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Maturing MBE Deployment via a Collaborative Model Authorized Product - Realization (MAPR-R) Project

Curtis Brown (KCSNC) Adrian Miura (SNL)

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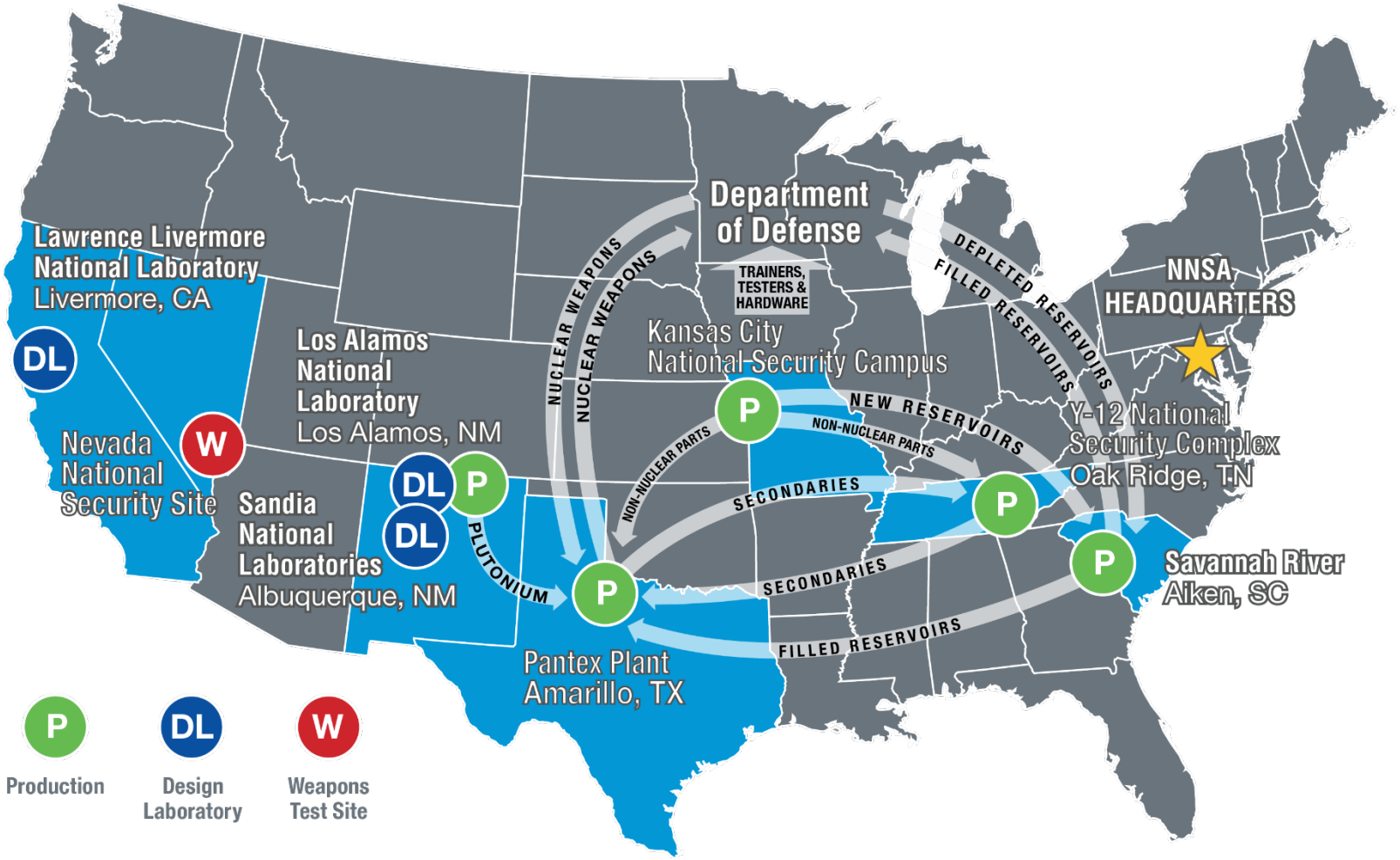
The Department of Energy's Kansas City National Security Campus is operated and managed by Honeywell Federal Manufacturing & Technologies, LLC under contract number DE-NA0002839

Presenting Today

- Curtis W. Brown
  Principal Mechanical Engineer
  Kansas City National Security Campus
  cbrown@kcp.com

- Adrian S. Miura
  Solution Architect
  Sandia National Laboratories
  asmiura@sandia.gov

NNSA's Nuclear Security Enterprise



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Sandia develops advanced technologies to ensure global peace.

As a multidisciplinary national laboratory and federally funded research and development center (FFRDC), Sandia accomplishes tasks that are integral to the mission and operation of our sponsoring agencies by

- anticipating and resolving emerging national security challenges
- innovating and discovering new technologies to strengthen the nation's technological superiority
- creating value through products and services that solve important national security challenges
- informing the national debate where technology policy is critical to preserving security and freedom throughout our world

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Government sponsored, multi-mission engineering and manufacturing enterprise delivering trusted national security products and government services

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Agenda

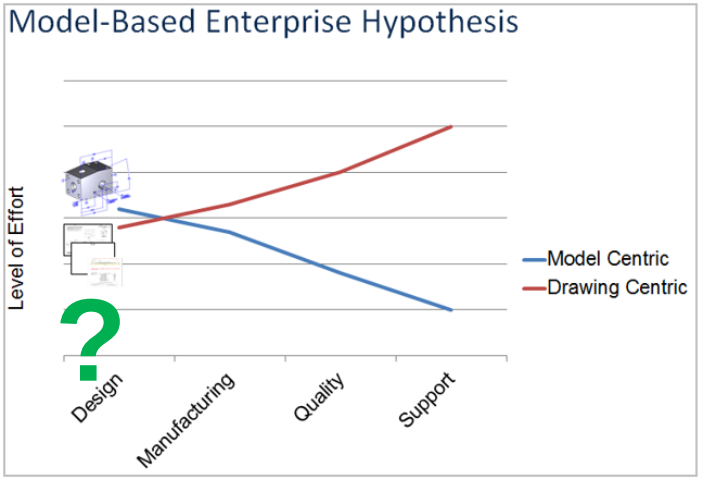
- MBE Maturity Brief
- Project background
- Data collected
- Observations
- Share Some Results

MBE Business Strategy

- MBE is a necessity due to:
  - Imperative **need** for greater **speed, responsiveness**, & innovation
  - **Complexity** of our product
  - **Demands** from our supply chain and downstream users
  - **Application** of additive manufacturing
  - Unsustainability of 70+ years status-quo of drawing-based practice
- Game changer toward sustaining & growing our business
- A journey in which enabling technology can be adopted along the way
- Pursue Insertion Opportunities in:
  - Programs,
  - Projects, &
  - Pilots

MBE Expected Benefits

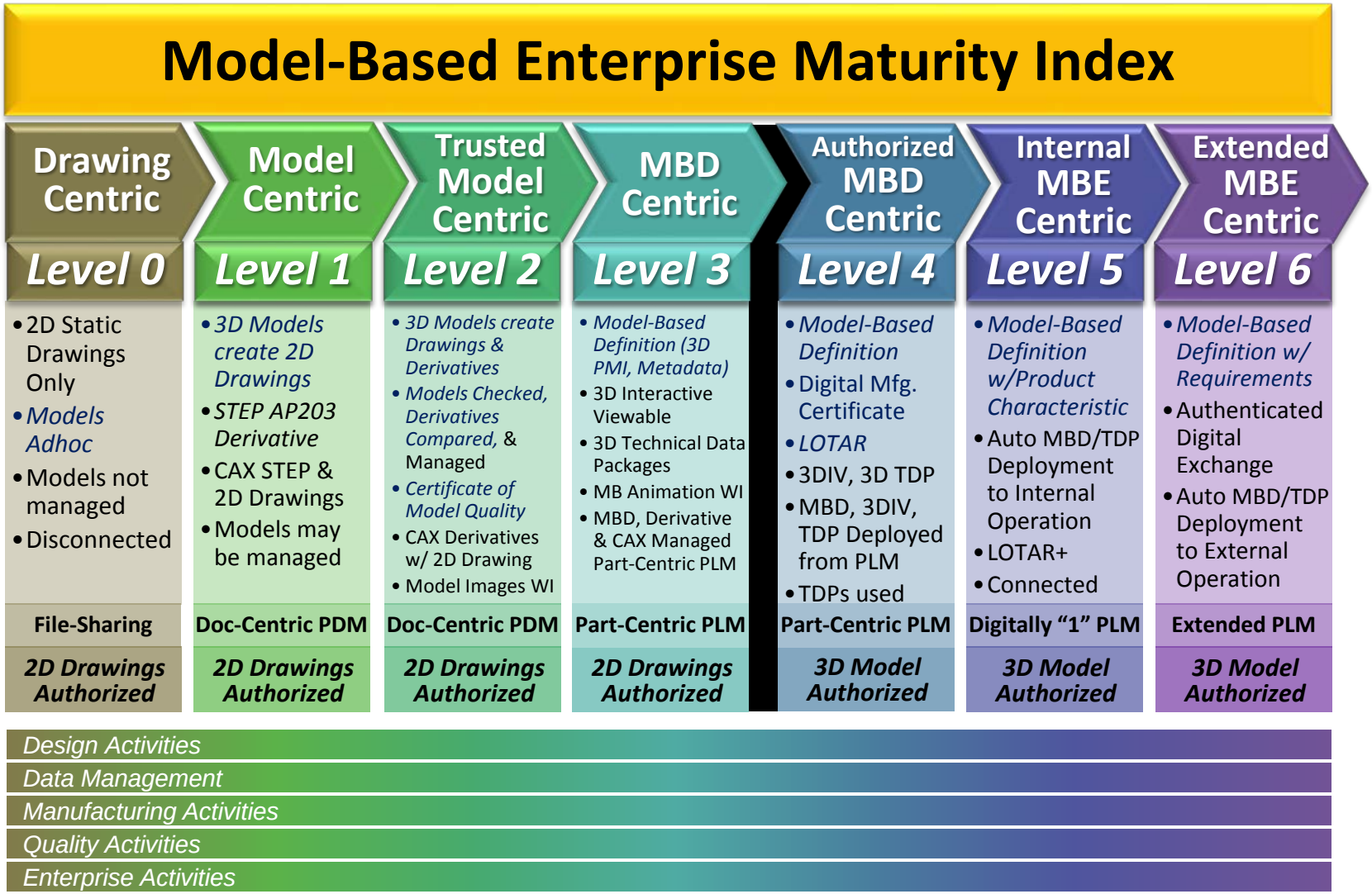
- **New Business Advantages in**
  - **Faster –** through Increasing Velocity of Product Realization & Responsiveness
  - **Smarter –** by easily Incorporating Innovative Ideas & Next Generation Automation
  - **Better –** through Improving both Model and Product Quality
  - **Cheaper –** via Enabling Cost-Effective Downstream Processes
  - **Safer –** by virtually Simulating First & analyzing Advanced Safing Concepts
  - **Securer** - through Digitally Controlling a Single Source of Truth
- **Major Benefits come from Downstream**
  - **Simulations & Analysis**
  - **Manufacturing (Additive & Subtractive)**
  - **Engineering & Tool Design**
  - **Purchased Products / Procurement**
  - **Quality's Contribution to the Enterprise**
  - **3D Technical Data Packages**
  - **Visualization & Animation**
  - **Automation via Digital Interoperability**
  - **Extends the Enterprise**



