Business as Unusual: Enabling Model-Based Manufacturing and Quality Assurance

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System Integration Division, Engineering Laboratory

Global Product Data Interoperability Summit

Phoenix, Arizona

10 September 2014

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

What is NIST up to in Manufacturing?

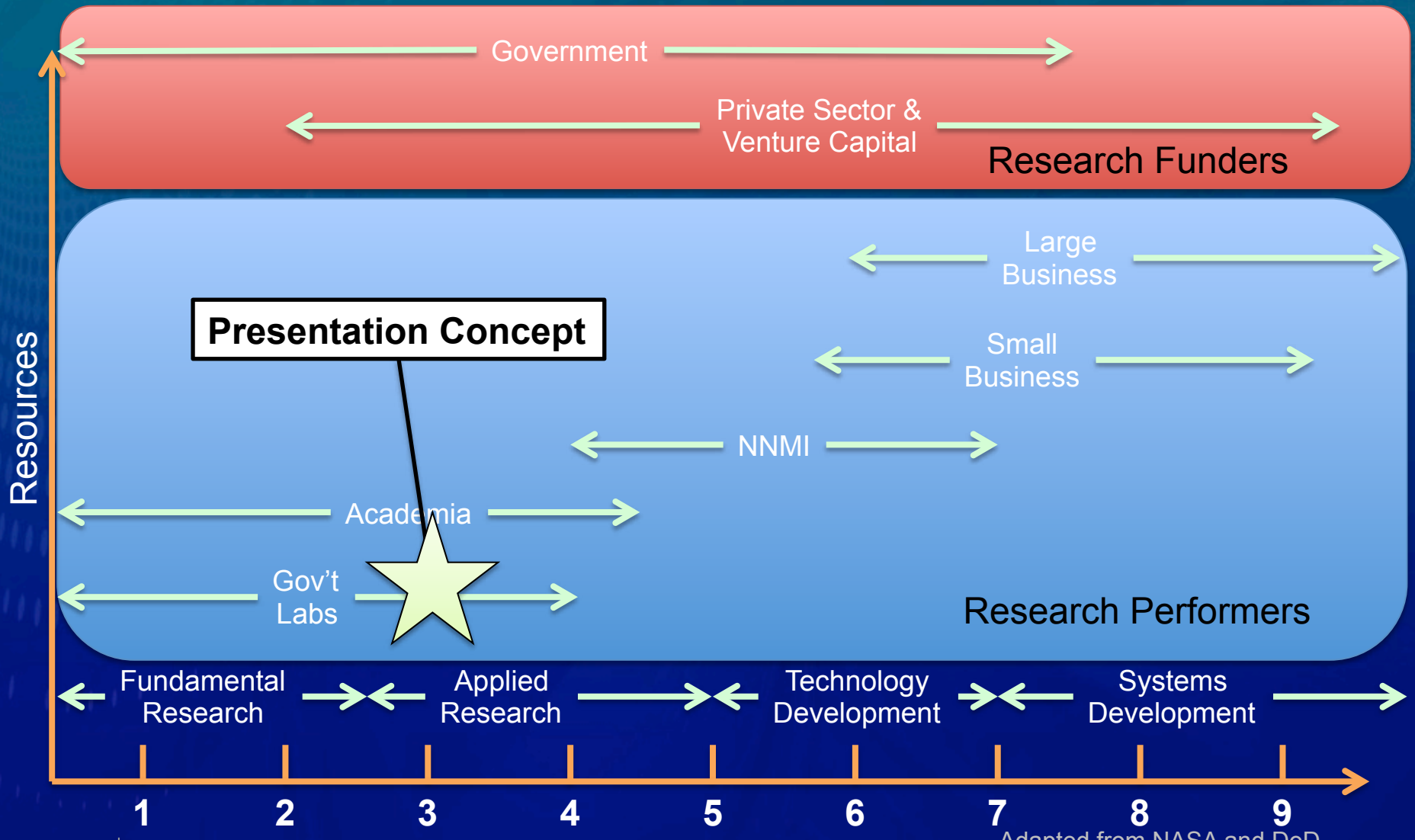
- Smart Manufacturing Operations Planning and Control (SMOPAC) Program
  - Program Manager: Allison Barnard Feeney
  - http://go.usa.gov/PMGh

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

- Enabling “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

T. Hedberg and A. Barnard Feeney (Systems Integration Division)

Presentation Overview

- Discuss the definition Product Lifecycle Management (PLM)
- Provide Data Exchange and Product Data Quality (PDQ) Overview
- Define the solution framework
- Provide application examples
- Draw conclusions and define next steps

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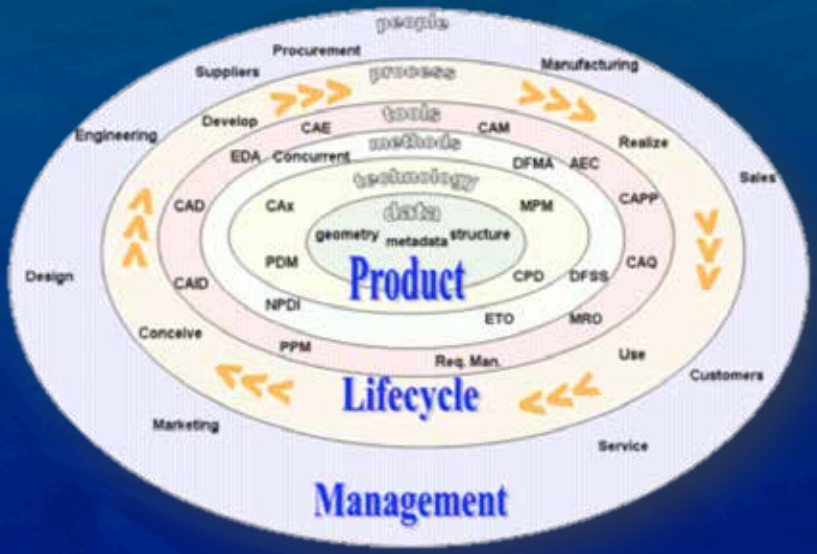
Components of the Product Lifecycle

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.

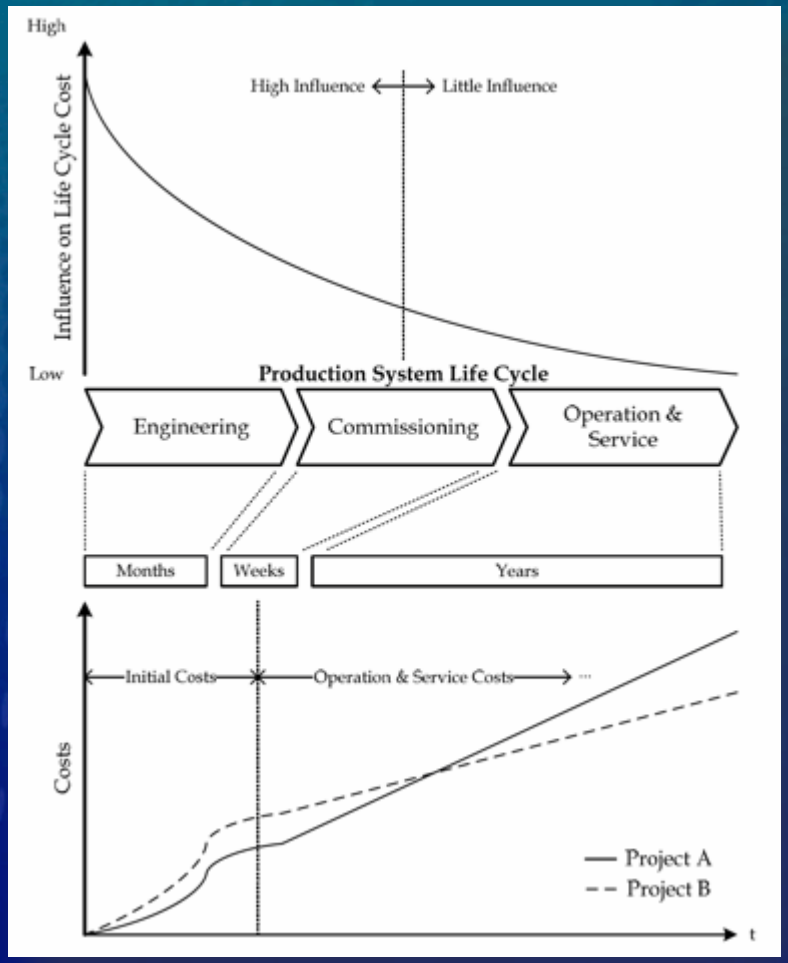
Theoretical View

- 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✚

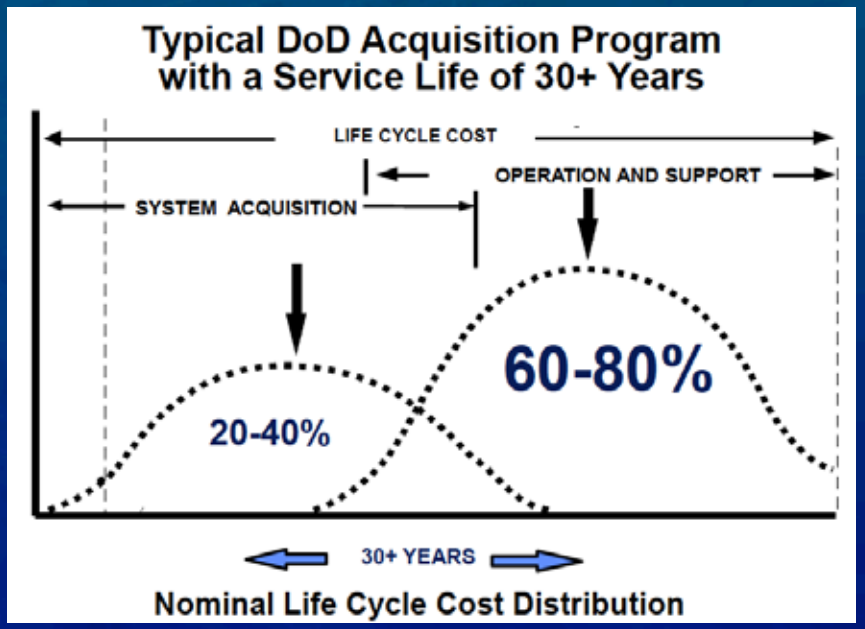
❖ Teresko, J., 2004, "The PLM Revolution," IndustryWeek, Penton.

✚ 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.

If Engineering owns the influence and Supply Chain gets the cost burden…

Then, where are supply chain's pitchforks and torches?

Couse-Baker, R., 2009, "Angry mob of four.jpg," Wikimedia Commons.

