLIGENT ENGINEERING CHANGE REQUEST (ECR) SYSTEM

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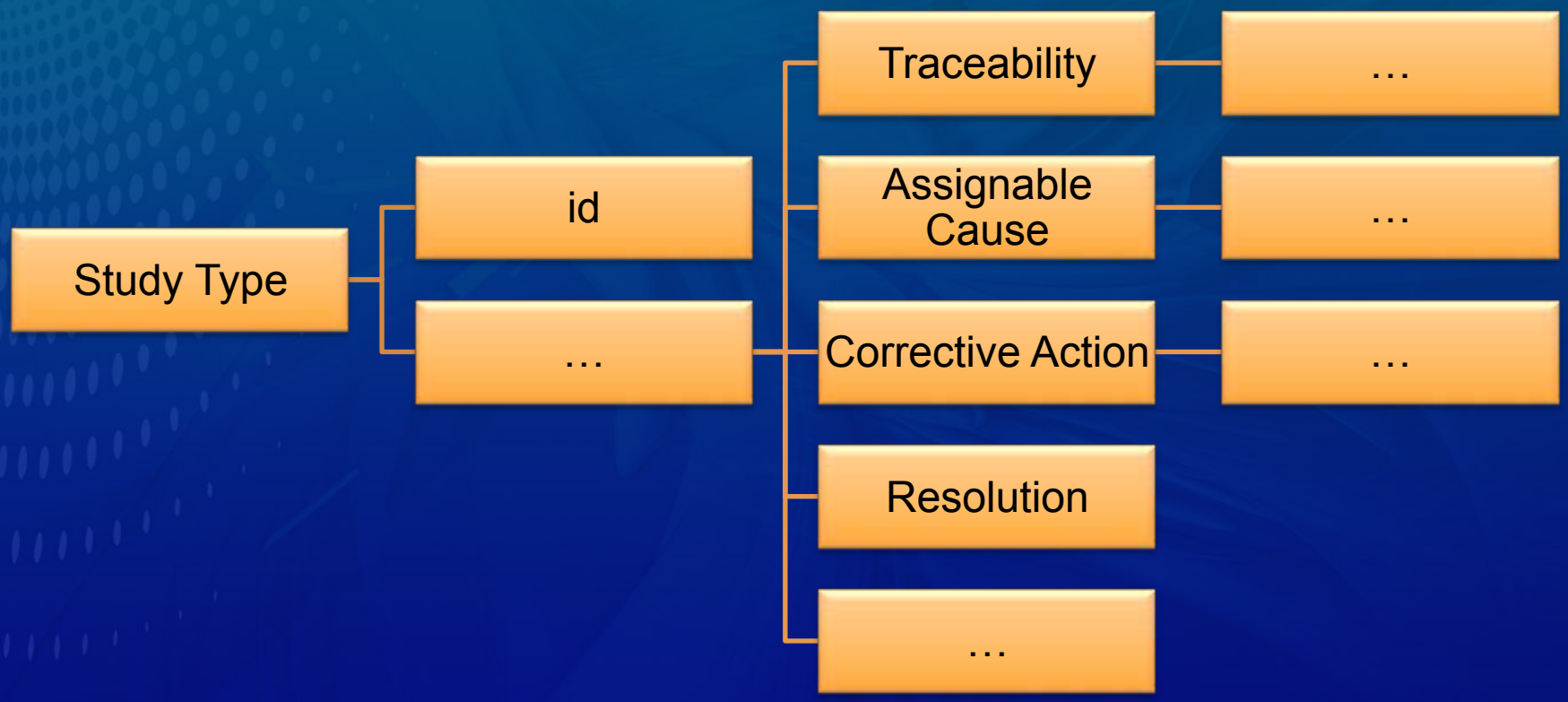
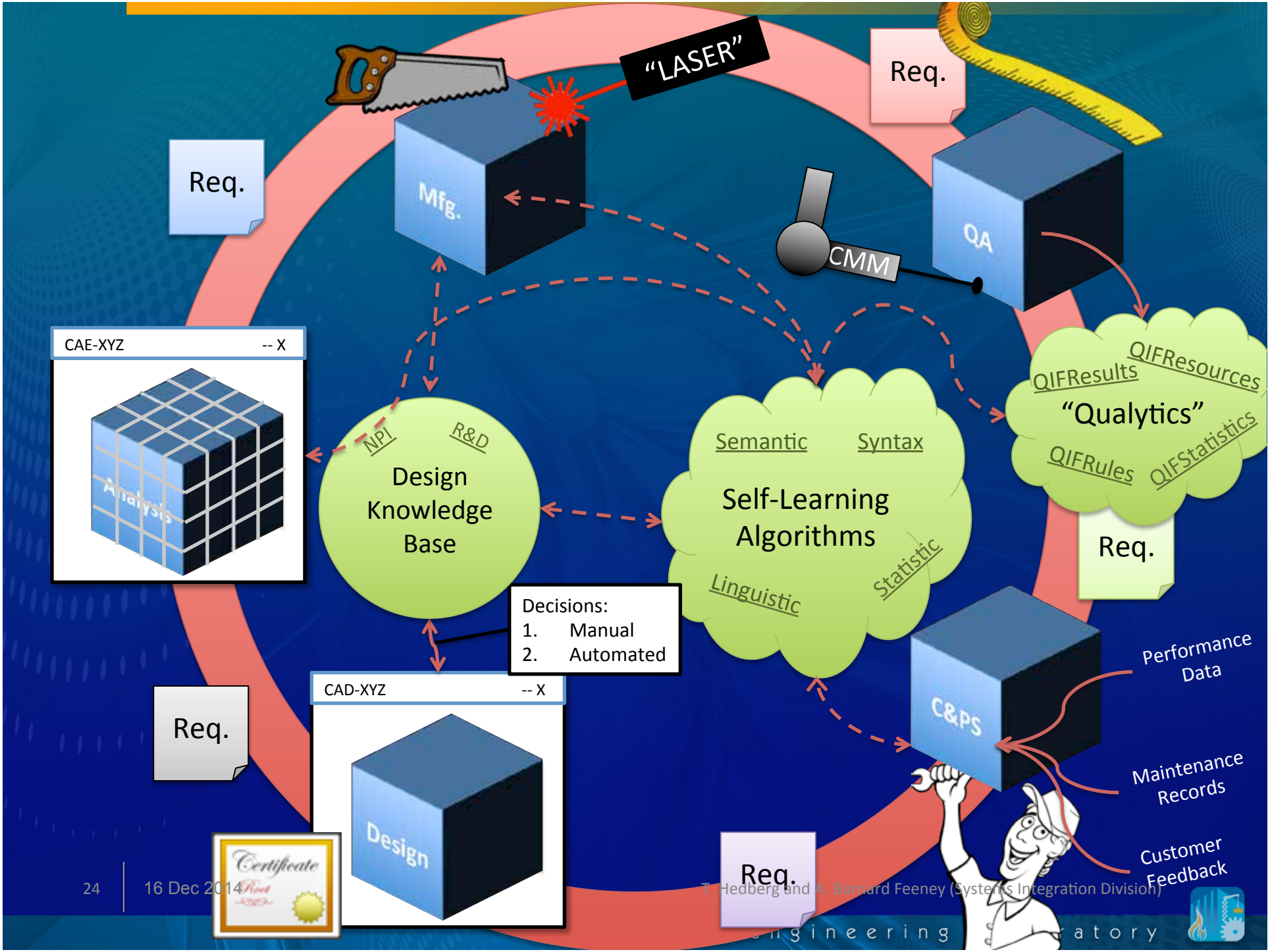