Value Proposition for the Enterprise

Results will benefit Product Realization and Acceptance

MBE Maturity Index*

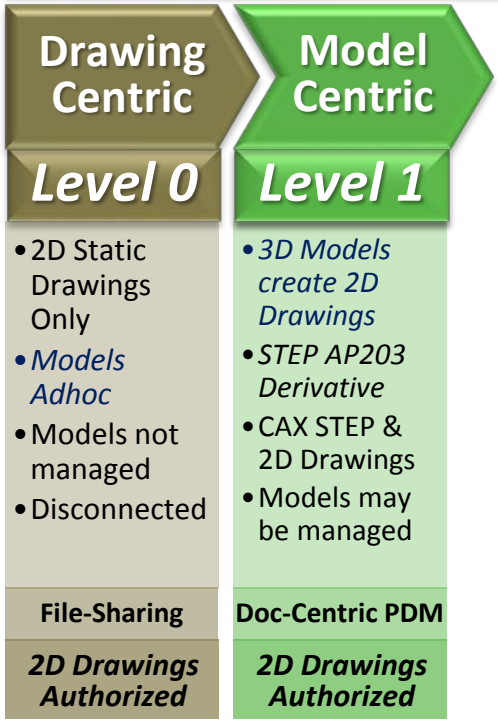


A Way to Map our MBE Journey

* Details are modified from original. Maintains the published MBE Capability Index baseline but Flavored for MBE at NSE

Current Situation at NSE

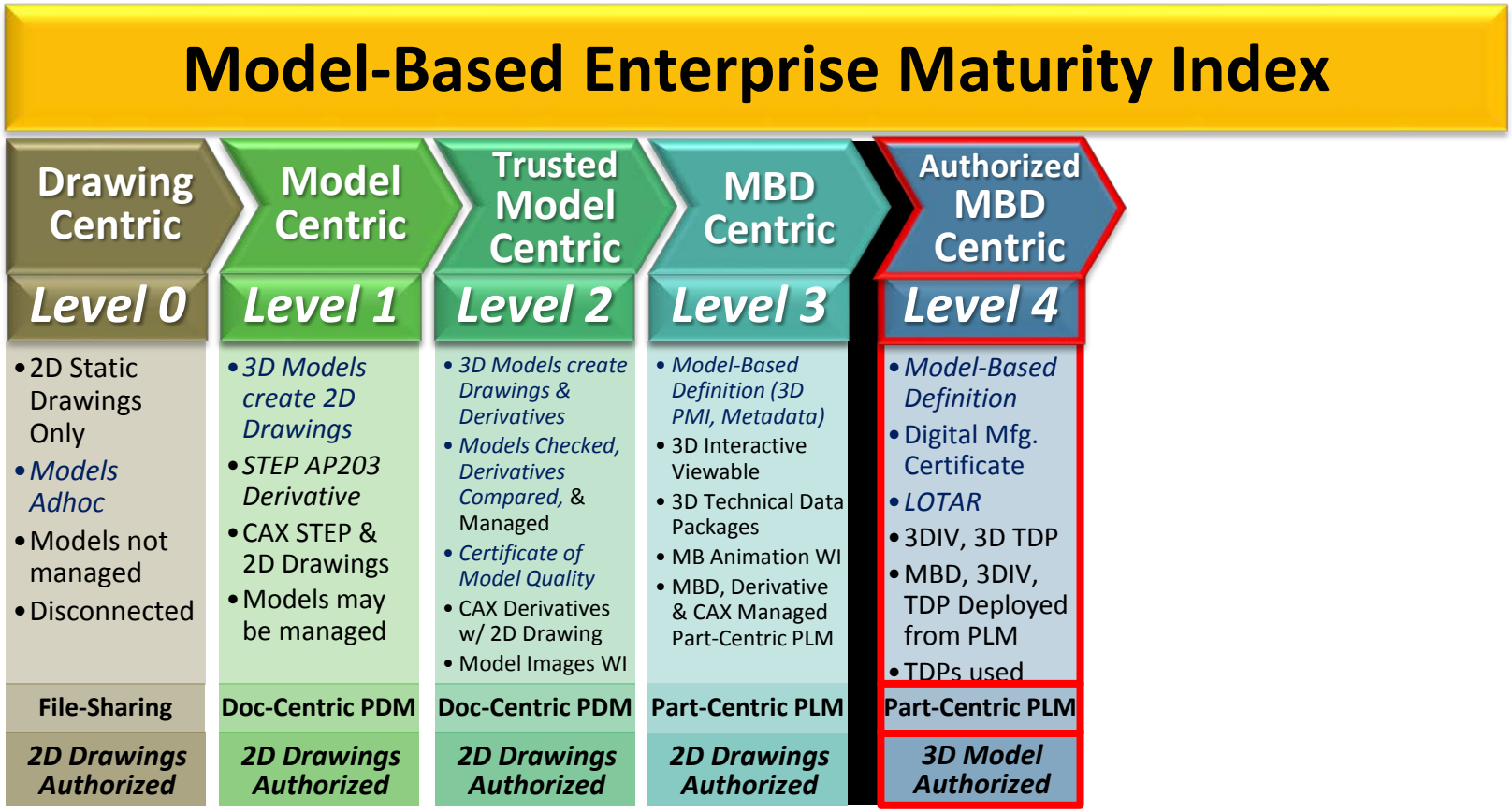
Model-Based Enterprise Maturity Index



- Document-Centric; Drawing-Based Enterprise
- Drawing Centric Level 0
- Model-Centric Level 1
  - 3D Models used to create 2D Drawings
  - 2D Drawing is the Authorized Product Definition
  - STEP AP203 Derivative Model may be Created
  - Production Agency uses 2D Drawing and if available/authorized a STEP derivative model
  - Drawings and Support Documents Managed
  - Design Models may be Managed; Disconnected
  - Other Models often File Shared; Disconnected

- NSE's MBE Adoption Maturity is assessed near Model-Centric: Level 1

Future Situation at NSE?

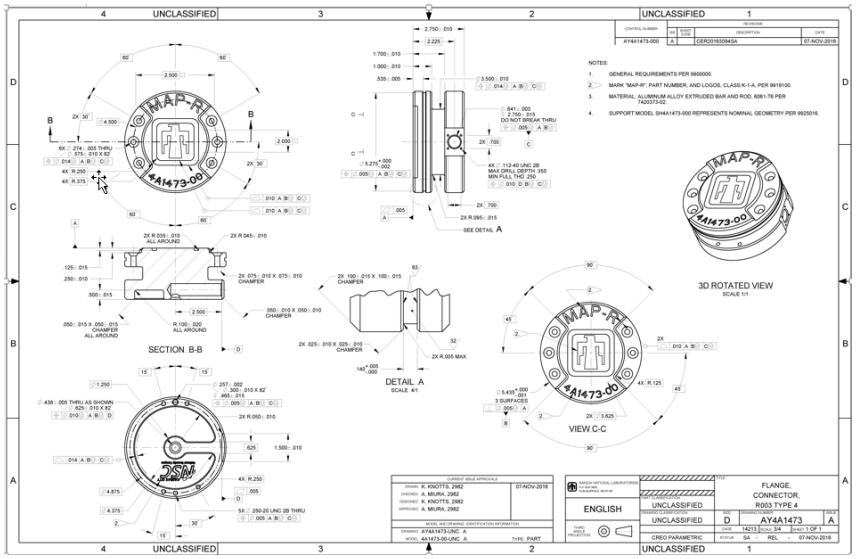


- How can we realize a product from an authorized part defining model?

* Details are modified from original. Maintains the published MBE Capability Index baseline but Flavored for MBE at NSE

MBE Collaboration Project

- Model Authorized Product Realization (MAP-R)
  - MBE Collaborative SNL-NM and KCNSC Project
  - Exercised an Authorized Part Defining Model (MBE Level 4)
  - 9925020 addressed Identification of a Part Defining Model
  - Help Quantify MBE Benefits and Identify Challenges
  - Quantify the differences and business practices for design, manufacturing , and inspection, QAIP
    - Traditional *drawing-based* processes
    - Responsive *model-based* paradigm



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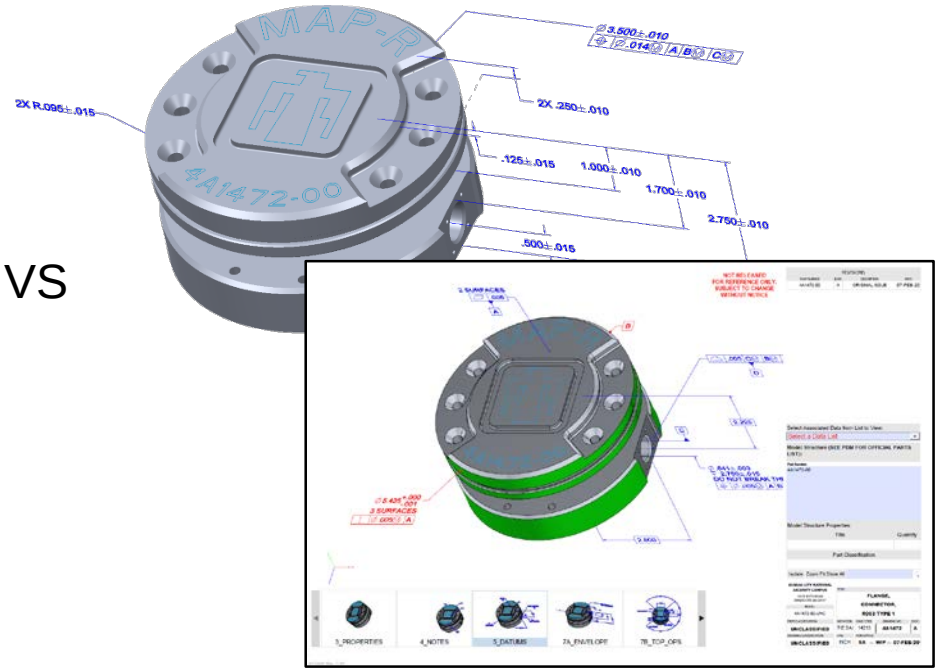
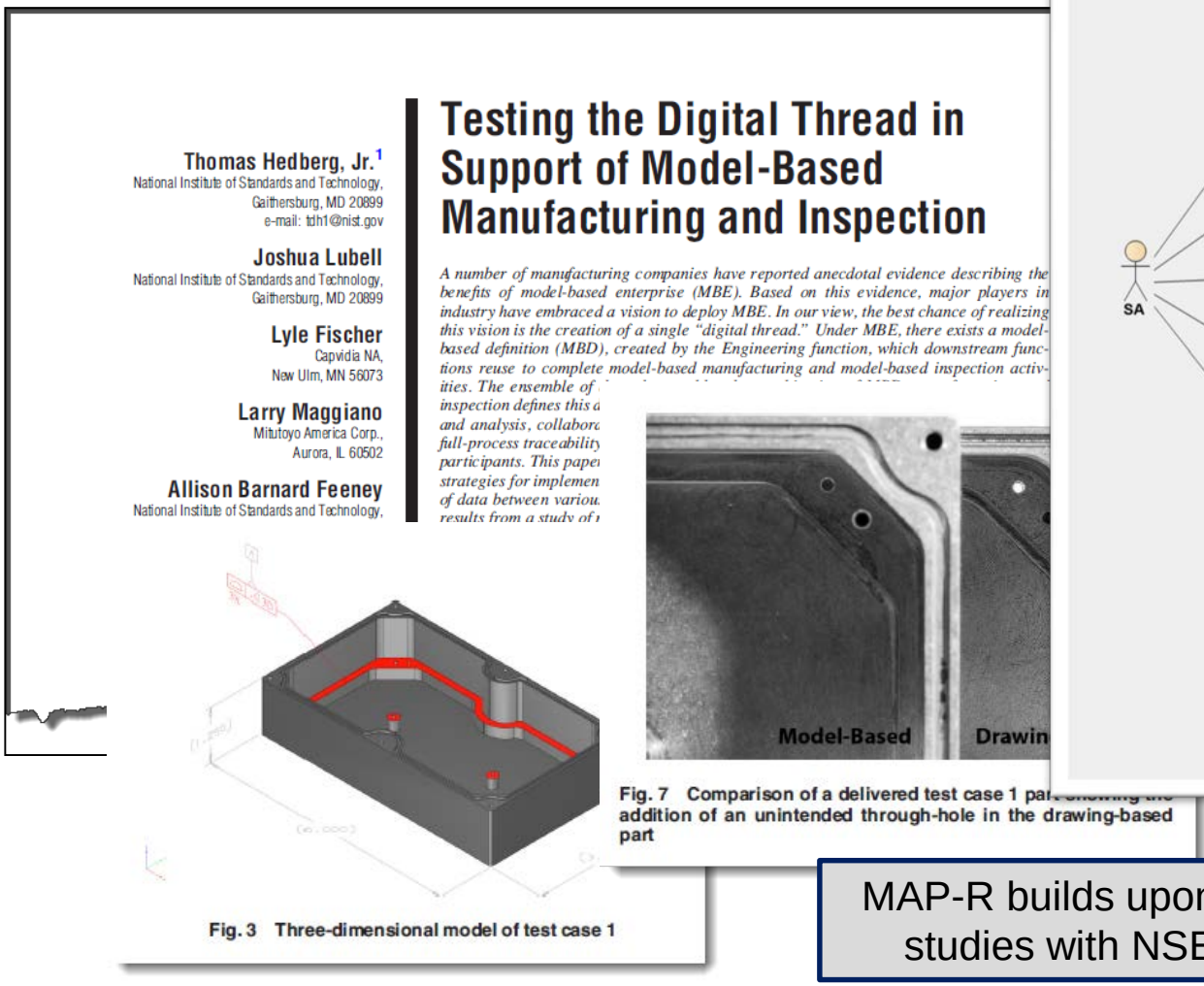