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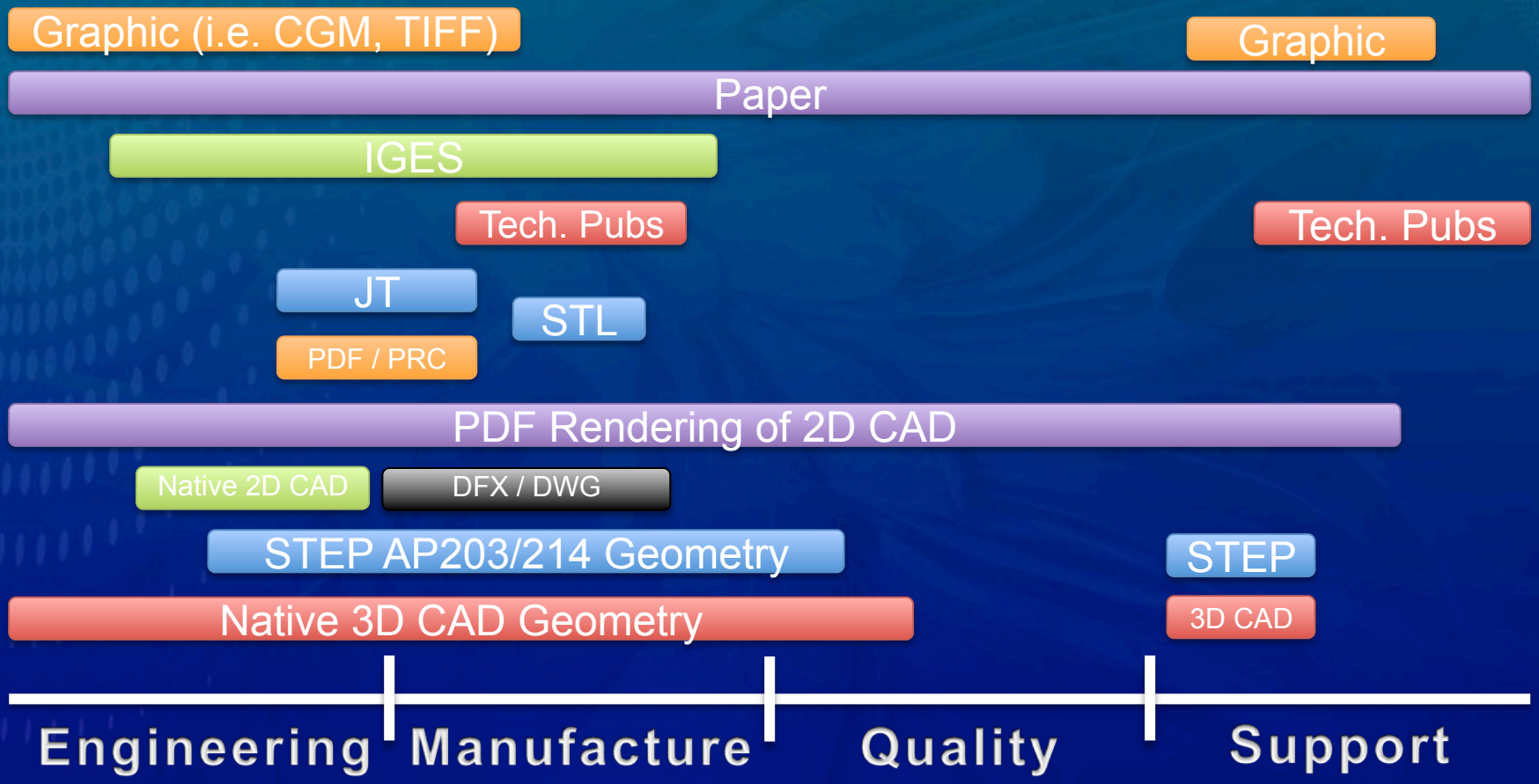
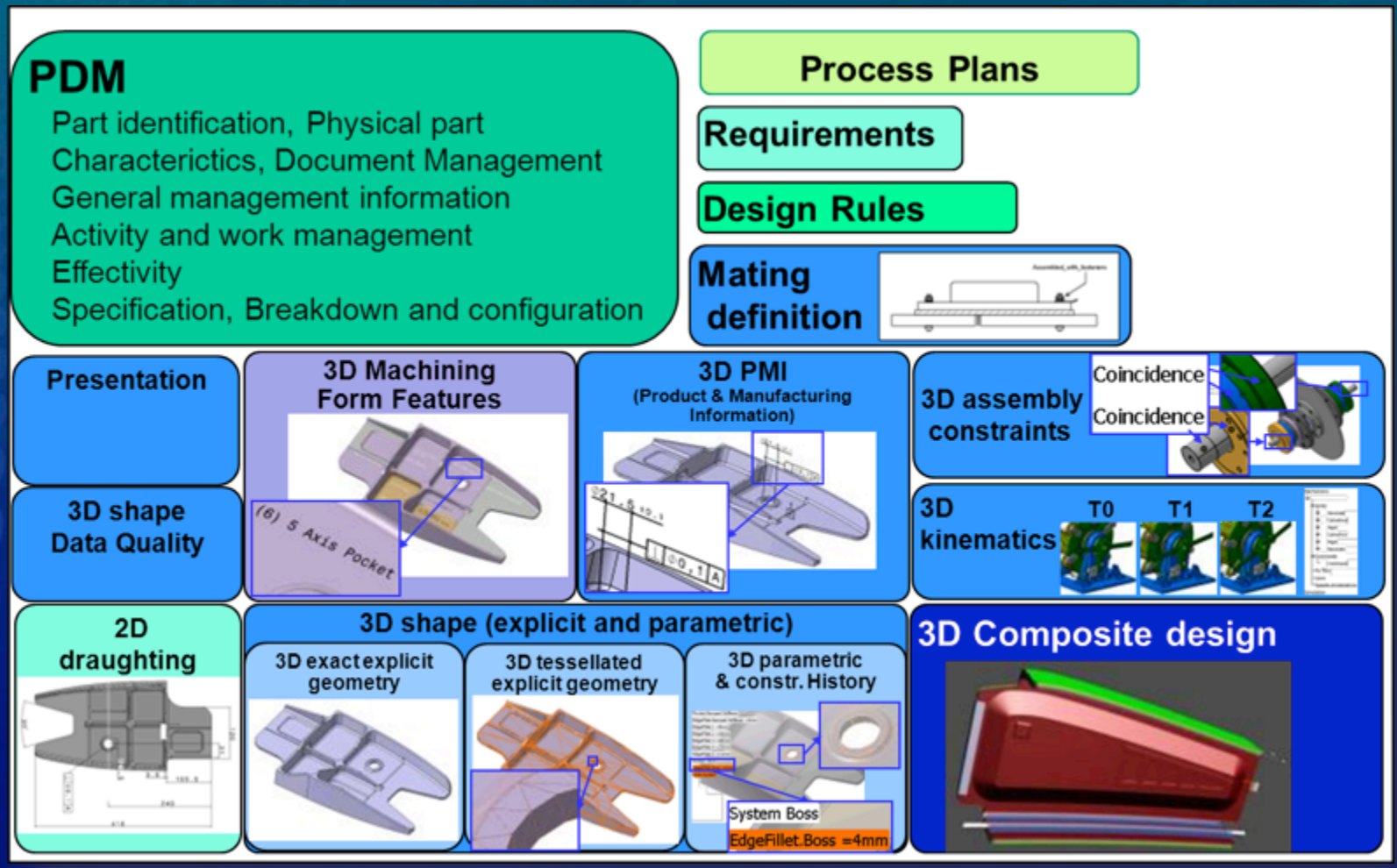
Product Data Exchange Usage Landscape

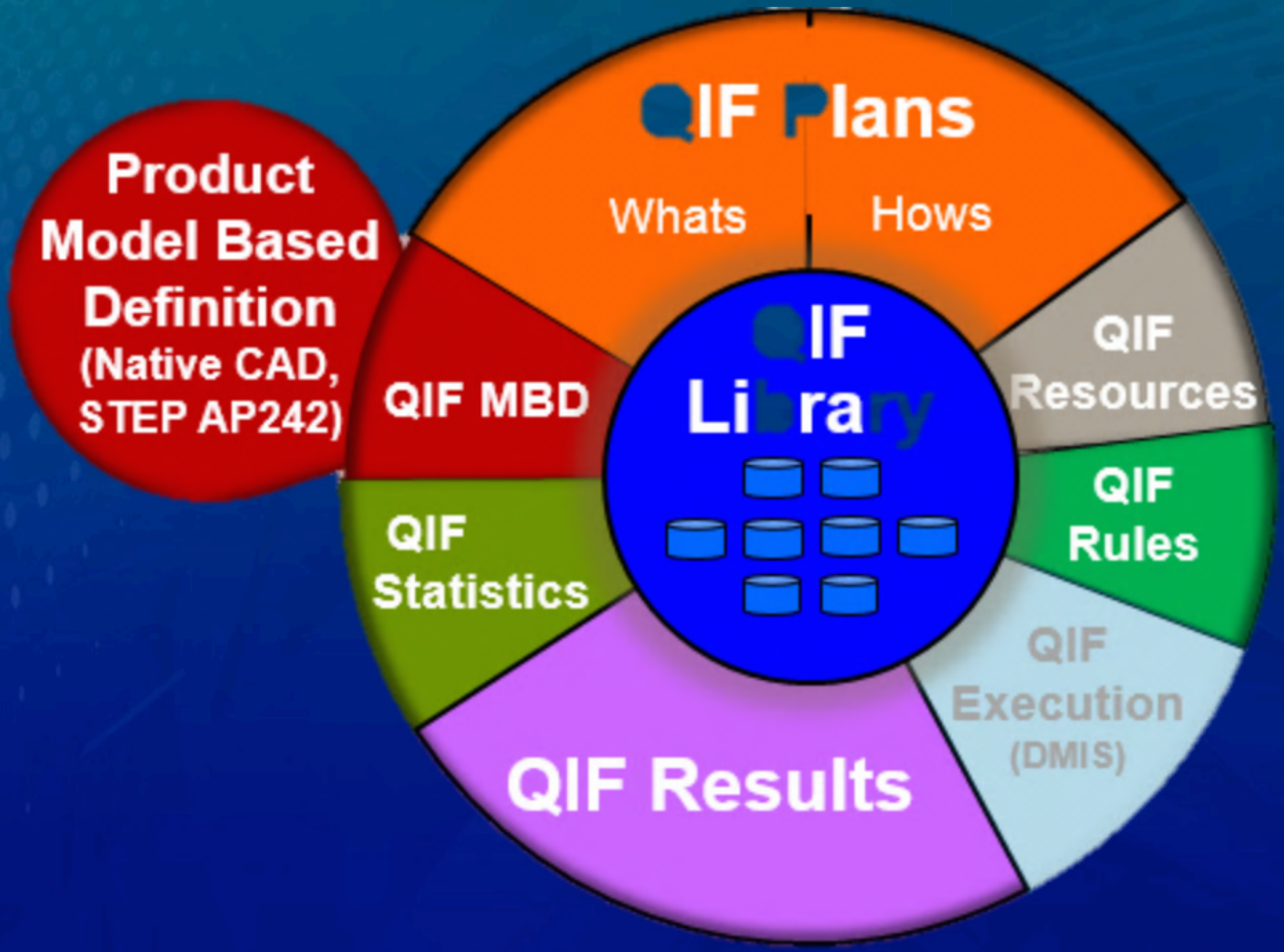


New: ISO 10303 – STEP AP242



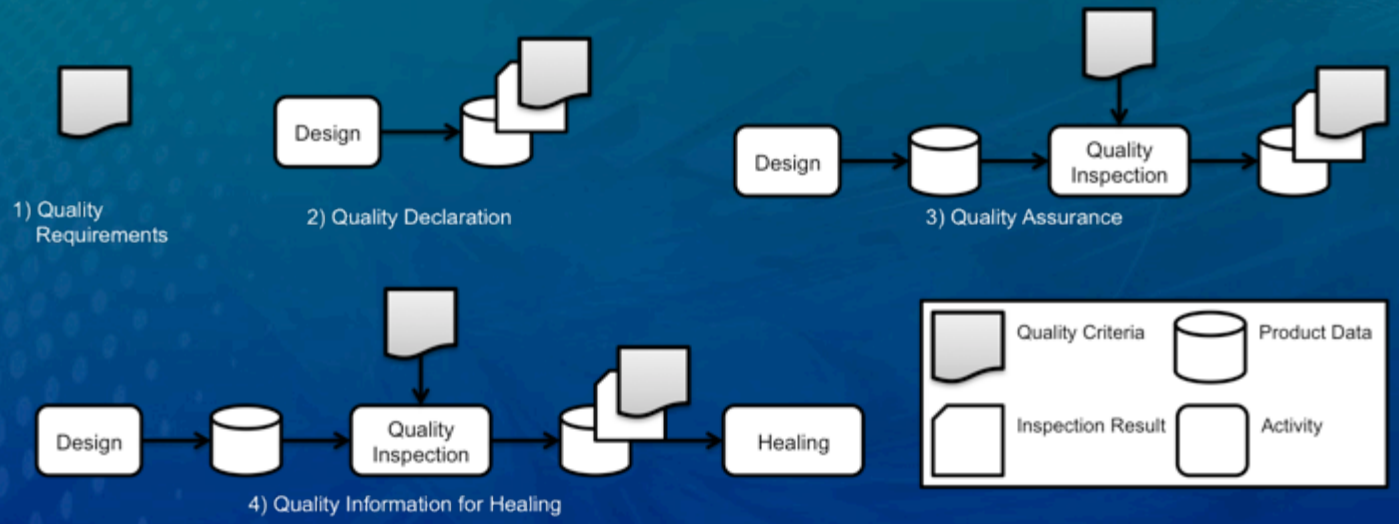
<Citation Needed>

New: Quality Information Framework (QIF) 2.0



Dimensional Metrology Standards Consortium, 2014, "Quality Information Framework (QIF) – An Integrated Model for Manufacturing Quality Information," Part 1: Overview and Fundamental Principles, American National Standards Institute.