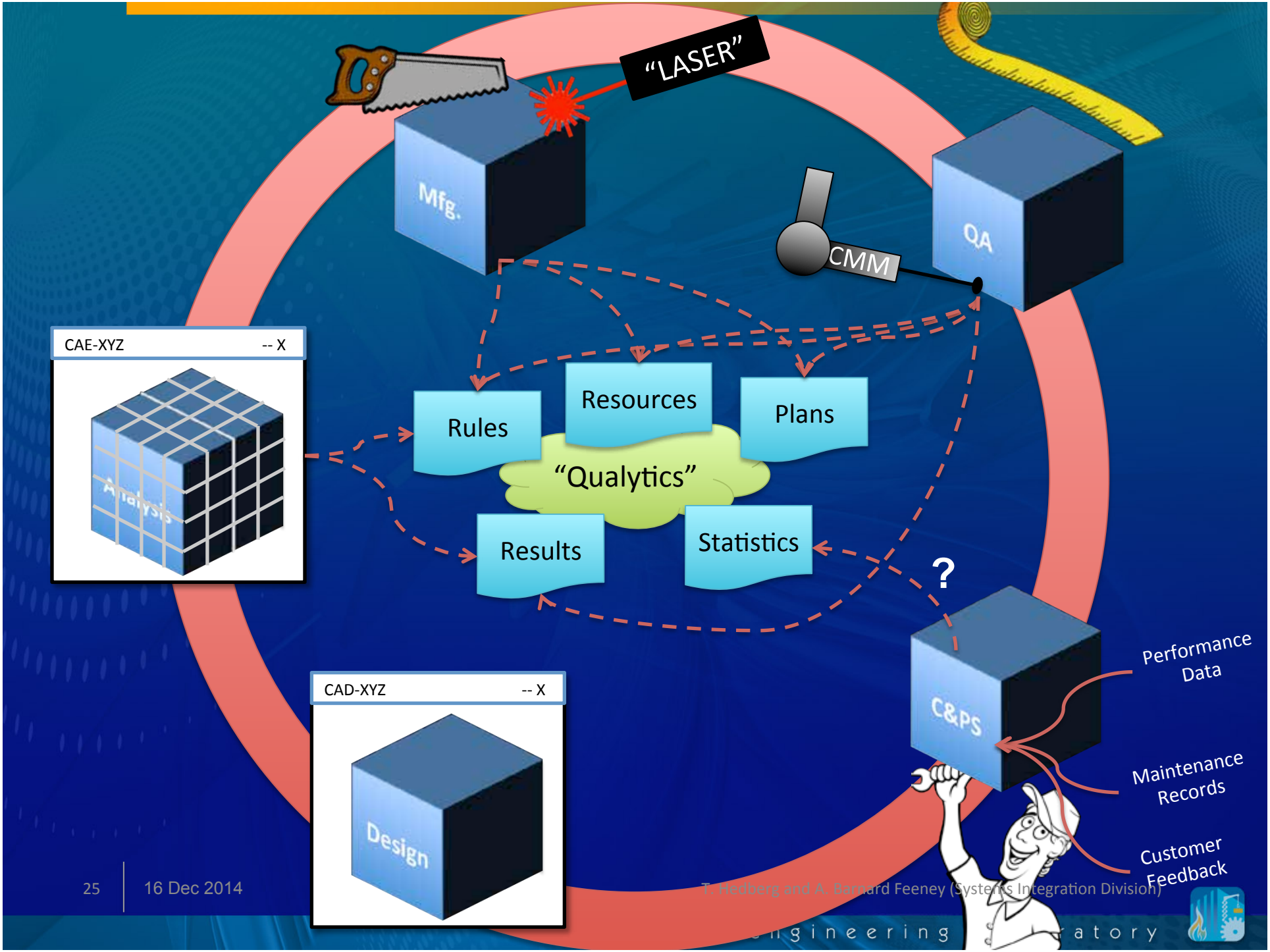
ANSI/QIF 2.0 Causes & Remedies