MAP-R Methodology



Testing the Digital Thread in Support of Model-Based Manufacturing and Inspection

Thomas Hedberg, Jr.[1]
National Institute of Standards and Technology,
Gaithersburg, MD 20899
e-mail: tdh1@nist.gov

Joshua Lubell
National Institute of Standards and Technology,
Gaithersburg, MD 20899

Lyle Fischer
Capvidia NA,
New Ulm, MN 56073

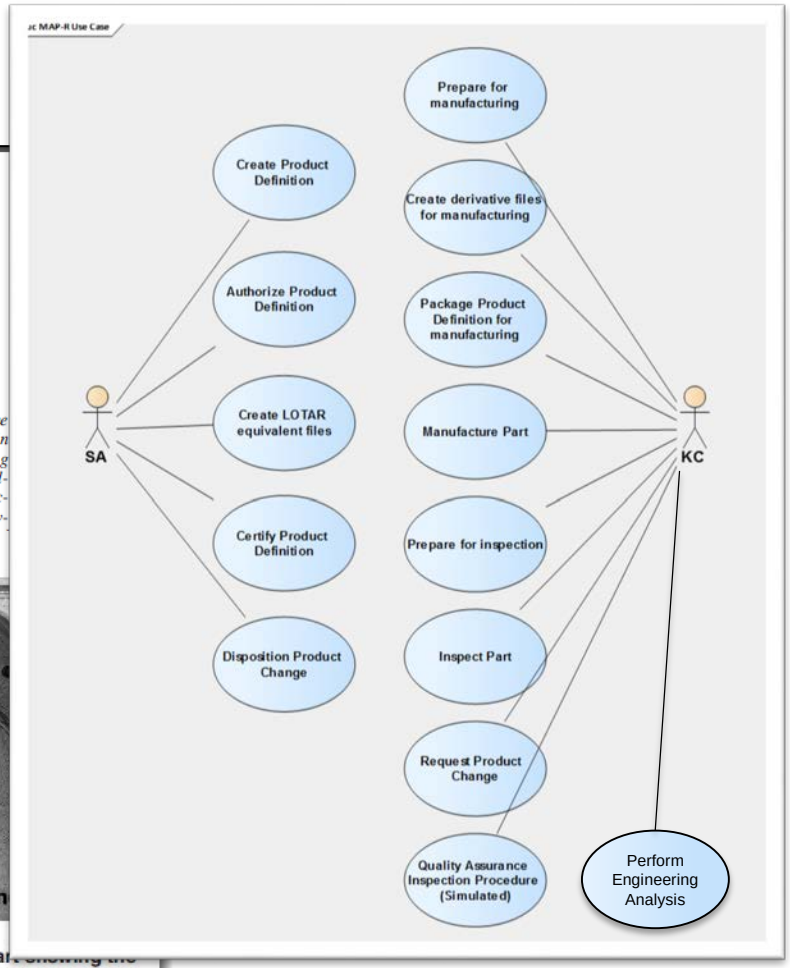
Larry Maggiano
Mitutoyo America Corp.,
Aurora, IL 60502

Allison Barnard Feeney
National Institute of Standards and Technology,

A number of manufacturing companies have reported anecdotal evidence describing the benefits of model-based enterprise (MBE). Based on this evidence, major players in industry have embraced a vision to deploy MBE. In our view, the best chance of realizing this vision is the creation of a single "digital thread." Under MBE, there exists a model-based definition (MBD), created by the Engineering function, which downstream functions reuse to complete model-based manufacturing and model-based inspection activities. The ensemble of
inspection defines this a
and analysis, collabora
full-process traceability
participants. This pape
strategies for implemen
of data between variou
results from a study of

Fig. 7 Comparison of a delivered test case 1 par… addition of an unintended through-hole in the drawing-based part

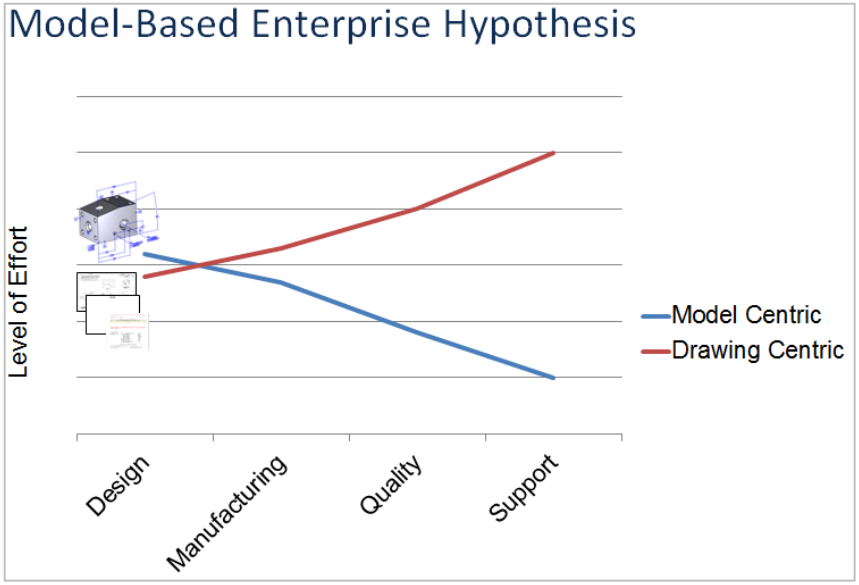
Fig. 3 Three-dimensional model of test case 1



MAP-R builds upon the findings of NIST studies with NSE unique use cases

MAP-R Deliverables

- Validate the Model-Based Hypothesis and answer critical questions such as:
  - Is there a quantifiable business benefit?
  - What Product Manufacturing Information (PMI) should be included?
  - What is a Trusted Model?
  - Does a 3D annotated model save time and improve quality?
  - What are our capabilities (people, processes, tools) and maturity to use models?
- Identify gaps in current processes, tools, training, and policies to effectively implement MBE (inputs for MBE Roadmap)
- Capture best practices and create new process documents/modify existing documentation



Understanding the value proposition for the Enterprise

MBE Level 2 - Trusted Model Centric

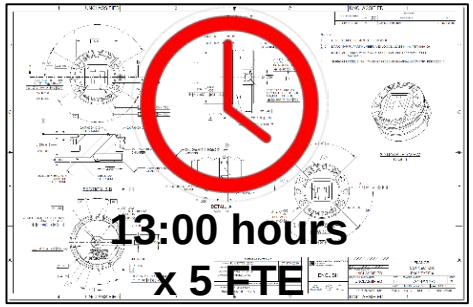
- Validate 3D Models

If you rely on a model, it must be a reliable model… then prove it.

- Create Derivative Models
- Compare Derivatives to Source
- Create Model Certificates

Create Certified Derivatives w.r.t. Source Model

- Example:



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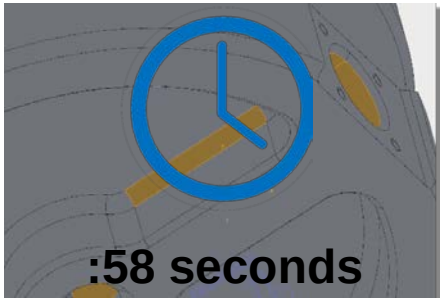
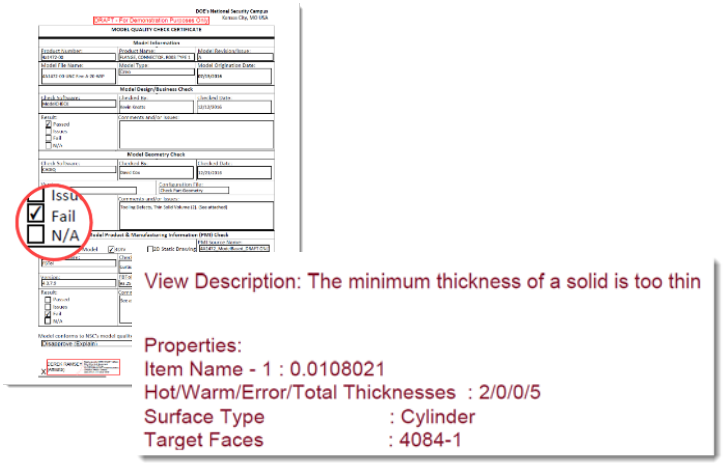