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.

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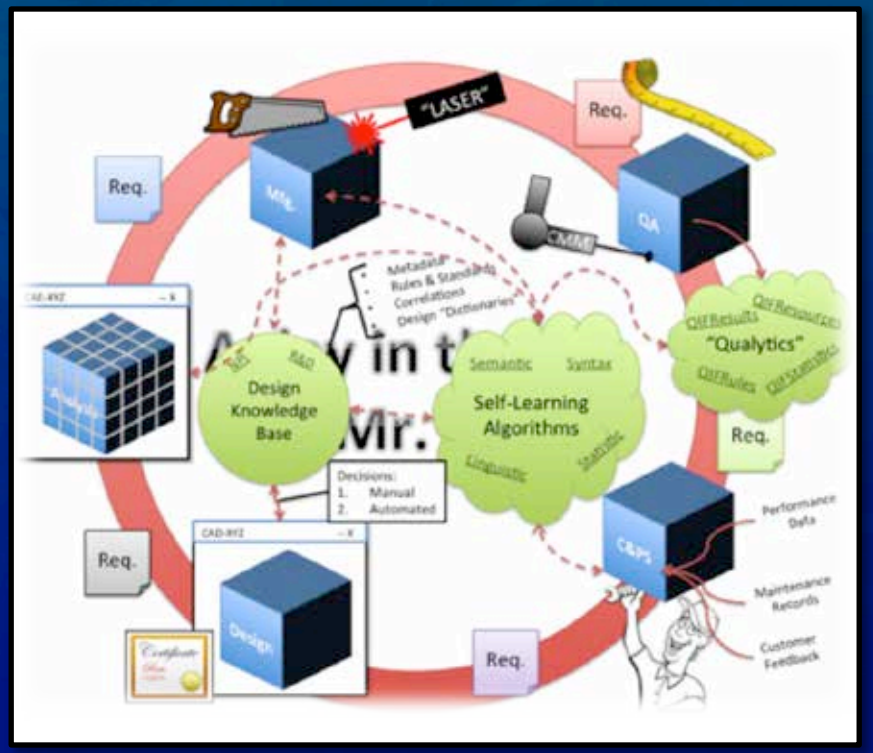
Proposing a Solution with an Infographic

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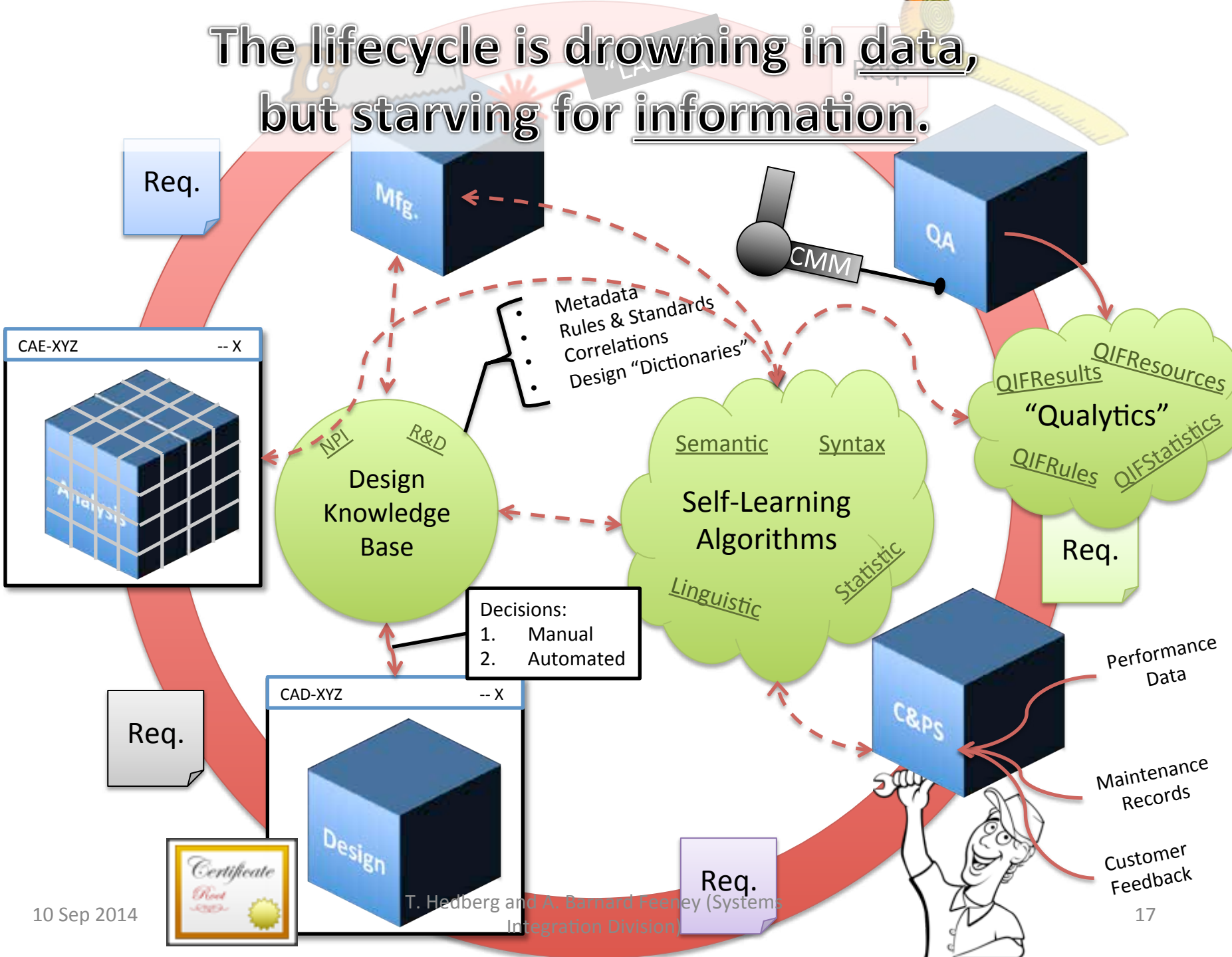
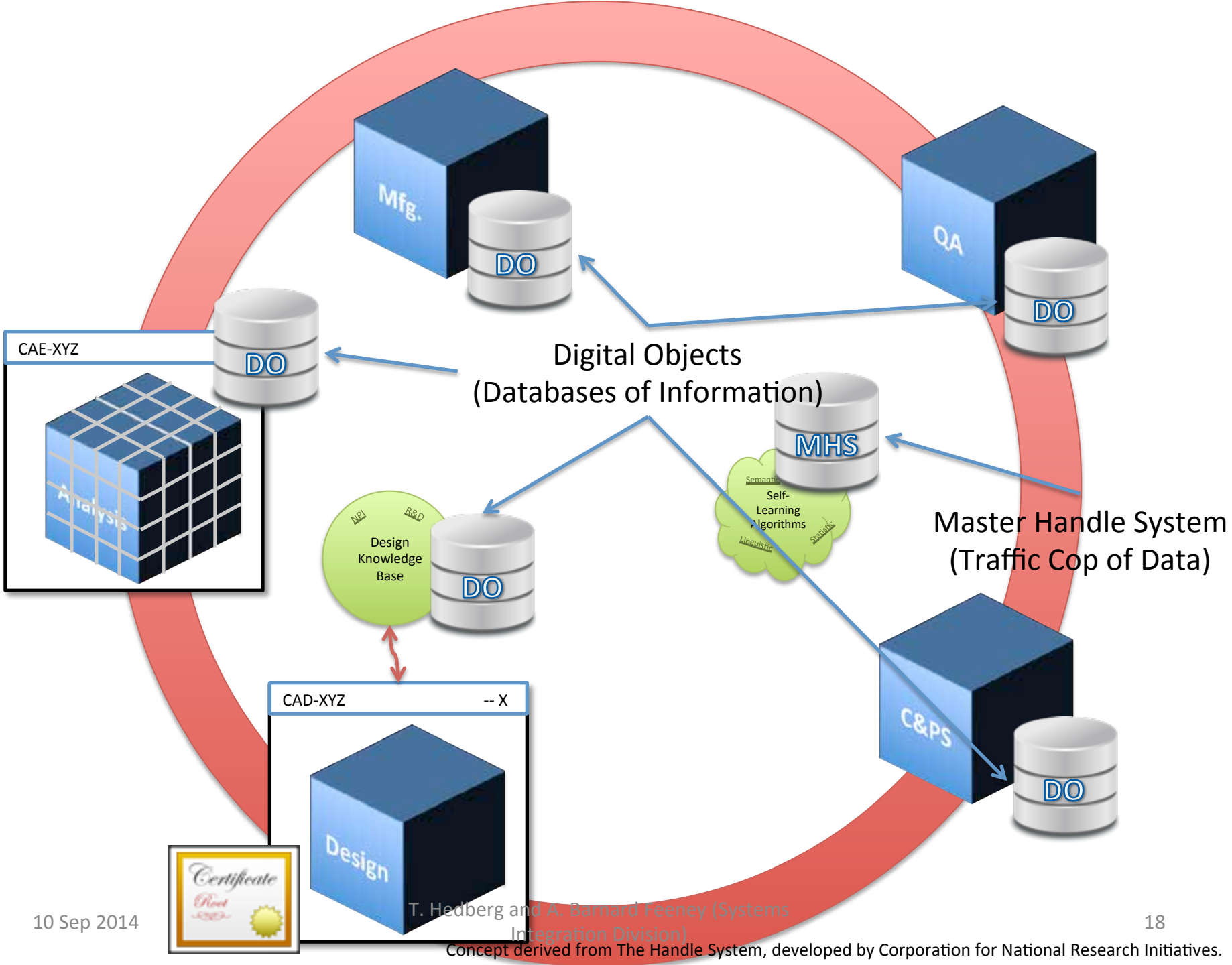
The lifecycle is drowning in data, but starving for information.