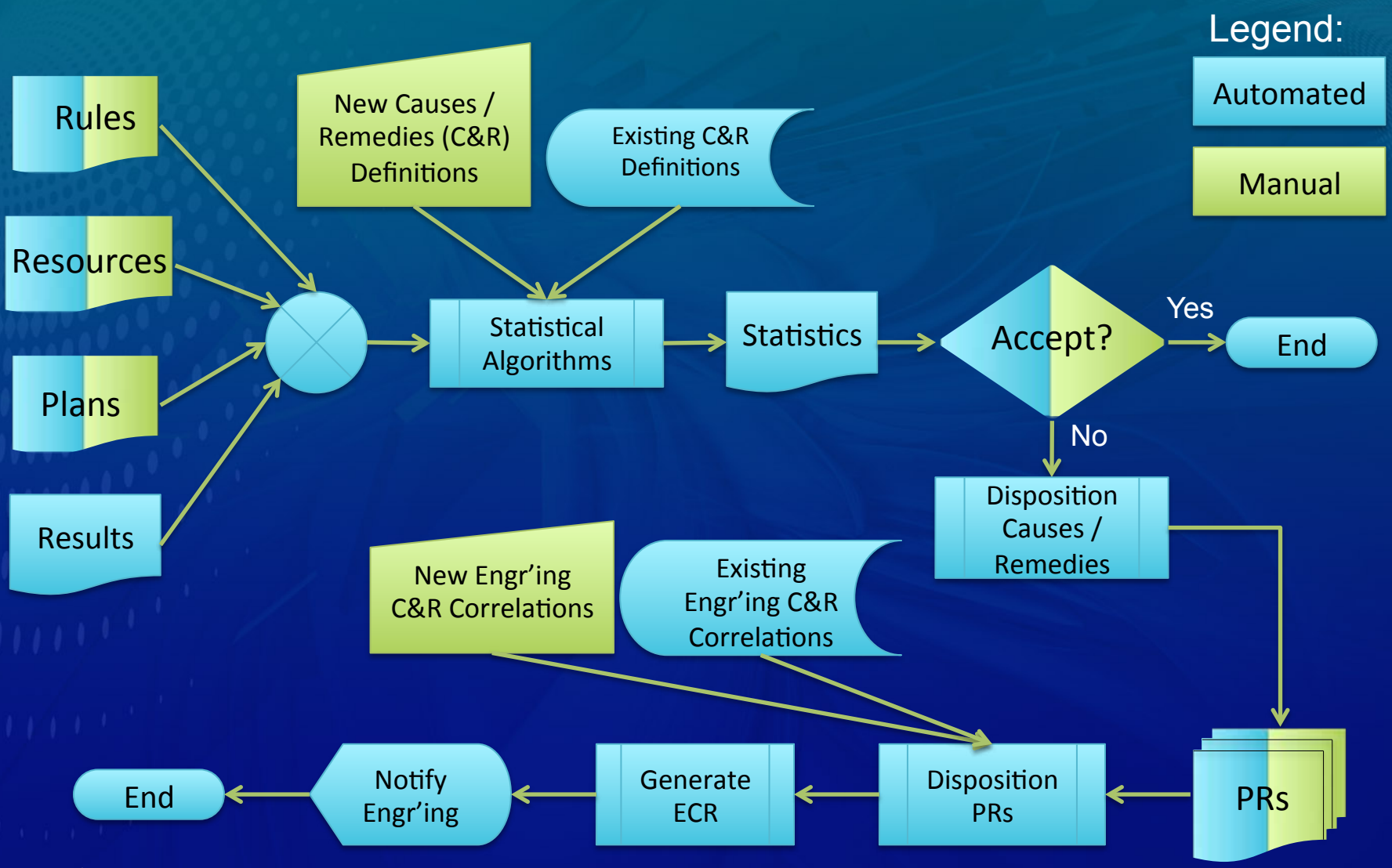


Dimensional Metrology Standards Consortium, 2014, "Quality Information Framework (QIF) – An Integrated Model for Manufacturing Quality Information," Part 8: QIF Statistics Information Model and XML Schema Files, American National Standards Institute.