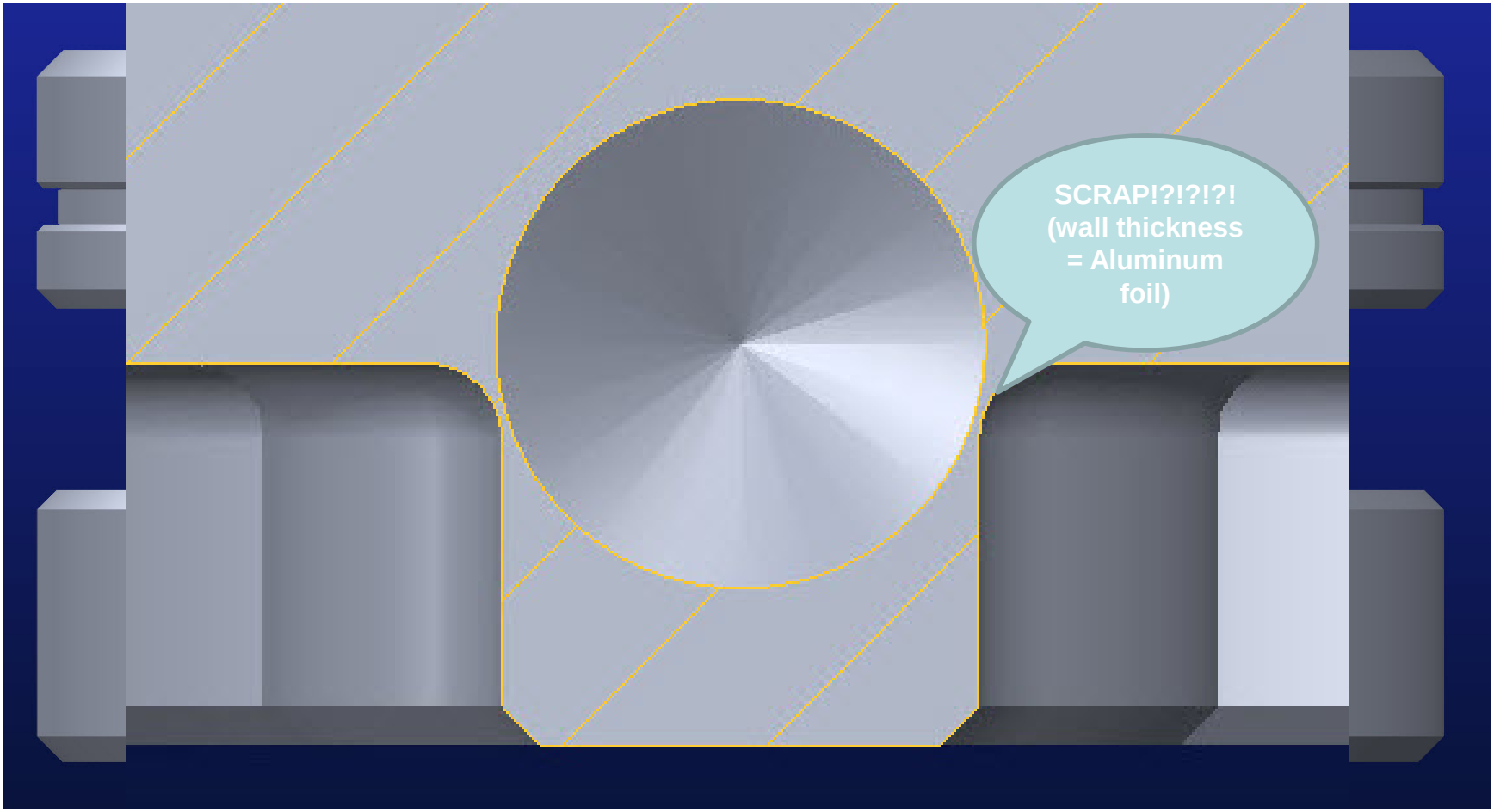


Drawing-Based Practice Model-Based Approach

Model Validation identifies issues not easily identified in drawing reviews

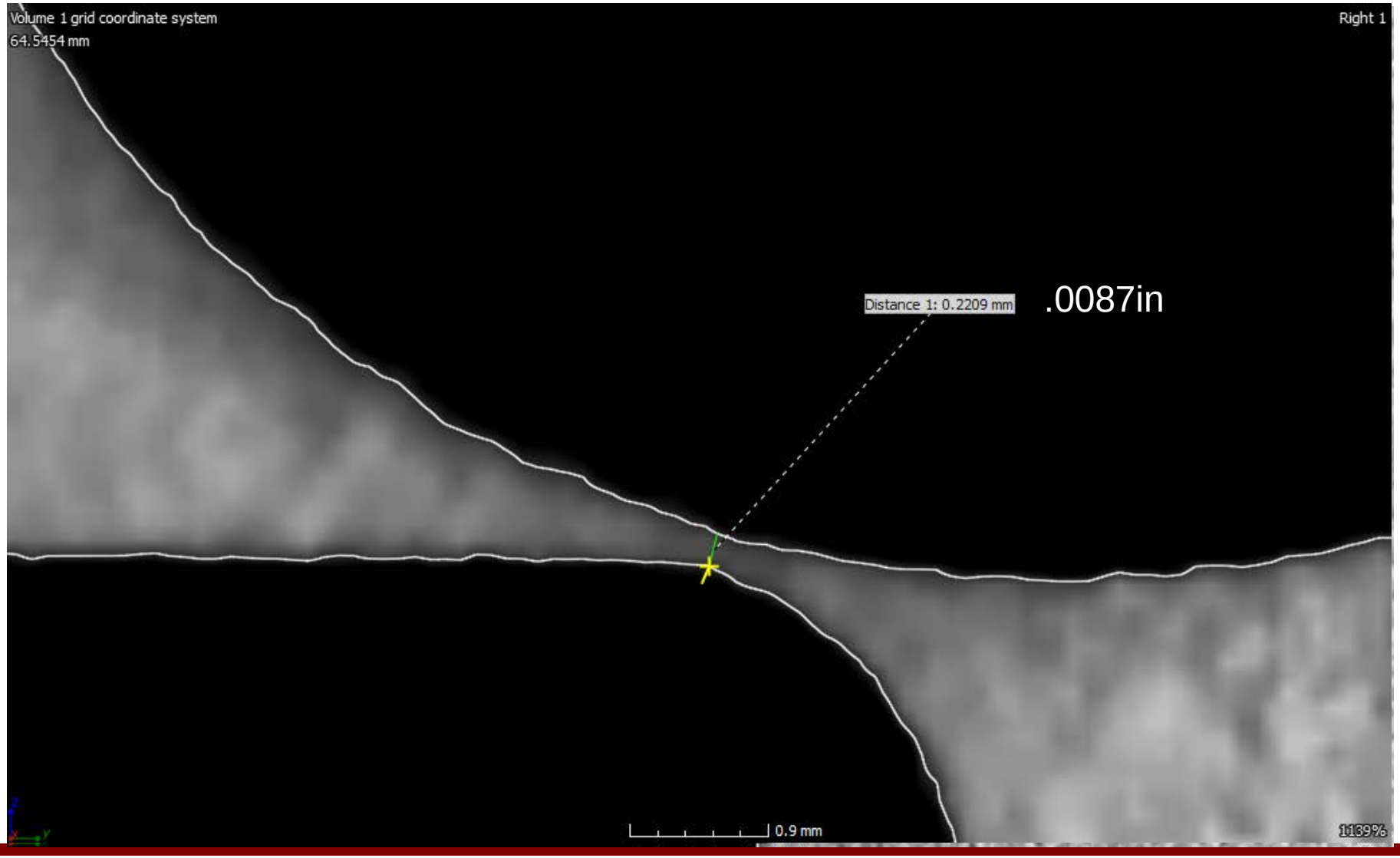
MBE Level 2 - Trusted Model Centric

Early Detection of Defects



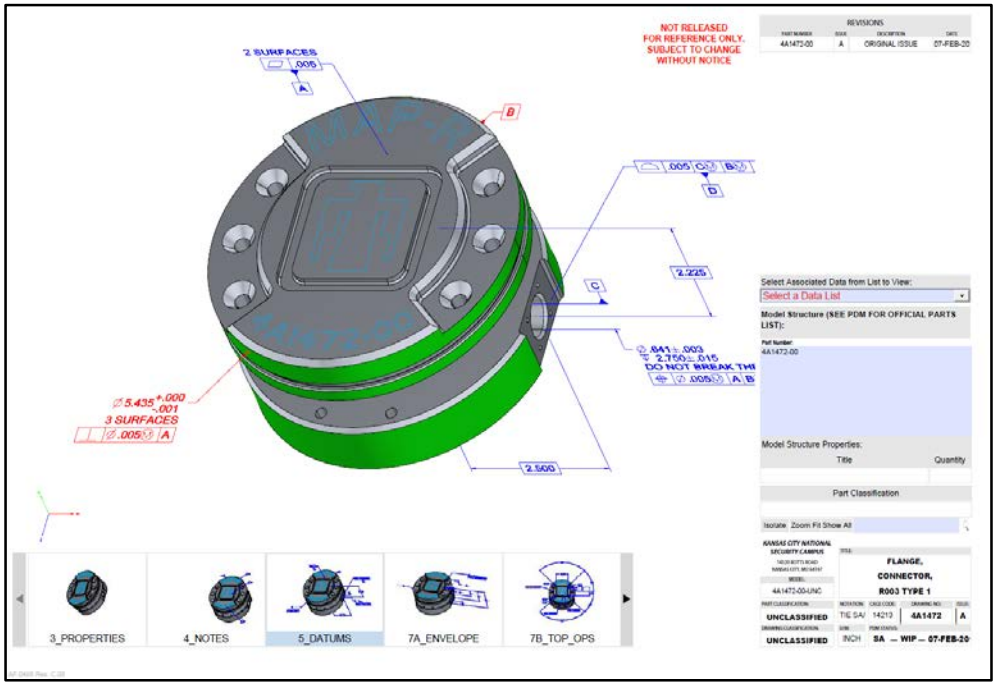
CT Scan of Interesting Area

- DB MAPR 4A1473 S/N 5001



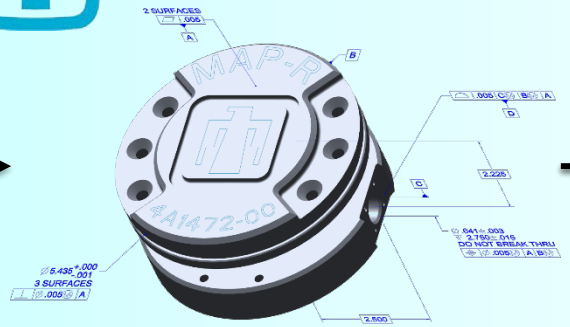
MBE Level 3 – Model-Based Definition

- 3D Interactive Viewable (3DIV)
  - Created from Model-Based Definitions (MBD)
  - Generate 3D Interactive Viewable (3DIV) for Human Consumption



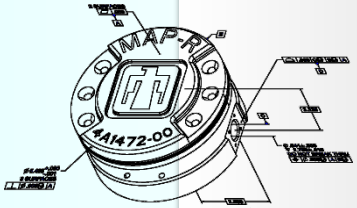
3D Interactive Viewable (3DIV) new preferred human consumption format

From Design Agency (DA) To Production Agency (PA)