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

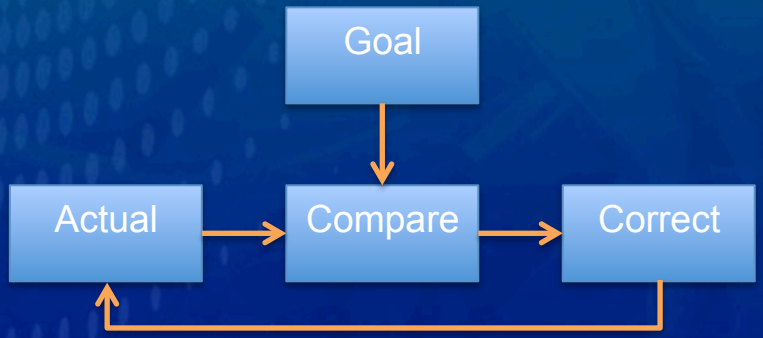
Support for Organizational Learning

- 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

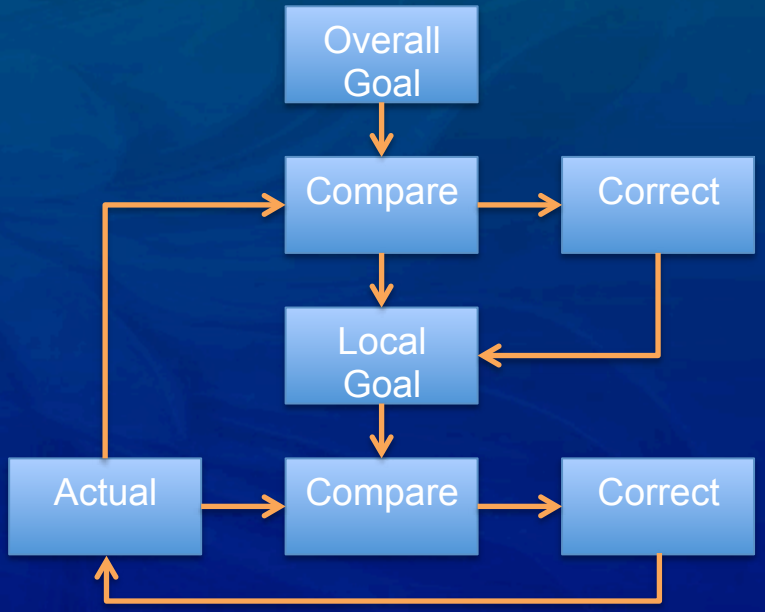
Argyris, C., and Schön, D. A., 1978, Organizational learning, Addison-Wesley Pub. Co., Reading, Mass.
Argyris, C., 2008, Teaching smart people how to learn, Harvard Business Press, Boston, Mass.

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.

PDQ is not enough…

- Data exchange must be trusted
- Information and the data quality must be traceable
- The lifecycle requires authentication and authorization of data

Authentication vs. Authorization, Which one builds trust? BOTH!

Authentication

- Process of determining if something is what it is declared to be*
- A valid public key infrastructure certificate typically guarantees a user is authentic
- For manufacturing, contracts typically define what data is declared to be

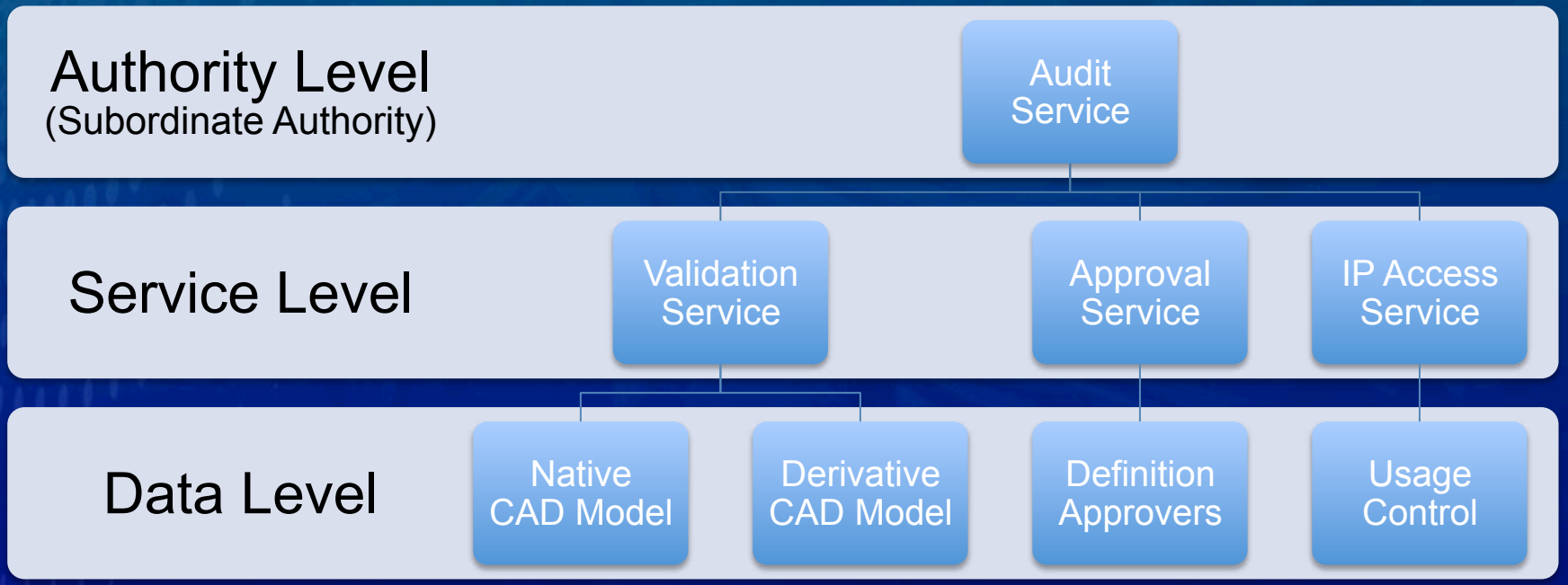
Authorization

- Process of determining which permissions something is suppose to have*
- Privilege management infrastructure authorization typically proceeds authentication
- For manufacturing, authorization is not negotiated (i.e. How can I use the drawing? Anyway I want!)

*Indiana University, 2014, "Authentication vs. Authorization," https://protect.iu.edu/cybersecurity/authn-authz.

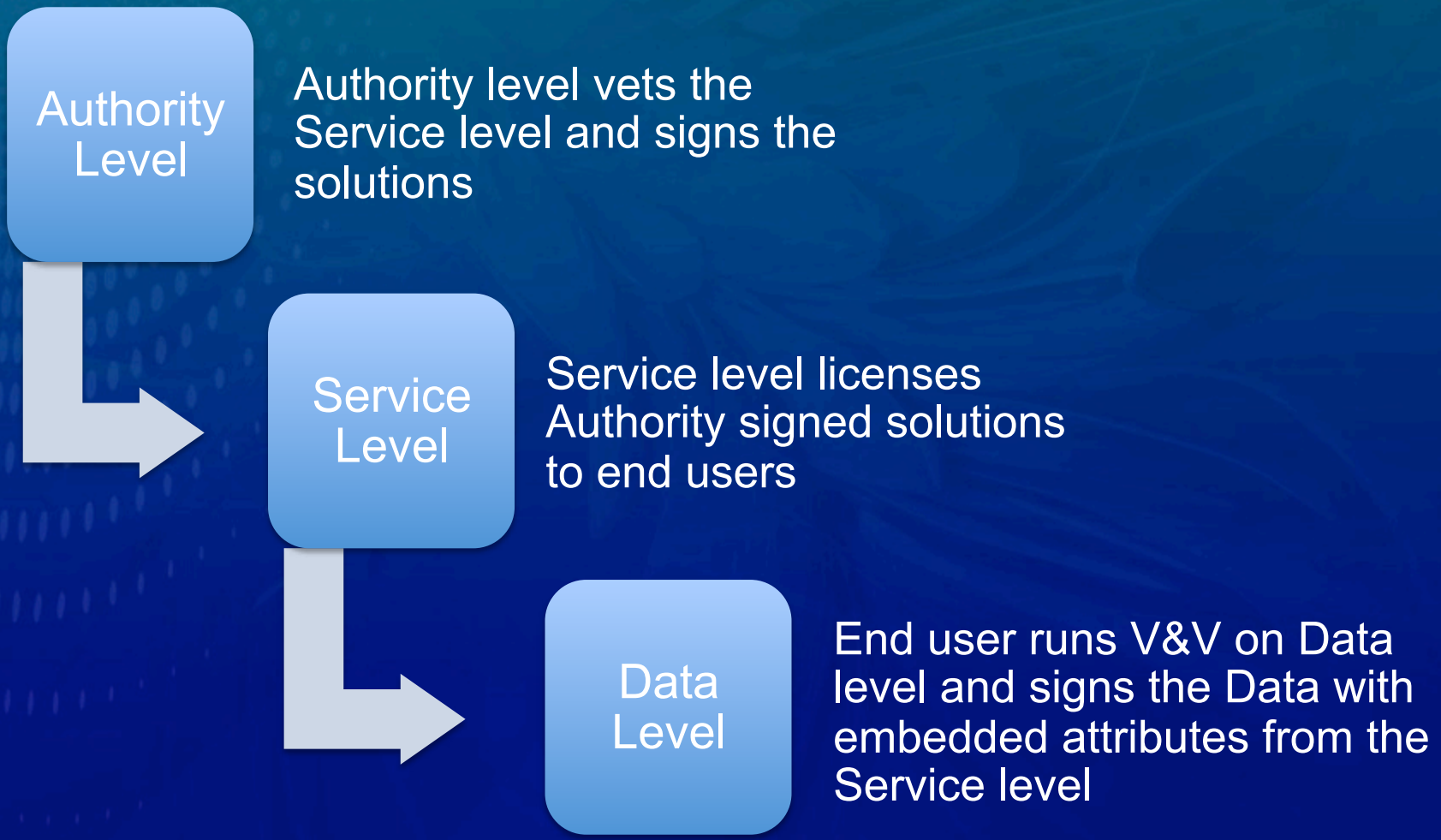
Building a Product Lifecycle of Trust (PLOT)

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

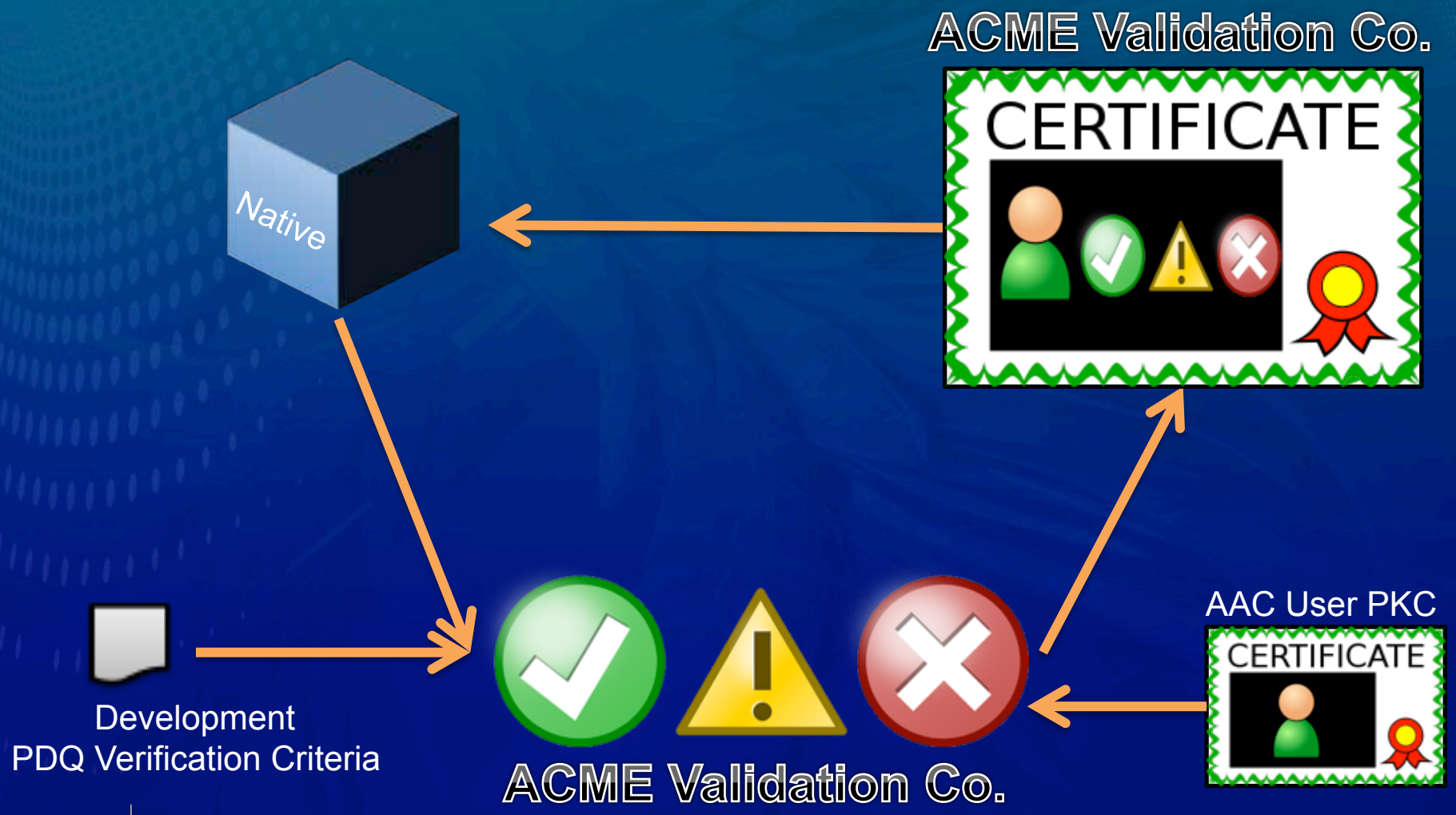


A system based on Authorization with embedded Authentication.