"LASER"
Req.
Req.
Mfg.
QA
CMM
CAE-XYZ -- X
Analysis
NPI
R&D
Design Knowledge Base
Semantic
Syntax
Self-Learning Algorithms
Linguistic
Statistic
QIFResources
QIFResults
"Qualytics"
QIFRules
QIFStatistics
Req.
Decisions:
1. Manual
2. Automated
CAD-XYZ -- X
Design
Req.
C&PS
Performance Data
Maintenance Records
Customer Feedback
Req.
Certificate


"LASER"
Mfg.
CMM
QA
CAE-XYZ -- X
Analysis
Rules
Resources
Plans
"Qualytics"
Results
Statistics
?
C&PS
Performance Data
Maintenance Records
Customer Feedback
CAD-XYZ -- X
Design

Quality Information Feedback



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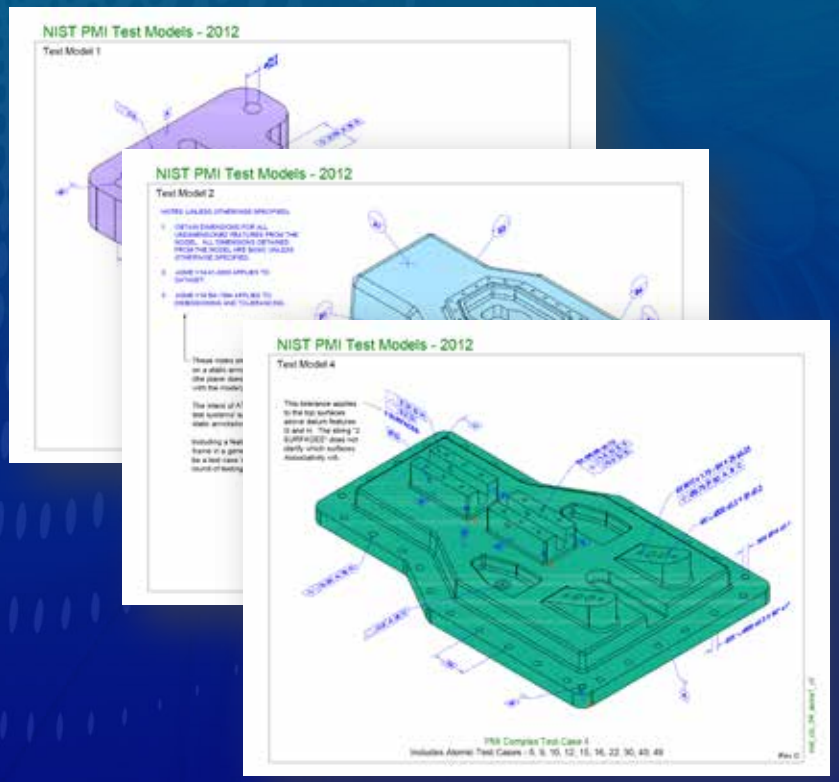
Standards Support: PMI Validation and Conformance Testing



- *What:* Supporting PMI standards implementation in CAD
- *Benefit:* Verified and validated representation of PMI concepts in CAD models
- *More info:* go.usa.gov/mGVm

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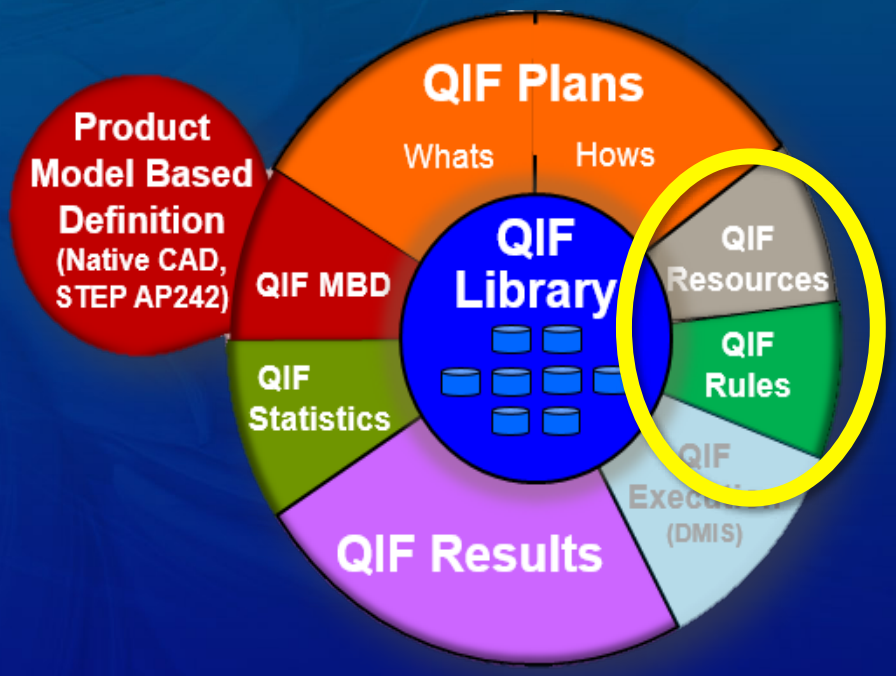
Decision Support: Tolerancing Standards and Modeling Challenge