Certify Part Defining Model

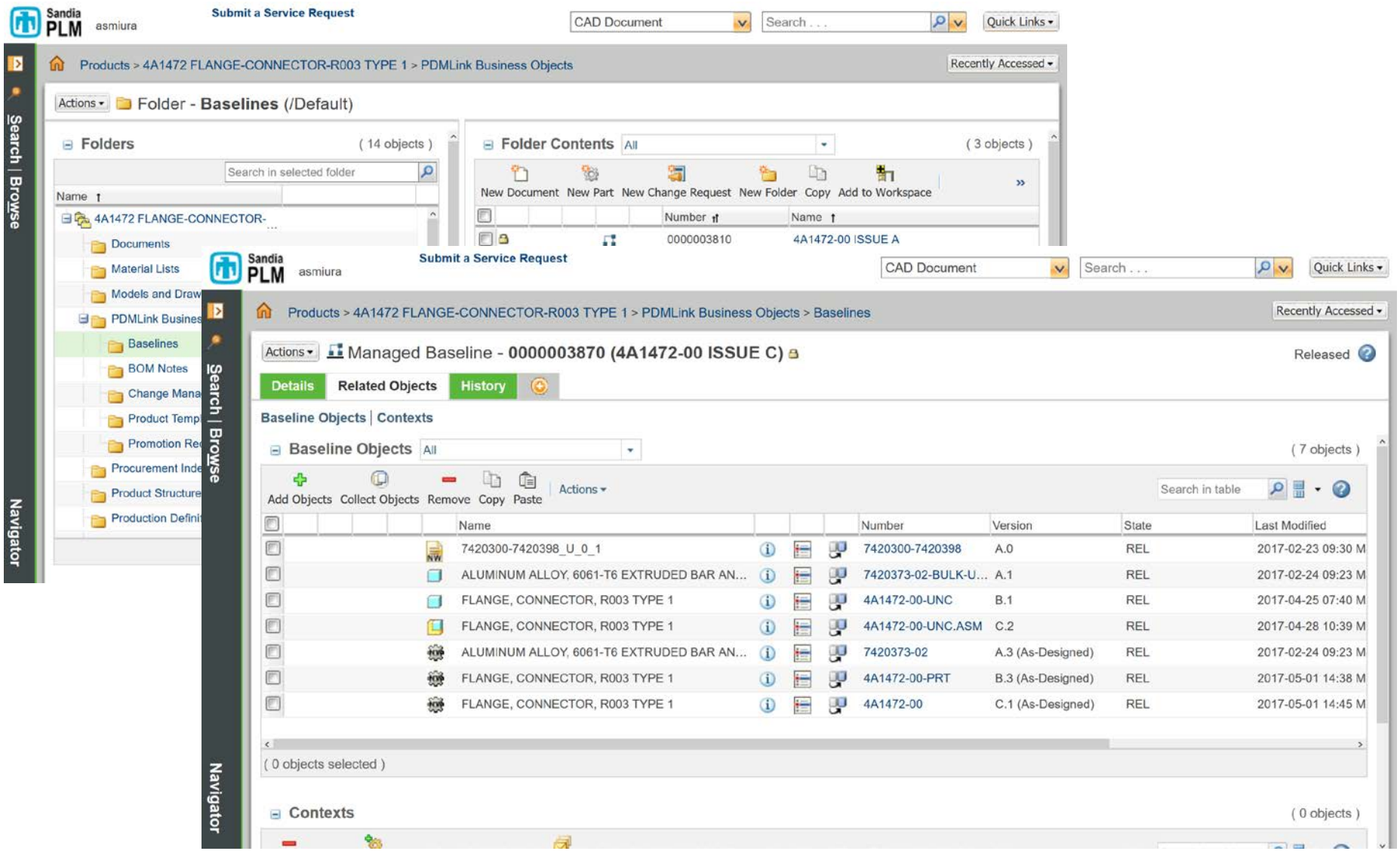
Authorize Part Defining Model



PA is ***authorized*** to use the ***certified*** part defining model and associated baseline for ***all*** production activities

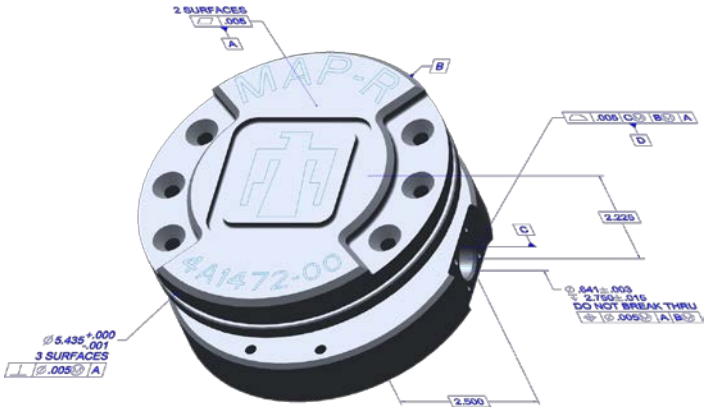
Authorized to use the Certified Part Defining Model for ALL Production Activities

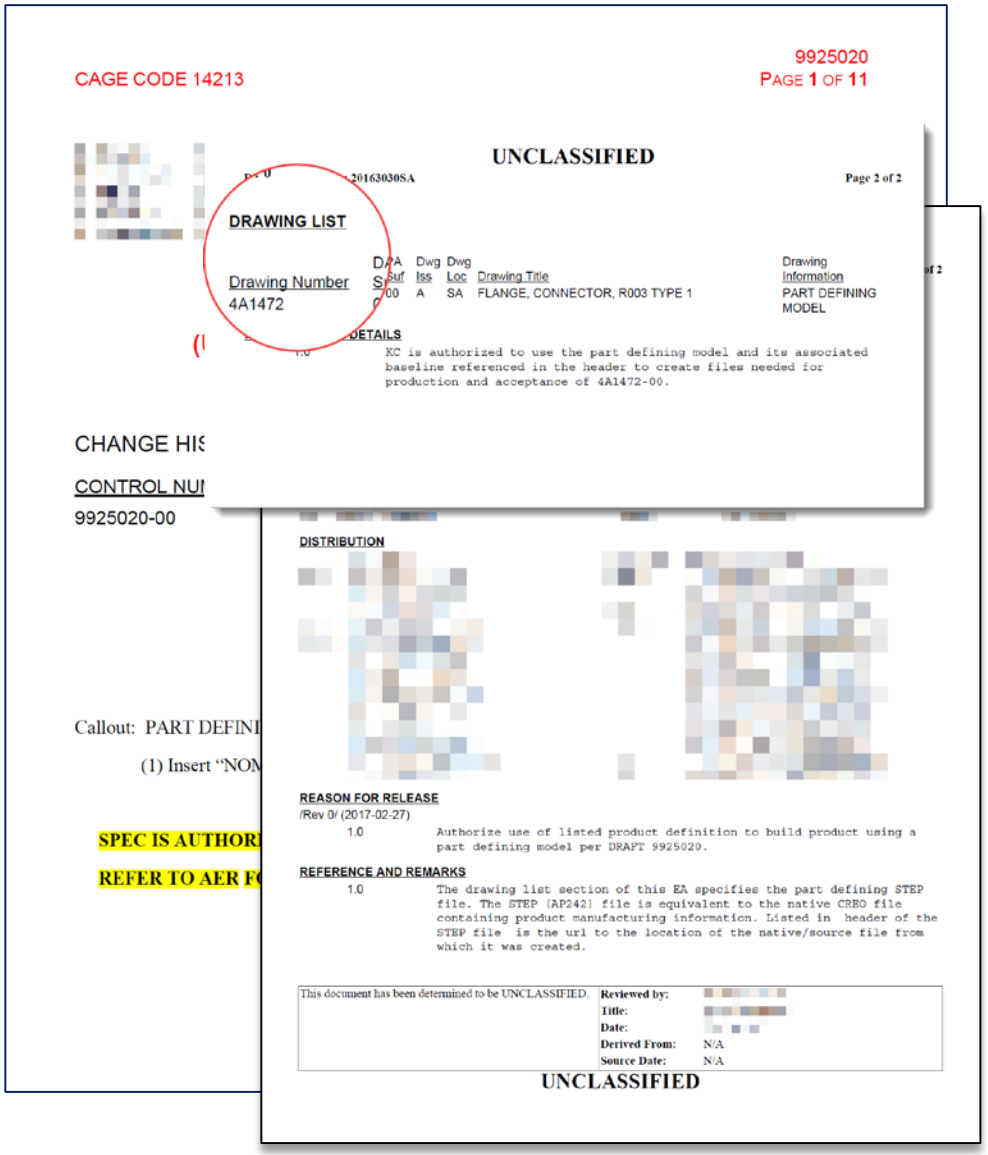
Authorization to Baseline



Authorizing models as product definition is required for MBE

- Part Defining Model specification 9925020 defines a method to certify and authorize native CAD and derived STEP files for use as product definition
- Current EA system only recognizes drawings

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9925020
PAGE 1 OF 11

UNCLASSIFIED

Page 2 of 2

DRAWING LIST

Drawing Number	Dwg Iss	Dwg Loc	Drawing Title	Drawing Information
4A1472	A	SA	FLANGE, CONNECTOR, R003 TYPE 1	PART DEFINING MODEL

DETAILS

KC is authorized to use the part defining model and its associated baseline referenced in the header to create files needed for production and acceptance of 4A1472-00.

CHANGE HIS

CONTROL NUI

9925020-00

Callout: PART DEFINI

(1) Insert "NOM

SPEC IS AUTHOR

REFER TO AER F

DISTRIBUTION

REASON FOR RELEASE

/Rev 0/ (2017-02-27)

1.0 Authorize use of listed product definition to build product using a part defining model per DRAFT 9925020.

REFERENCE AND REMARKS

1.0 The drawing list section of this EA specifies the part defining STEP file. The STEP (AP242) file is equivalent to the native CREO file containing product manufacturing information. Listed in header of the STEP file is the url to the location of the native/source file from which it was created.

This document has been determined to be UNCLASSIFIED.