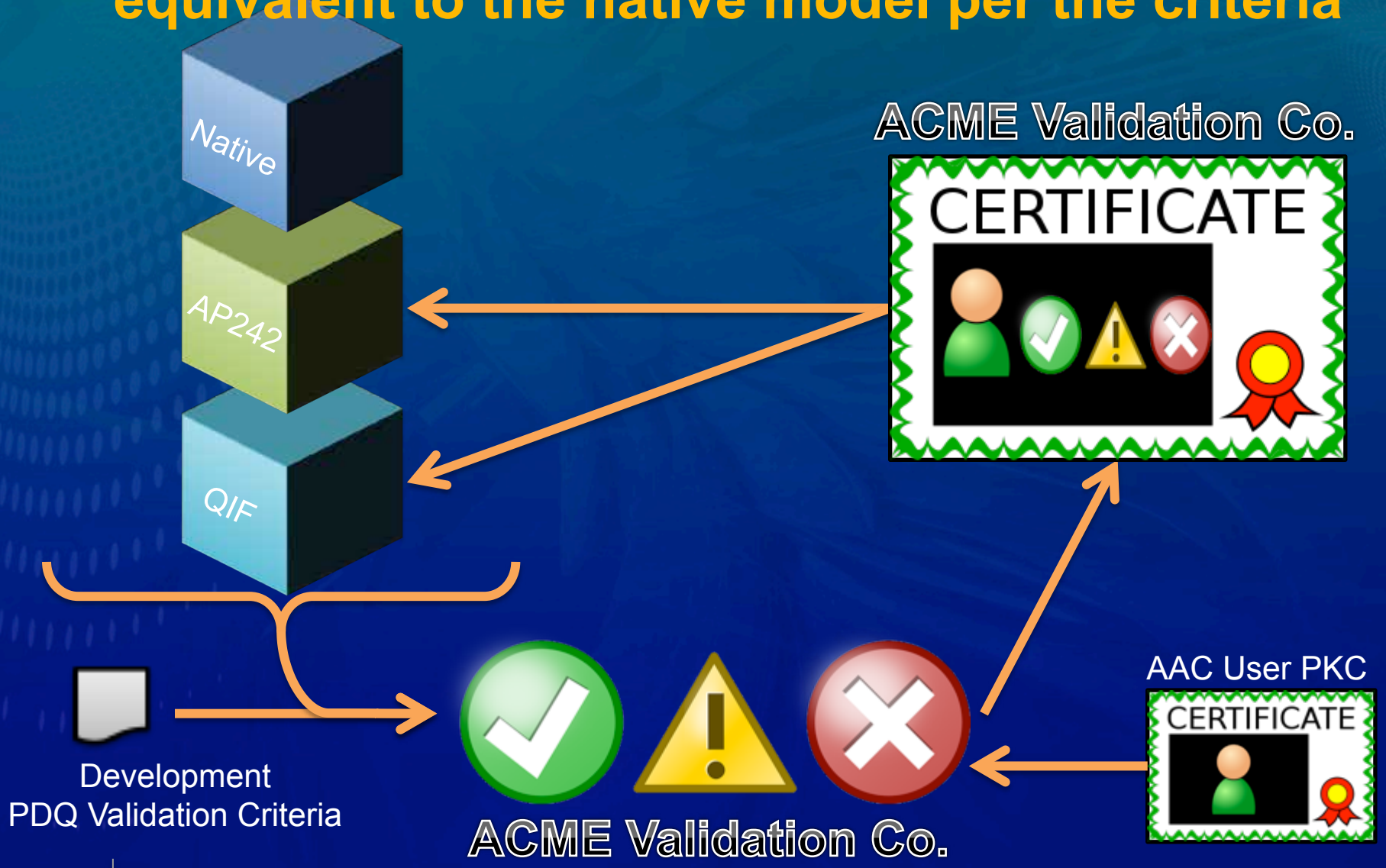
Trust, Who does what to whom?



Building Trust: Verify the model meets the criteria



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



Current Certificates Work in Industry

- Some CAD vendors support digital signatures on 2D Drawings for use in product definition release process
- ISO TC184 SC4 WG11: adding digital certificates / signatures to Part 21 Edition 3
  - NIST is participating
- UL, LLC: investigating digital certificates usage for requirements traceability and digital rights management
  - Opportunities for collaboration with NIST

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Scenarios

1. Manufacturing and Quality knowledge feedback to Engineering

2. The generation of traceable G-code for CNC

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

.:: Scenario One ::.

MANUFACTURING AND QUALITY KNOWLEDGE FEEDBACK TO ENGINEERING

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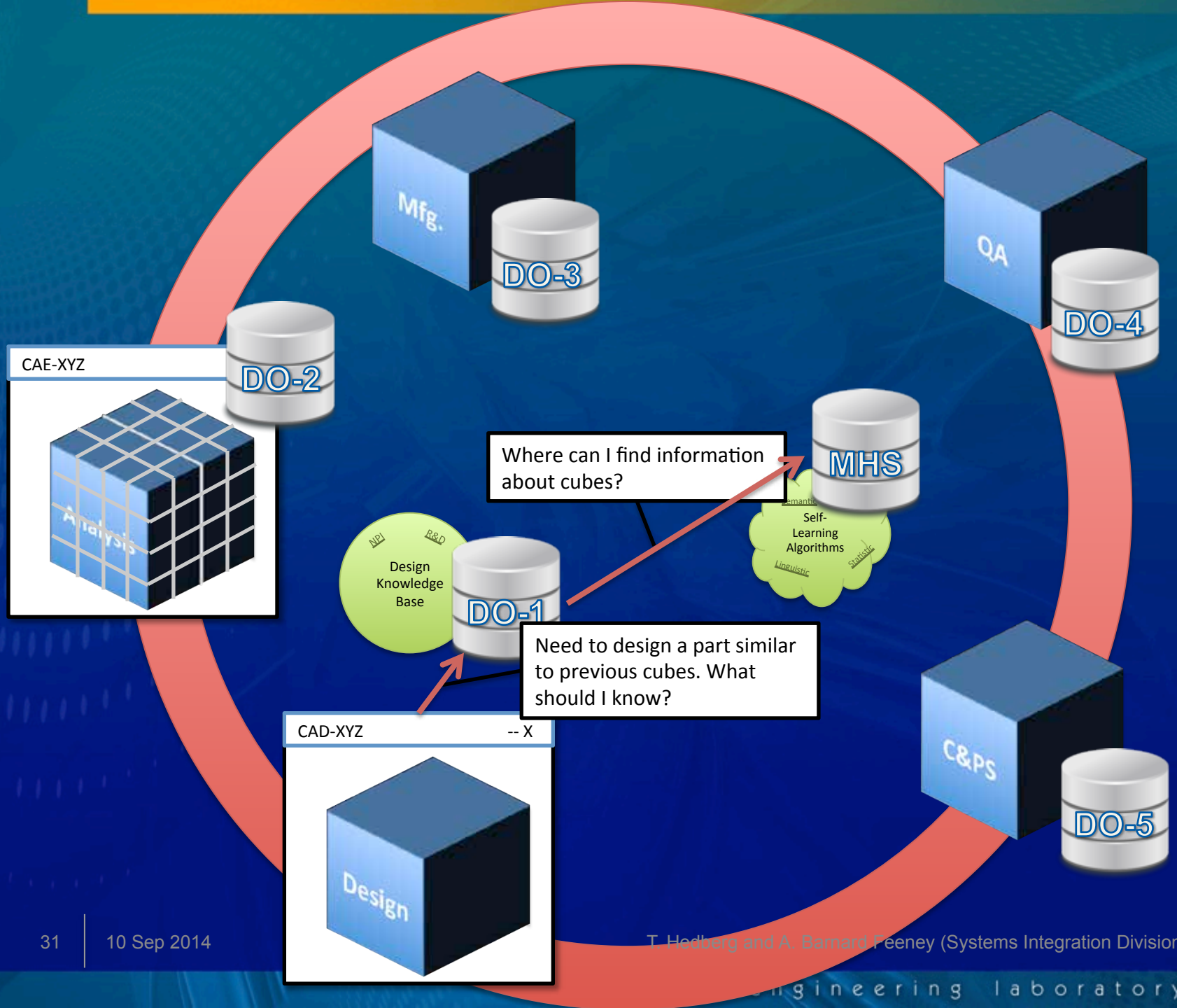
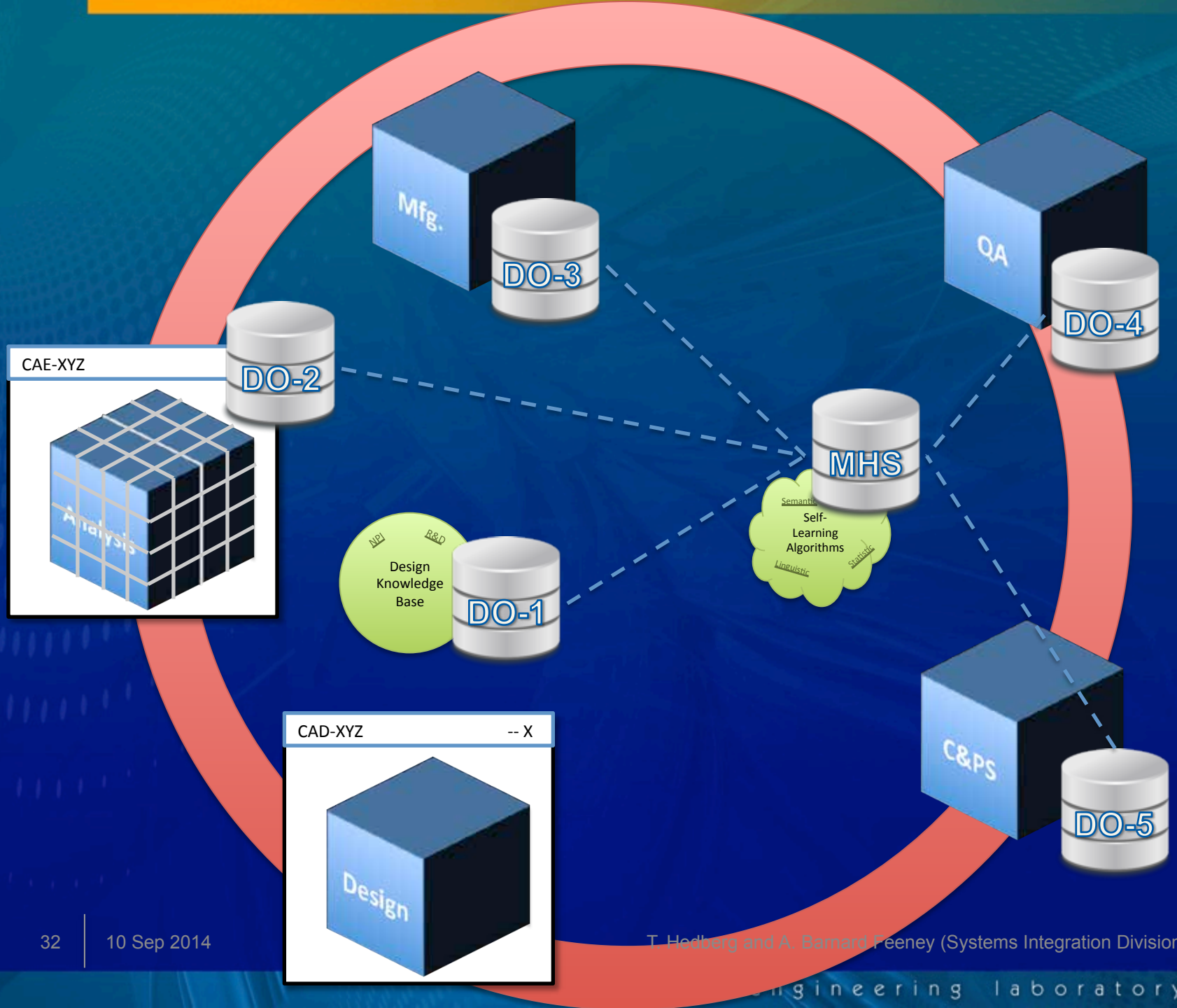
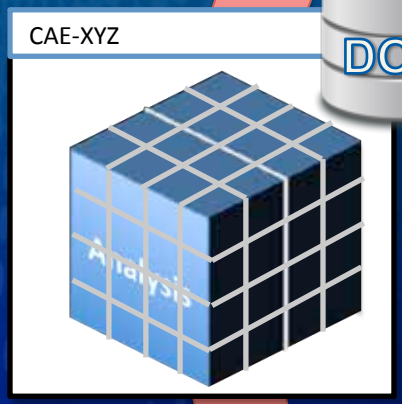