- *What:* Utilize data interchange standards for design and metrology information to capture metrology capability
- *Benefit:* Metrology capability encoded in a standardized format and used to support design, manufacturing, and metrology activities
- *More Info:* go.usa.gov/6nPh



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DFM Validation: Validation for Downstream Computer-Aided Manufacturing and Coordinate Metrology

- *What:* Studying the development of algorithms to allow validation of downstream CAM and coordinate metrology data relative to its source CAD content
- *Benefit:* Better understanding of geometry-related and PMI-related producability and measurability process requirements
- *More Info:* go.usa.gov/6nPh

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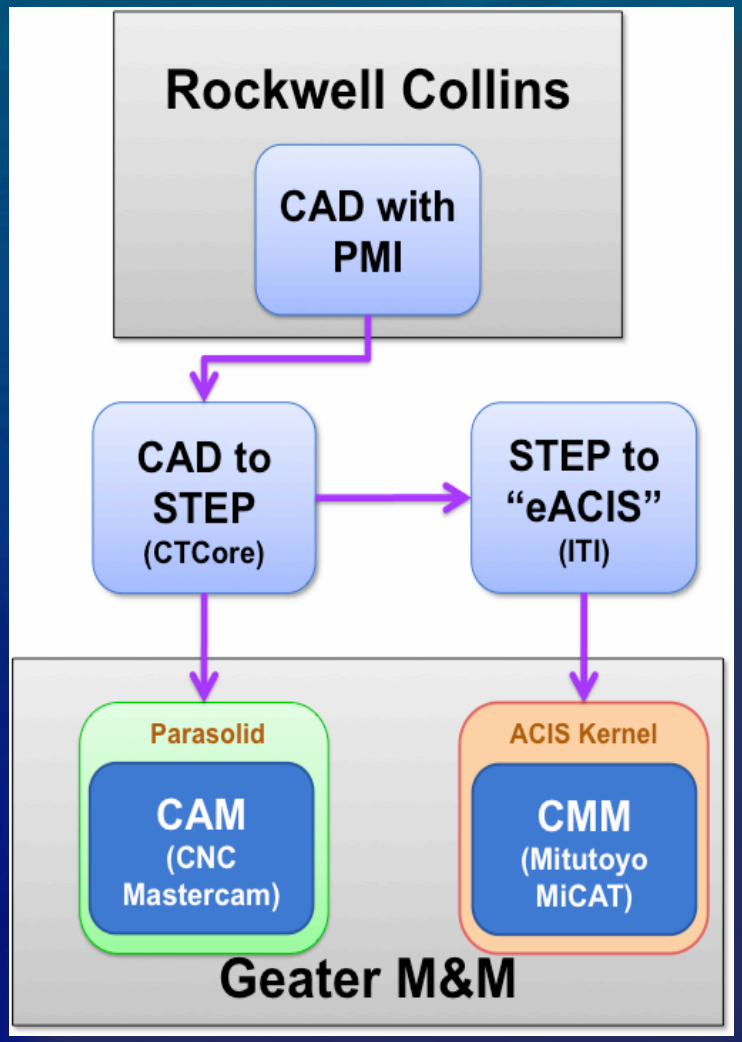
Data Reuse: Design to Manufacturing and Inspection

- *What:* Proof-of-Concept demonstrator for transport of PMI downstream to manufacturing and First Article Inspections (FAI)
- *Benefit:* Reduced and/or eliminate recreation of part design data, reduce risk of error introduction downstream
- *More Info:* go.usa.gov/6nPh