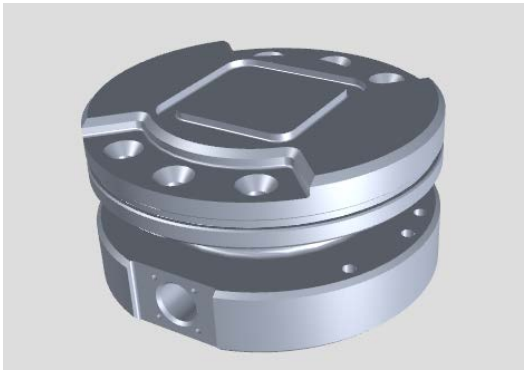
Reviewed by:
Title:
Date:
Derived From: N/A
Source Date: N/A

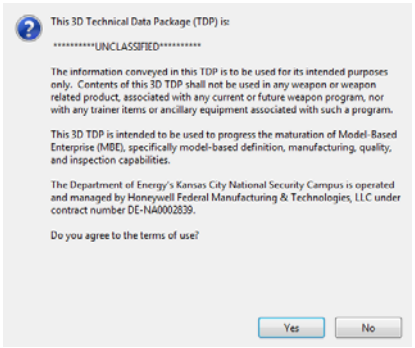
UNCLASSIFIED

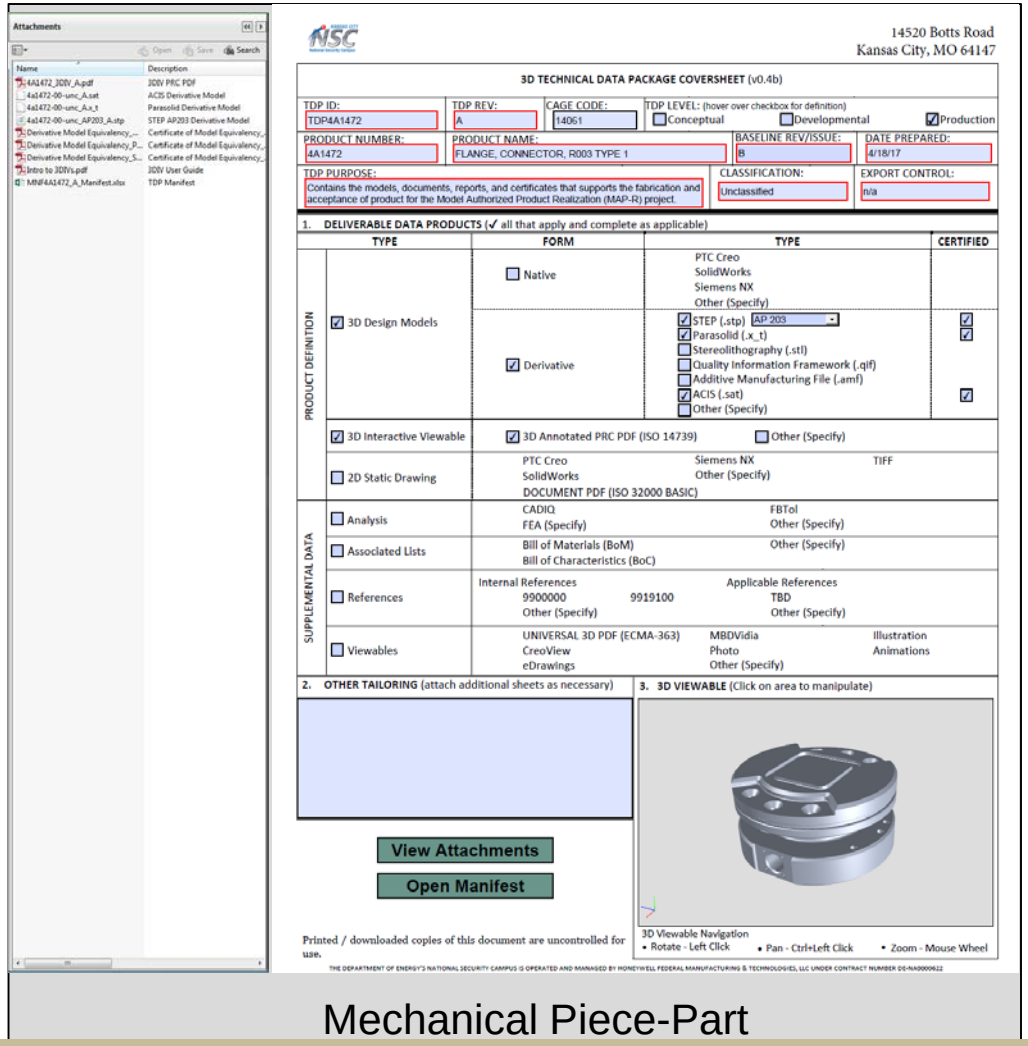
MBE Level 3 – Model-Based Definition

3D Technical Data Package

- **Manufacturing Authority**
- **PDF Container**



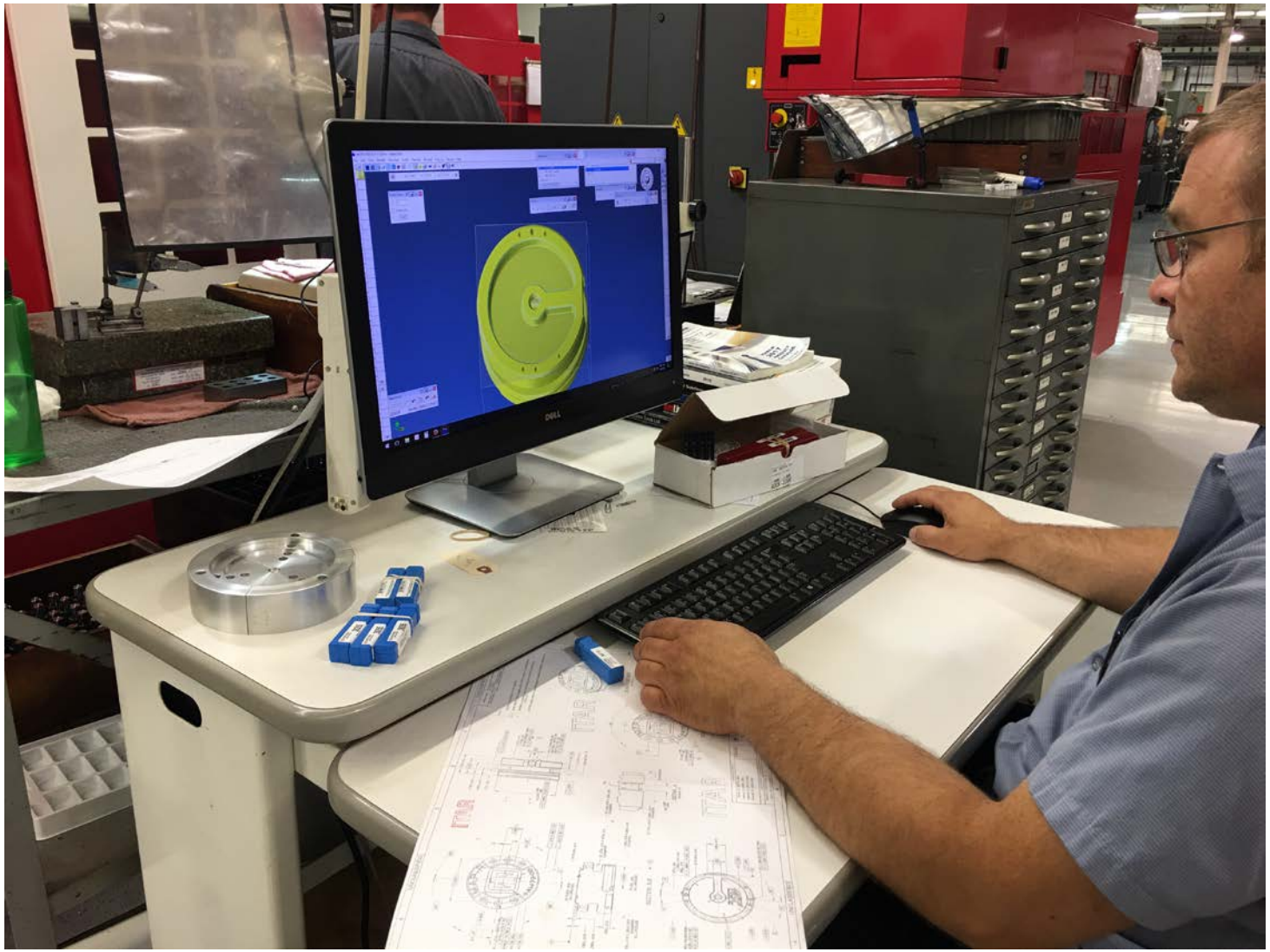




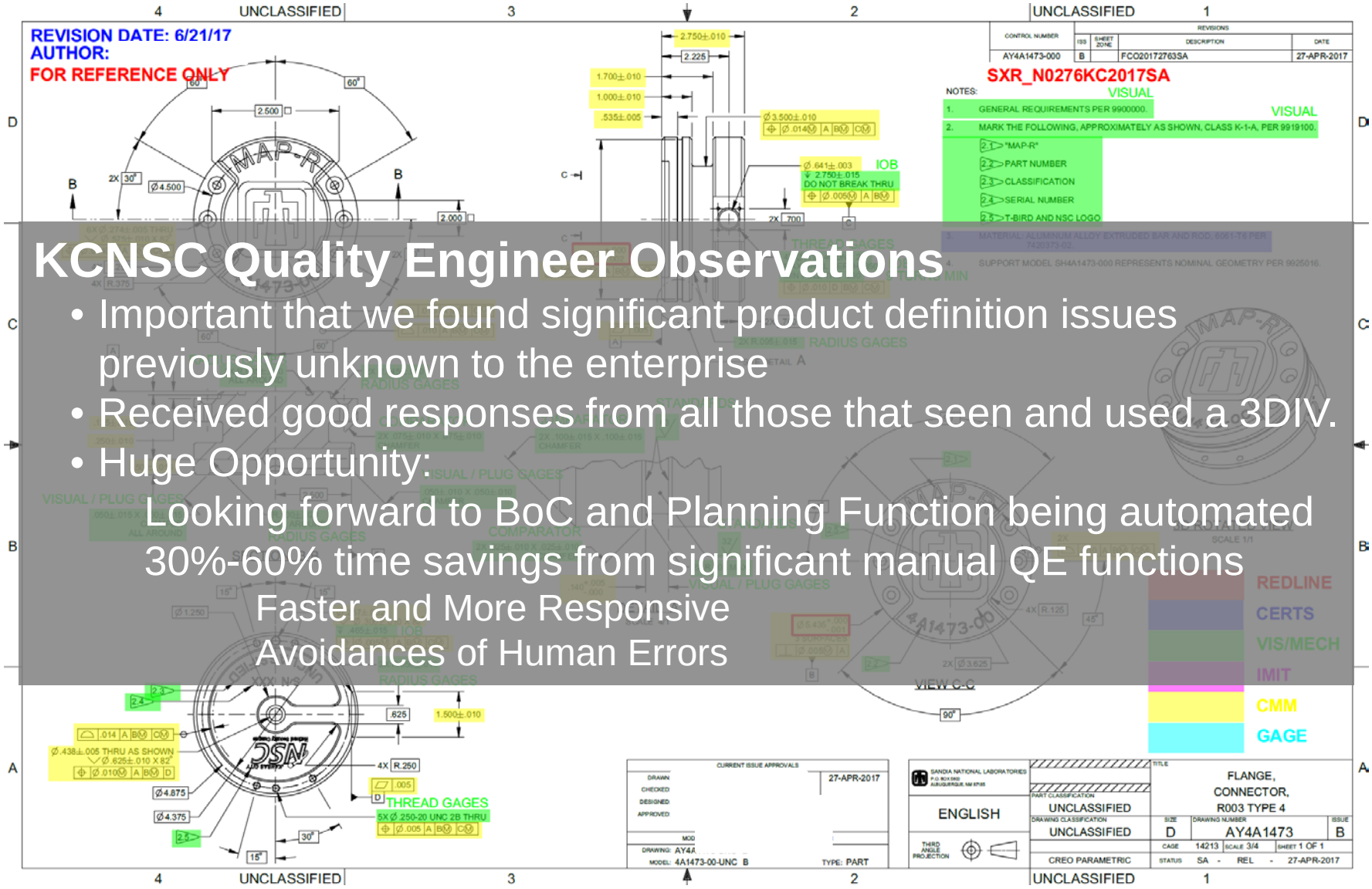
Mechanical Piece-Part

KCNSC's 3D Manufacturing Technical Data Package Example!