Mfg.
DO-3
QA
DO-4
CAE-XYZ
DO-2
Analysis
Where can I find information about cubes?
MHS
Self-Learning Algorithms
Semantic
Statistic
Linguistic
NPI
R&D
Design Knowledge Base
DO-1
Need to design a part similar to previous cubes. What should I know?
CAD-XYZ
-- X
Design
C&PS
DO-5

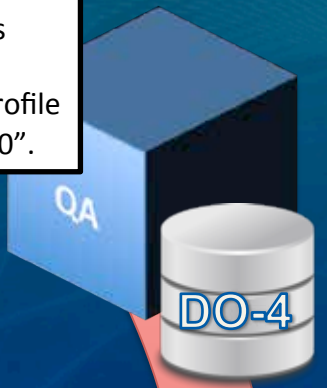

Mfg.
DO-3
QA
DO-4
CAE-XYZ
DO-2
MHS
Semantic
Self-
Learning
Algorithms
Linguistic
Statistic
NPI
R&D
Design
Knowledge
Base
DO-1
C&PS
DO-5
CAD-XYZ
-- X
Design

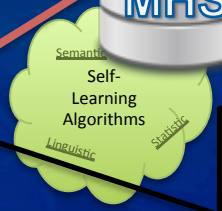
DO-3 says cubes with sharp edges are difficult to manufacture.

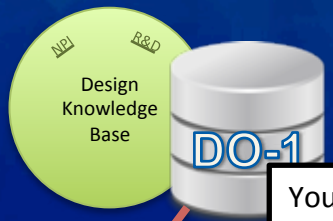
DO-4 confirms that cubes with sharp edges are consistently outside of profile tolerances less than 0.060".

DO-2 says cubes with pointy corners are no go for fatigue.



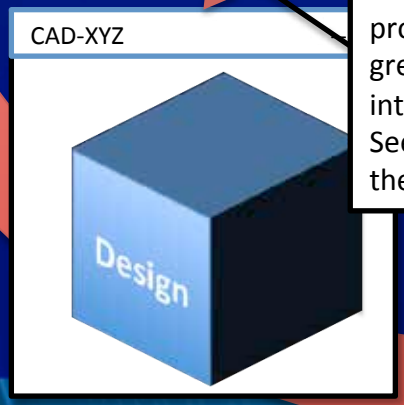






DO-5 reports that field support engineers have difficulties with retro fitting cubes into the round holes of legacy configurations.

You should create a cube without pointy corners, without sharp edges, a profile tolerance of 0.060" or greater, and easy to retrofit into legacy configurations. See the attached report for the reasons why.

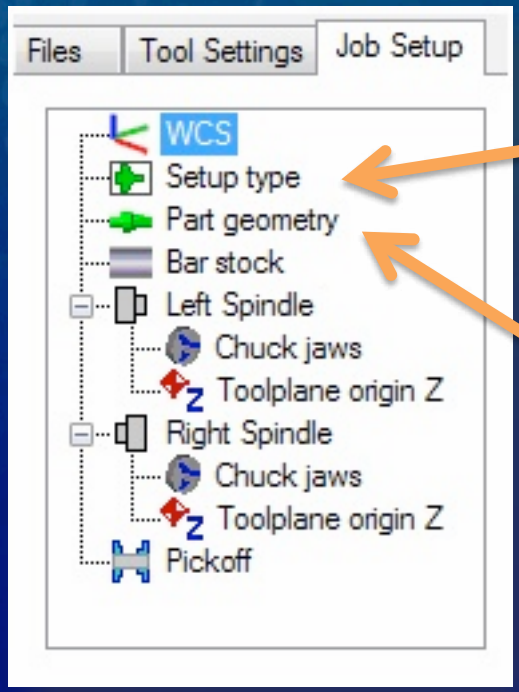


.:: Scenario Two ::.

THE GENERATION OF TRACEABLE G-CODE FOR CNC

Computer Aided Manufacturing - Inputs

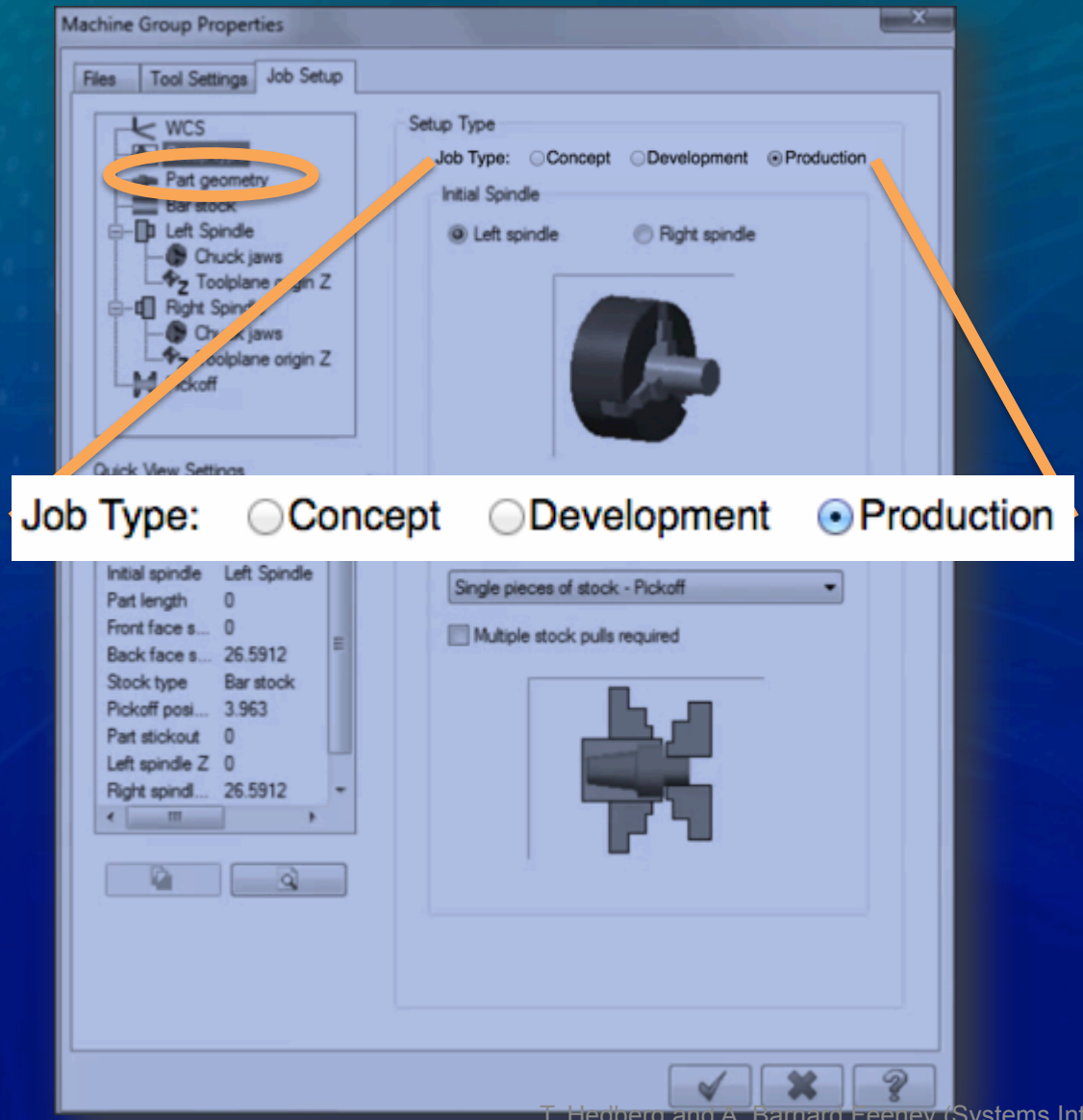
GrabCAD claims 75% of their customers have processed a production run from the wrong model*



Concept? or Development? or Production?

*GrabCAD, 2014, "Where did the time go?," GrabCAD, Boston.

Computer Aided Manufacturing - Type



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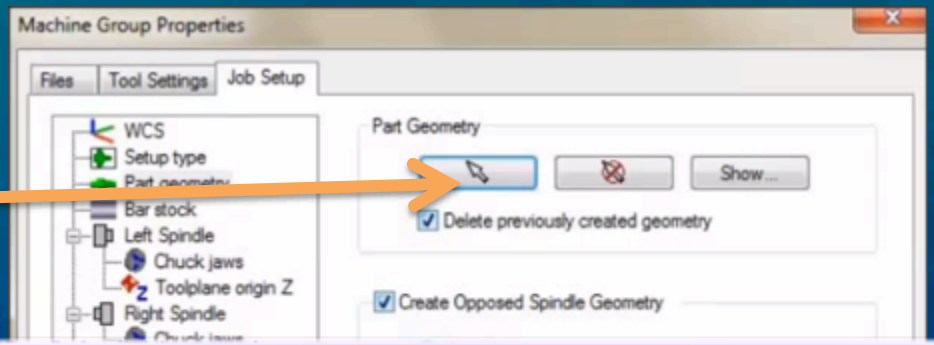
Computer Aided Manufacturing - Part