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In conclusion, The Solution Benefits…

- It puts **information** into the hands of the roles and functions that have a need to know
- It **educates** the cost and quality **influencers** on how to make designs better and more producible
- It supports **double-loop learning** in organizations to remove the disconnect between *theory* and *action*

Next Steps

- FY14, developed activity models of current industry processes in the lifecycle
  - Paper will publish soon
- Build upon FY14 work to propose augmentation to the lifecycle activities to increase efficiency and effectiveness of information for smart manufacturing
- Use the augmented lifecycle activities to test and mature the LIFT concept

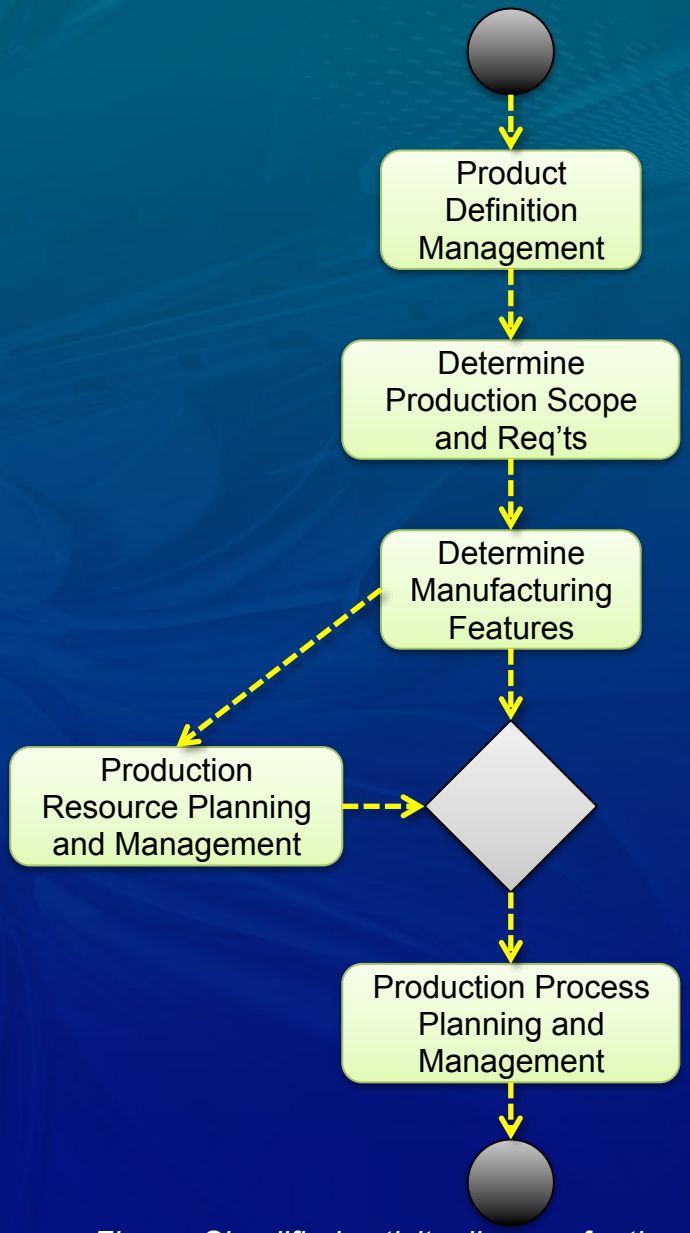

Figure: Simplified activity diagram for the researched manufacturing tasks

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Next Steps, Cont.

- Developing a test bed for maturing concepts and conduct pilot project with industry to verify and validate the concept definitions
- Test bed includes a CAx Lab and Manufacturing Lab to support experiments
- For example, testing the information needs for the *Unless otherwise specified (UOS)* requirement by manufacturing test cases

Unless otherwise specified Experiment

- Low
  - Pres: Text-based note
  - Rep: None
- Medium
  - Pres: Text-based note
  - Rep: Overall default tolerance with explicit exceptions applied to select features
- High
  - Pres: Text-based note
  - Rep: Explicit tolerance applied to all features

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Thank you.

Questions?

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