Drawing Based – NC Programming



KCNSC QE's Inspection Planning



KCNSC Quality Engineer Observations

- Important that we found significant product definition issues previously unknown to the enterprise
- Received good responses from all those that seen and used a 3DIV.
- Huge Opportunity:

Looking forward to BoC and Planning Function being automated

30%-60% time savings from significant manual QE functions

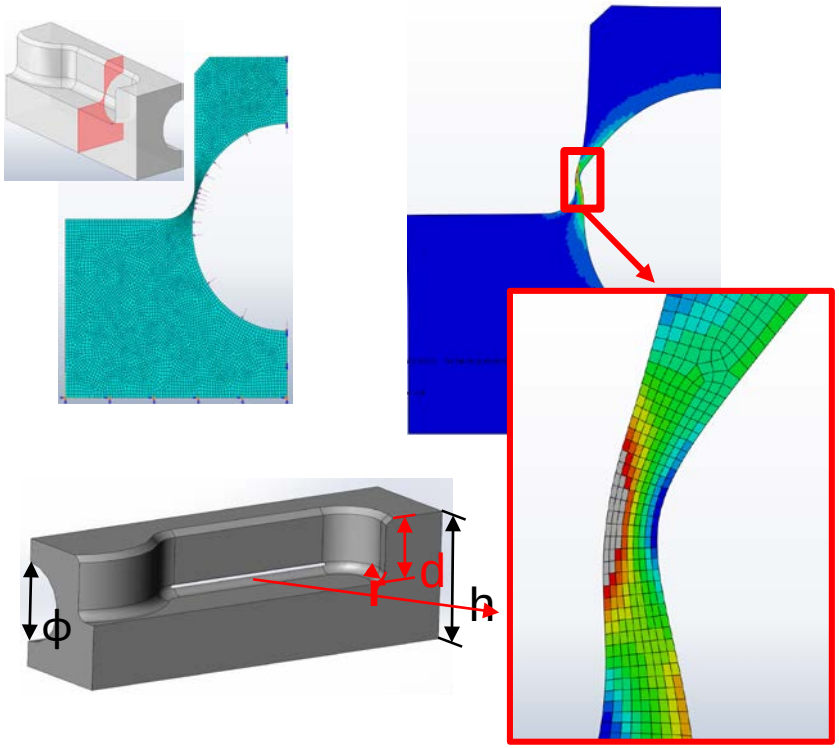
Faster and More Responsive

Avoidances of Human Errors

Drawing Based

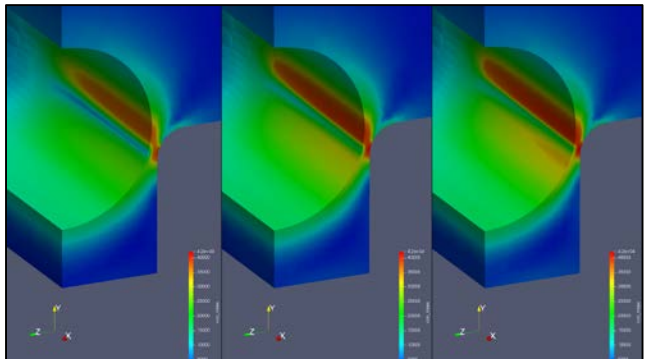
Perform Engineering Analysis

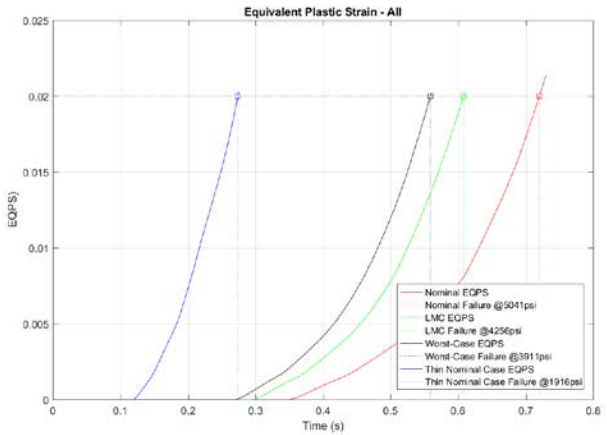
- Drawing-Based MAPR
- Analyze thin wall issue
- 2D Drawing and STEP AP203



Time Spent: 50 hrs.
Time Spent on Model Prep: 31.5 hrs.
Time Spent Analyzing: 18.5 hrs.

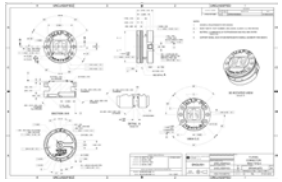
- Model-Based MAPR
- Analyze thicker channel
- 3DTDP w/3D Derivatives Models & 3DIV



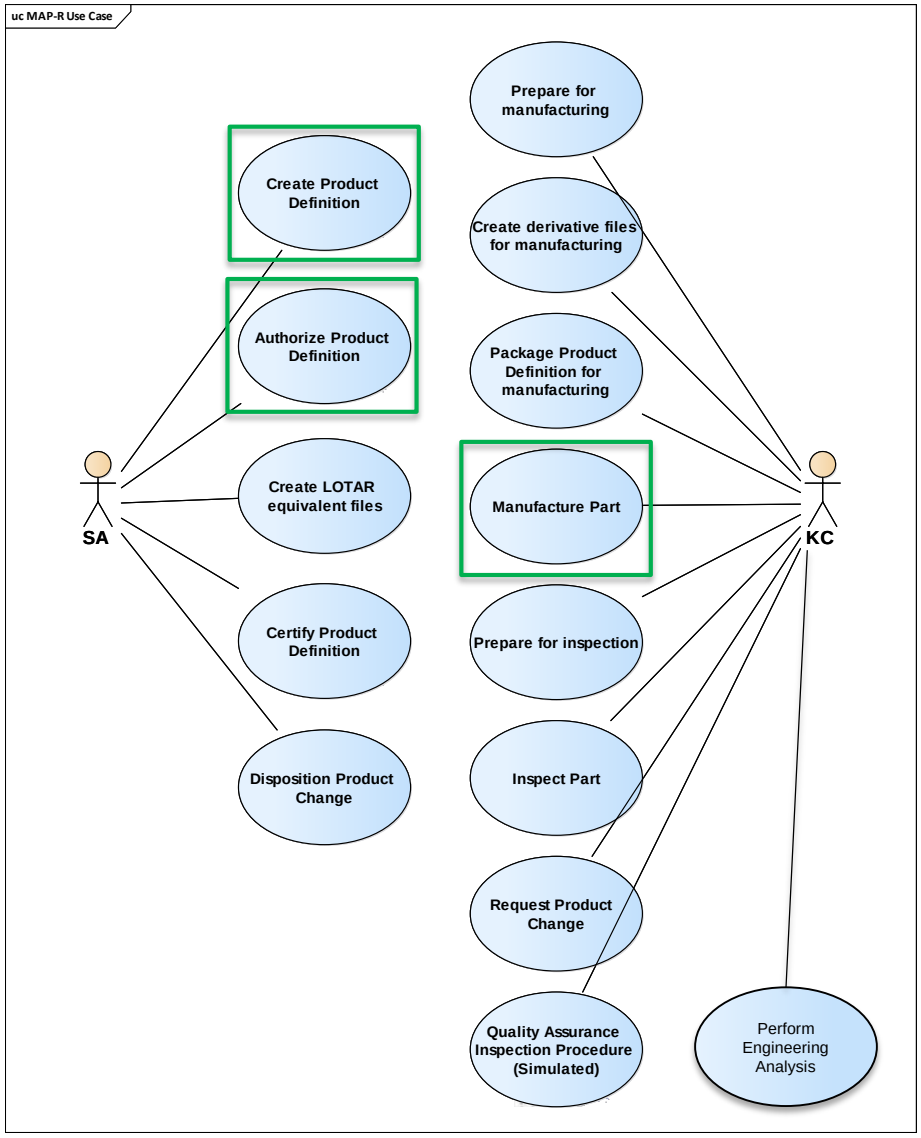


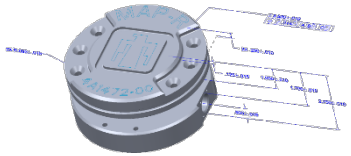
Used ACIS Model from 3DTDP
Time Spent: 12.2 hrs.

MAP-R Project Status



Drawing-Based
All Use Cases Completed





Model-Based
All Use Cases Completed

Current Task: Analyzing the Results & Writing Report

MAP-R Data Analysis

- **Methods**
  - **Workload:** The workload scores were generated based on the Multiple Resource Theory of workload (Wickens and Yeh, 1986). Each score represents an aggregate of the modeled Cognitive (C), Fine Motor (FM) and Visual (V) channels, summed and multiplied by subtask time to denote magnitude, and then divided by overall task time (summed time of all tasks).
  - **Success Rate:** Success rates were determined through applying known error rates from pre-existing research (Melchers & Harrington, 1982; Grudin, 1983; Swain & Guttman, 1983; Dhillon, 1986) and then providing a product of all error rates for the entire task.
- **Overall Underlying Theory:**

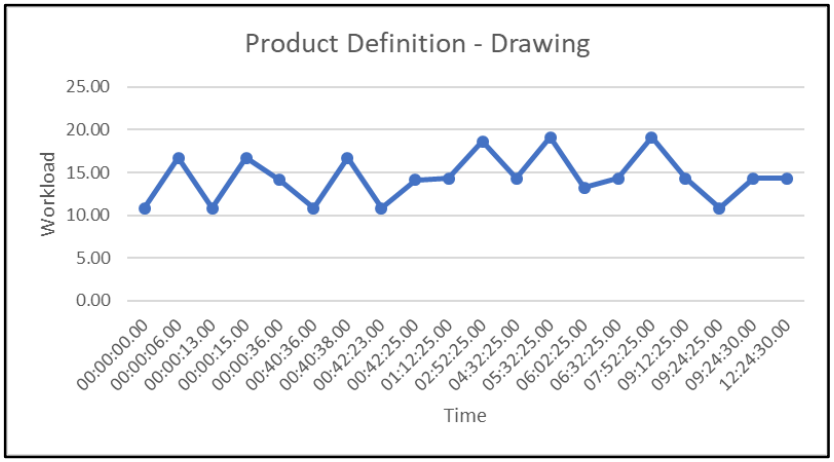
  Workload can affect performance and be a predictor of possible error rates (Yerkes, Dodson, 1908; Swain, 1964; Paas, 1992). We hypothesize that the model-based process will show less time in the high-workload condition than the drawing-based process. This can be used as a predictor for possible error rate of the task(s) in question and could result in less errors over time through implementing the process.
- **Workload Levels:**

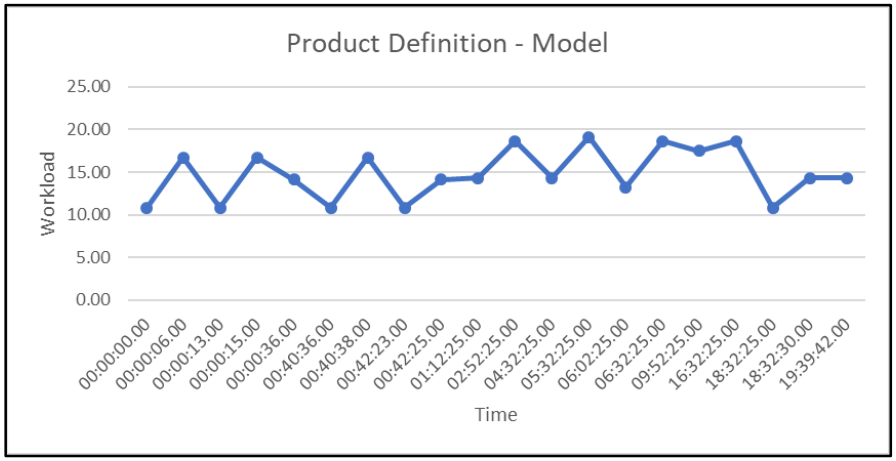
  The low, medium and high workload levels were assigned based on the aggregate workload score for each task for both processes. Low = 0-14.9, medium 15 to 18.9, high 19-21. These determinations were based on Multiple Resource Theory scores for task types, where 21 is the maximum of possible workload to be experienced for the three channels modeled, and the concept of stress-based workload levels and predicted performance.