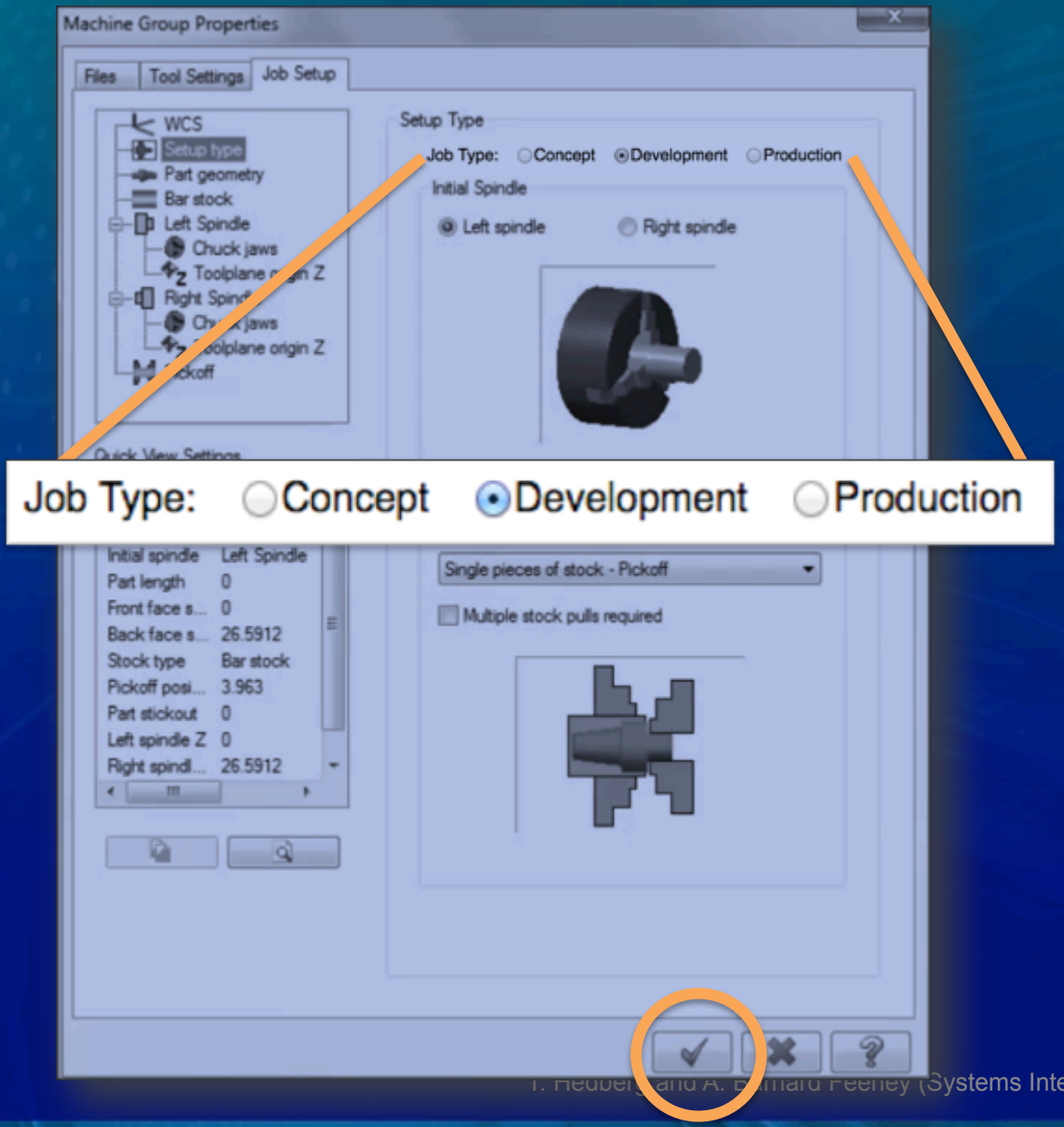
Model Attributes Mismatch

Incorrect Job Setup.

You are attempting to create a production job type with a development certified model. The model does not contain the required certificate attributes. Please select a model that contains the required production certificate attributes.

OK

Computer Aided Manufacturing – Fix It



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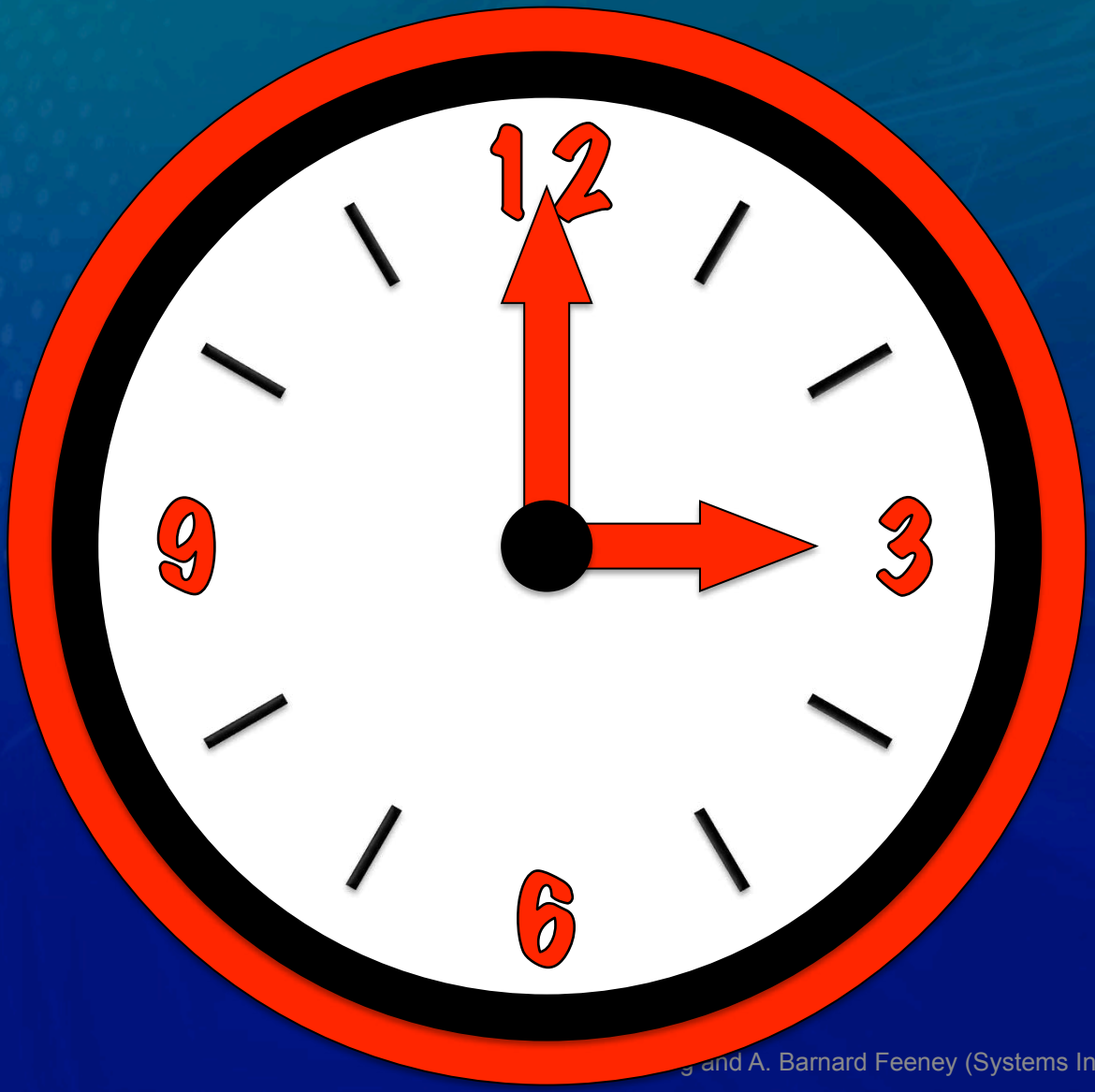
Add a little Hollywood Magic…