Selected Use Cases

Total Execution Time	
Drawing	Model
89:15:14	83:42:11
Time in Low Workload	
Drawing	Model
19:48:31	18:14:28
Time in Med Workload	
Drawing	Model
5:24:38	12:08:38
Time in High Workload	
Drawing	Model
64:02:05	53:19:05

Create Product Definition





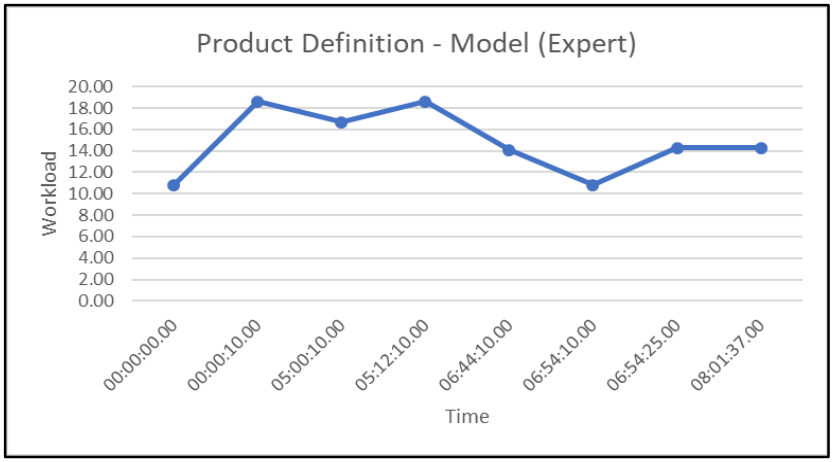
Time at Load		
Low 0-14	Med 15-18	High 19-21
8:52:17	0:02:13	3:30:00

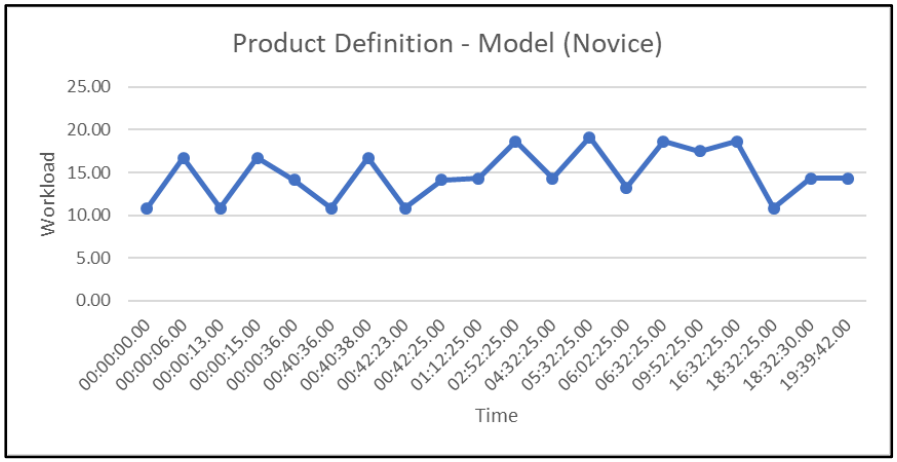
Total Time 12:24:05

Time at Load		
Low 0-14	Med 15-18	High 19-21
5:27:29	6:42:13	7:30:00

Total Time 19:39:42

Create Product Definition (Novice vs. Expert)





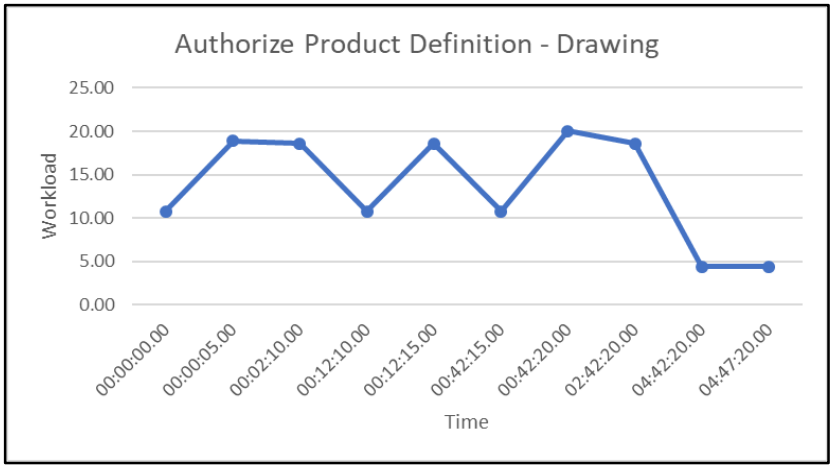
Time at Load		
Low 0-14	Med 15-18	High 19-21
1:17:37	0:12:00	6:32:00

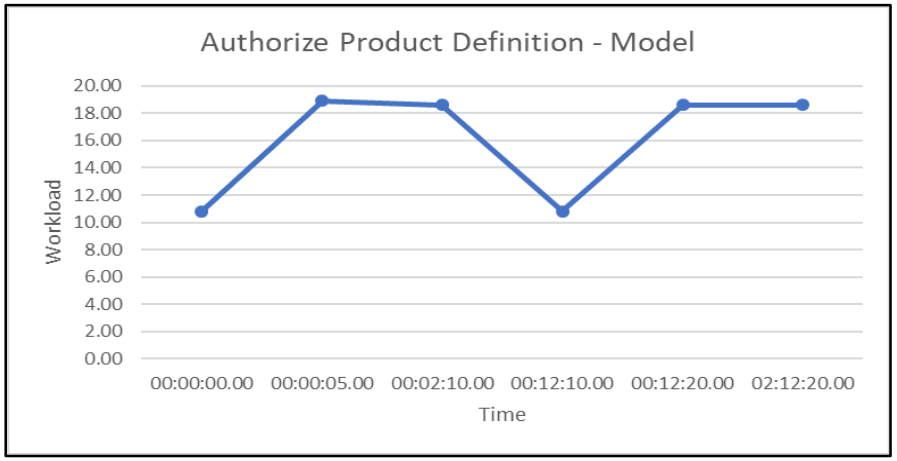
Total Time 8:01:37

Time at Load		
Low 0-14	Med 15-18	High 19-21
5:27:29	6:42:13	7:30:00

Total Time 19:39:42

Authorize Product Definition





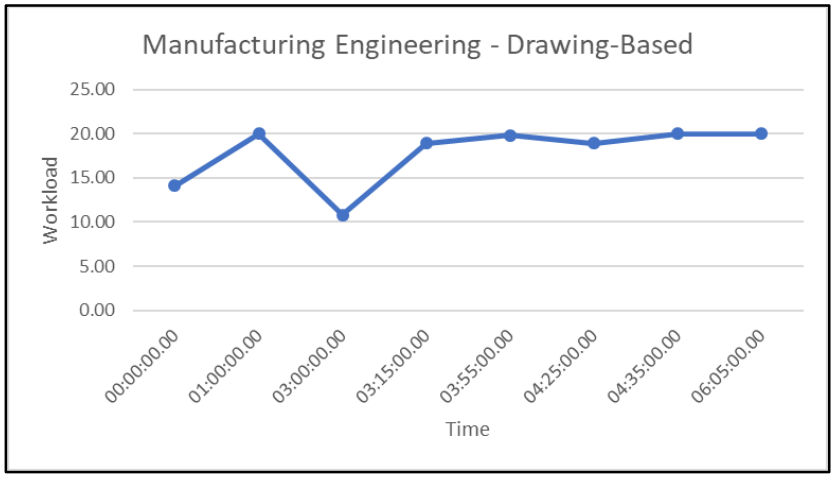
Time at Load		
Low 0-14	Med 15-18	High 19-21
0:05:15	0:00:00	4:42:05

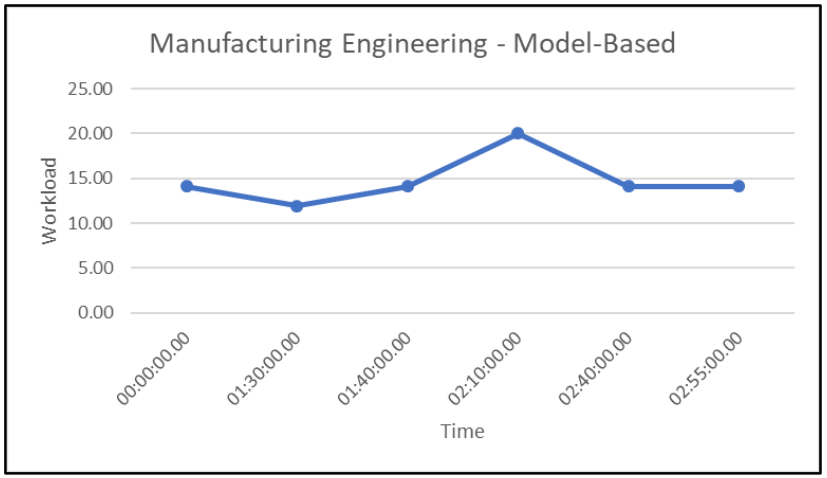
Total Time 4:47:20

Time at Load		
Low 0-14	Med 15-18	High 19-21
0:00:15	0:00:00	2:12:05

Total Time 2:12:20

Manufacture Part (Engineering)





Time at Load		
Low 0-14	Med 15-18	High 19-21
1:15:00	0:00:00	4:50:00

Total Time 6:05:00

Time at Load		
Low 0-14	Med 15-18	High 19-21
2:25:00	0:00:00	0:30:00

Total Time 2:55:00

Review

- NSE is committed to MBE Transition
- A MBE Maturing Index has been updated and proposed
- SNL/KCNSC conducted a first Authorized Part Defining Model
- MAPR Project confirms:
  - Realization of Product from a MBD
  - Acceptance of Product from a MBD
  - Identification of Quality Improvements
  - Increase Responsiveness
  - Shifting of Human Cognitive Load == Reduction of Mistake Opportunities
  - Increased Readiness for MBE Implementation
  - Identification of Opportunities for MBE
  - Results are most positive to pursue significant MBE Insertion Opportunities

Thank You

Questions