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Traceability in the code…

```
G109 L1 (Cube-001)
(CNC FILE    - C:\FILES\NF FILES\Cube-001.cnc)
(NC File     - C:\FILES\NC FILES\Cube-001-paths.nc)
(MATERIAL    - ALUMINUM INCH - 6061)
(PROGRAM     - Cube-001.NC)
(NC DATE     - 07 / 21 / 2014 @ 08:19:35 UTC)
(JOB TYPE    - Development)
(MODEL       - C:\FILES\STP FILES\Cube-001.stp)
(FNGRPRT     - SHA1 97 2A EF 86 C3 5E 3D A1 66 CB 7B BF 69 AD AF A7 C0 07 82 B1)
(CERT TREE   - Roots CAs 'R Us -> PDQ CA -> ACME V&V Processor -> Cube-001)
(VALID FROM - 06 / 16 / 2014 @ 11:39:54 UTC)
(VALID TO    - 06 / 16 / 2015 @ 11:39:54 UTC)
(NWDTOOL N" 1/8 FLAT ENDMILL" T232 D.125 F.375 L2.25 CD2. CL1. SD2. C0)
(NWDSTOCK X10. Y10. Z.0625 OTC OX5. OY5. OZ0.)

N10 G00 G17 G20 G40 G49 G80 G90
N20 T232 M06 ( 1/8 FLAT ENDMILL)
N30 (MAX - Z1.)
N40 (MIN - Z.0625)
N50 G00 Z1. ...
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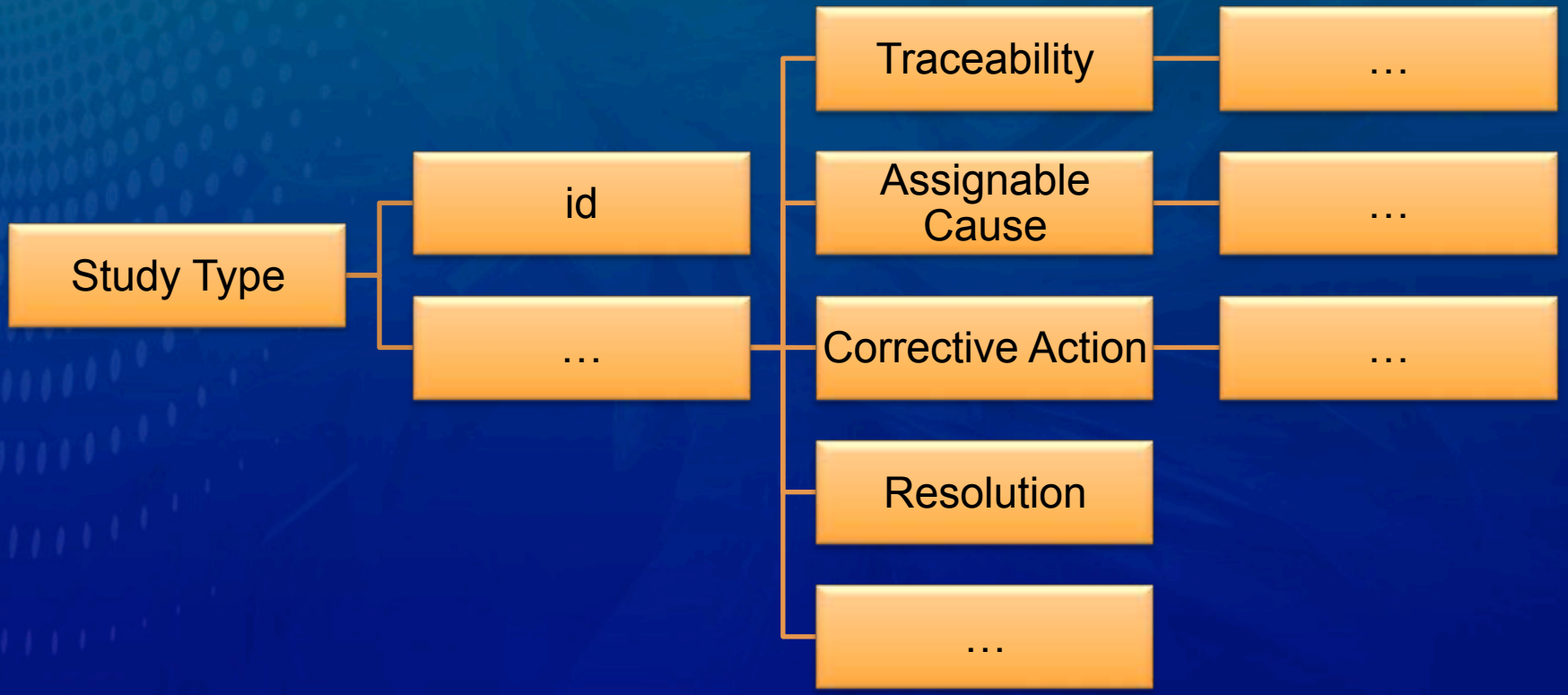
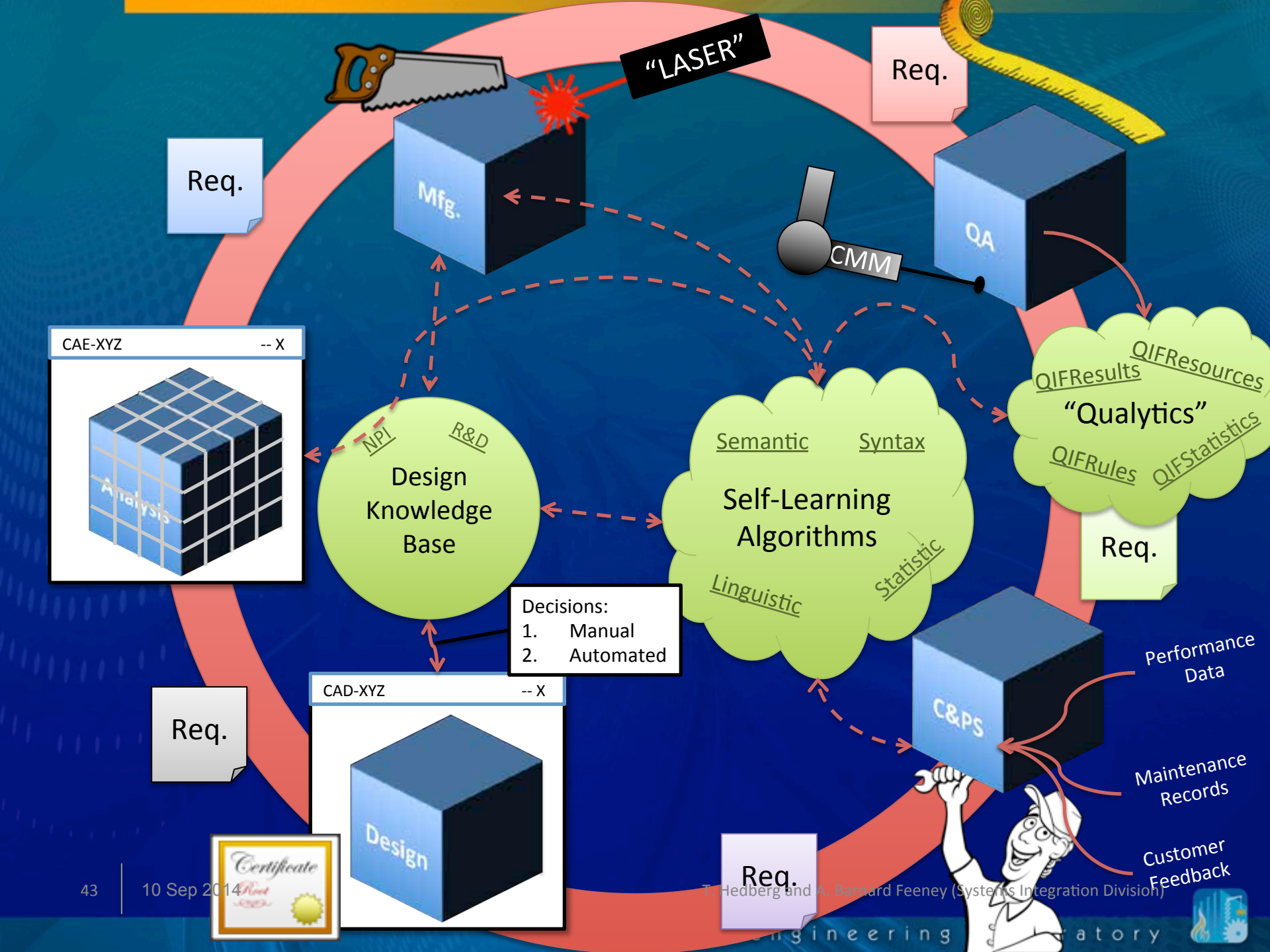
.:: Scenario Three ::.

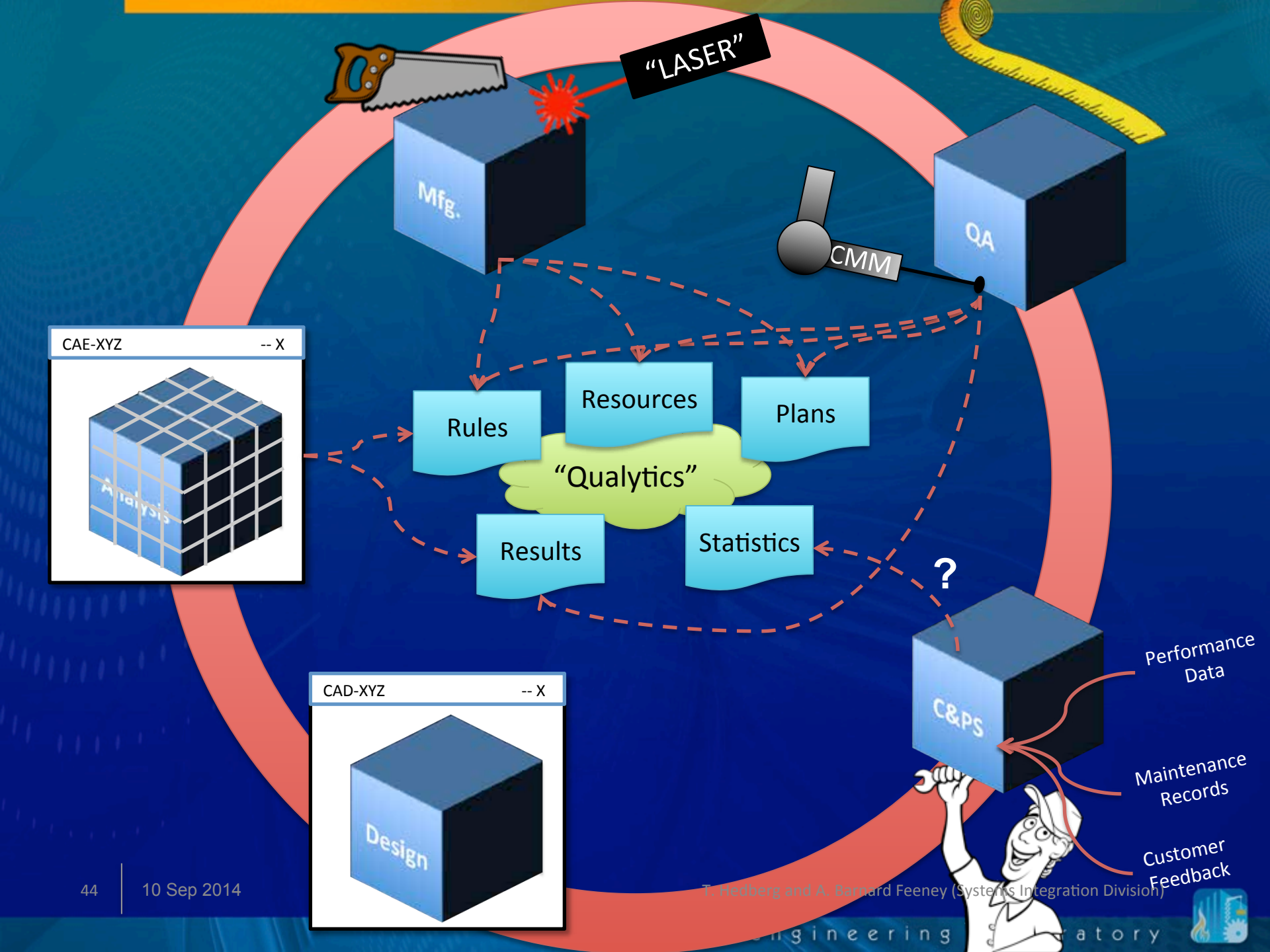
THE CAPTURE OF QUALITY INFORMATION AND INTELLIGENT ENGINEERING CHANGE REQUEST (ECR) SYSTEM

ANSI/QIF 2.0 Causes & Remedies

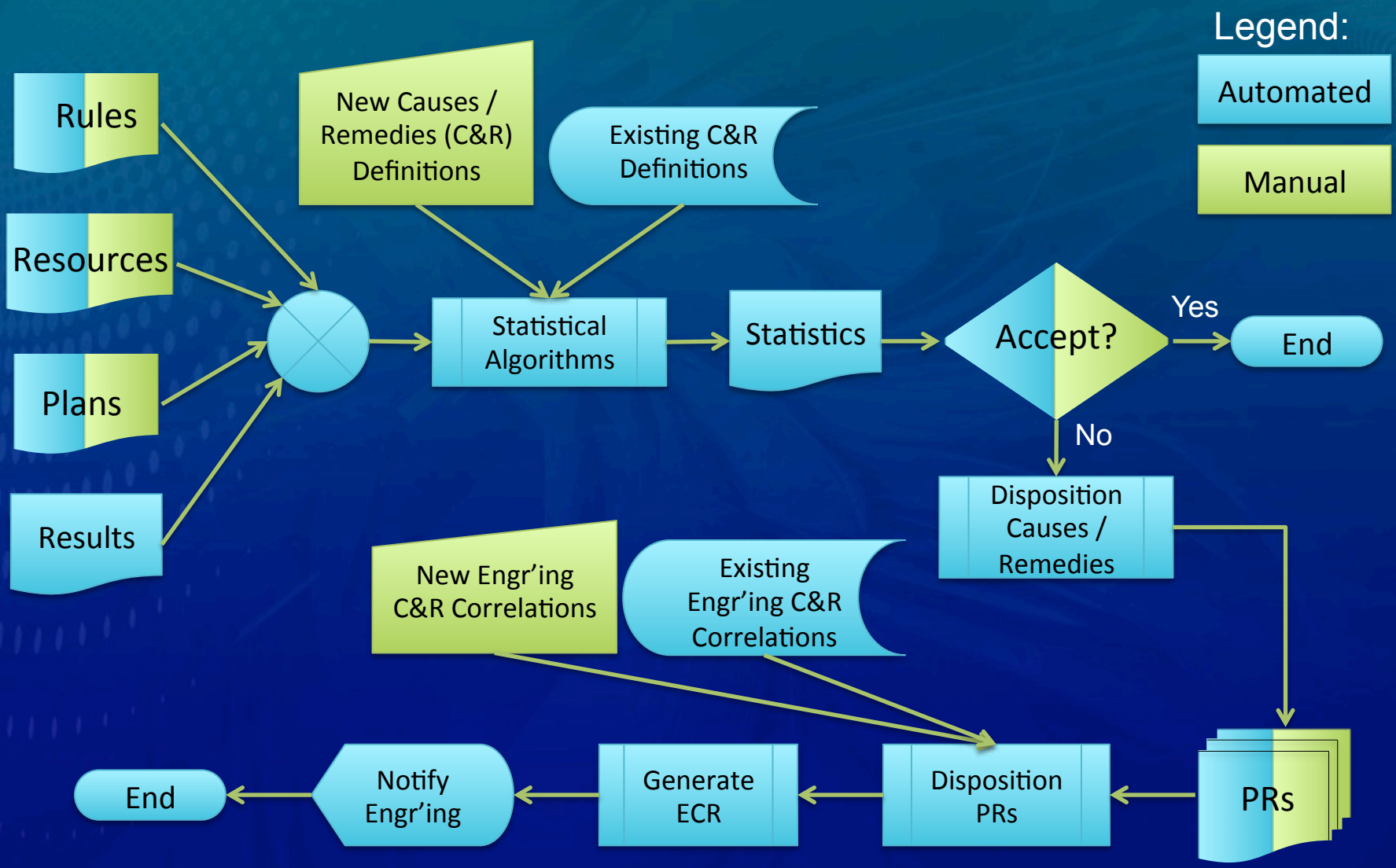


Dimensional Metrology Standards Consortium, 2014, "Quality Information Framework (QIF) – An Integrated Model for Manufacturing Quality Information," Part 8: QIF Statistics Information Model and XML Schema Files, American National Standards Institute.


"LASER"
Req.
Req.
Mfg.
CMM
QA
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
Certificate
Req.


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

Quality Information Feedback



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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 – will publish paper to be published
- Build upon FY14 work to propose augmentation to the lifecycle activities to increase efficiency and effectiveness of information for smart manufacturing
- Develop a test bed for maturing concepts and conduct pilot project with industry to verify and validate the concept definitions

Thank you.
Questions?

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