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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

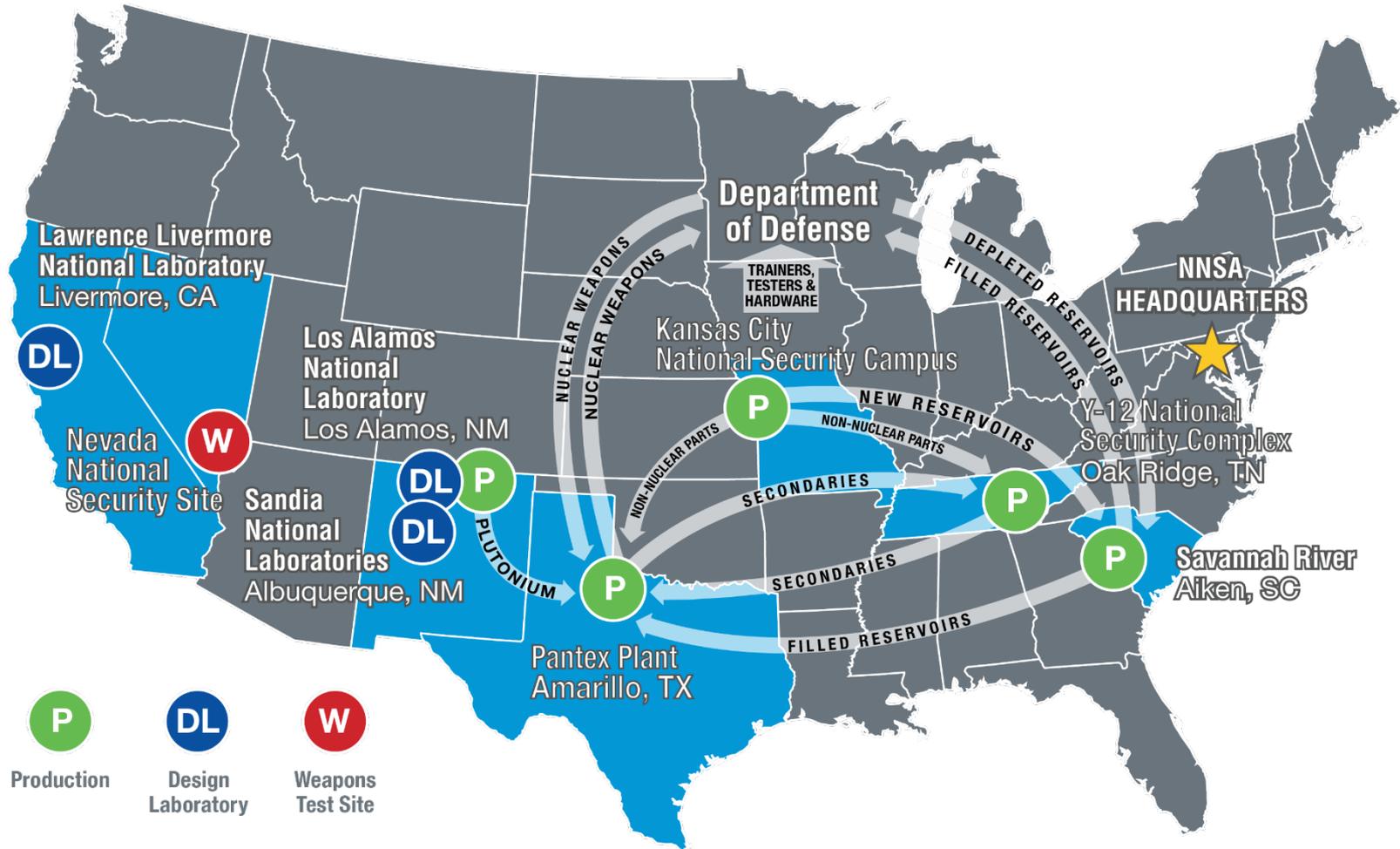
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NNSA's Nuclear Security Enterprise



Sandia National Laboratories

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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Kansas City National Security Campus

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



Managed and Operated by **Honeywell FM&T**

Nuclear Weapon Programs - Core Mission



A large portion of the Campus is dedicated to NNSA's mission of keeping our nation's nuclear stockpile safe, secure and reliable by delivering mission-critical mechanical, electrical, and engineered material components and services.

Global Security – Other Government Agencies



Our unique expertise extends beyond the nuclear security enterprise to benefit national security and promote nonproliferation with field-ready solutions for other government agencies.

Supply Chain Management Center – DoE



By catalyzing the DOE & NNSA Contractor community to behave like a Contractor buying consortium to use our innovative & collaborative strategic sourcing processes, we enable the sites to leverage their annual spend to save millions each year.

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

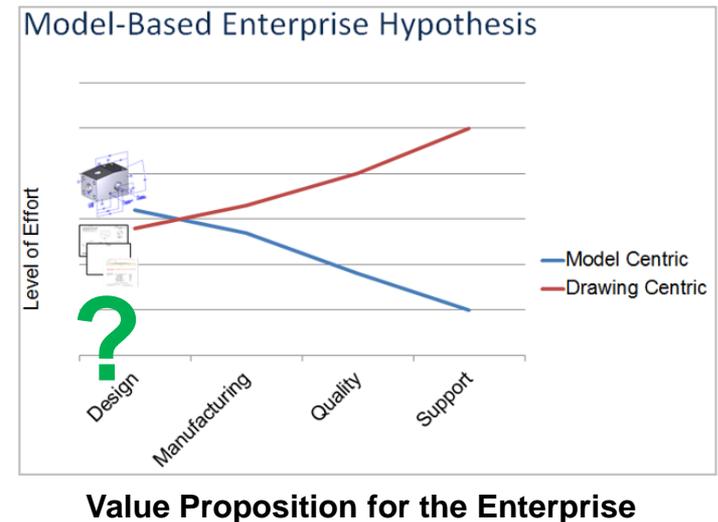
MBE Expected Benefits

■ 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

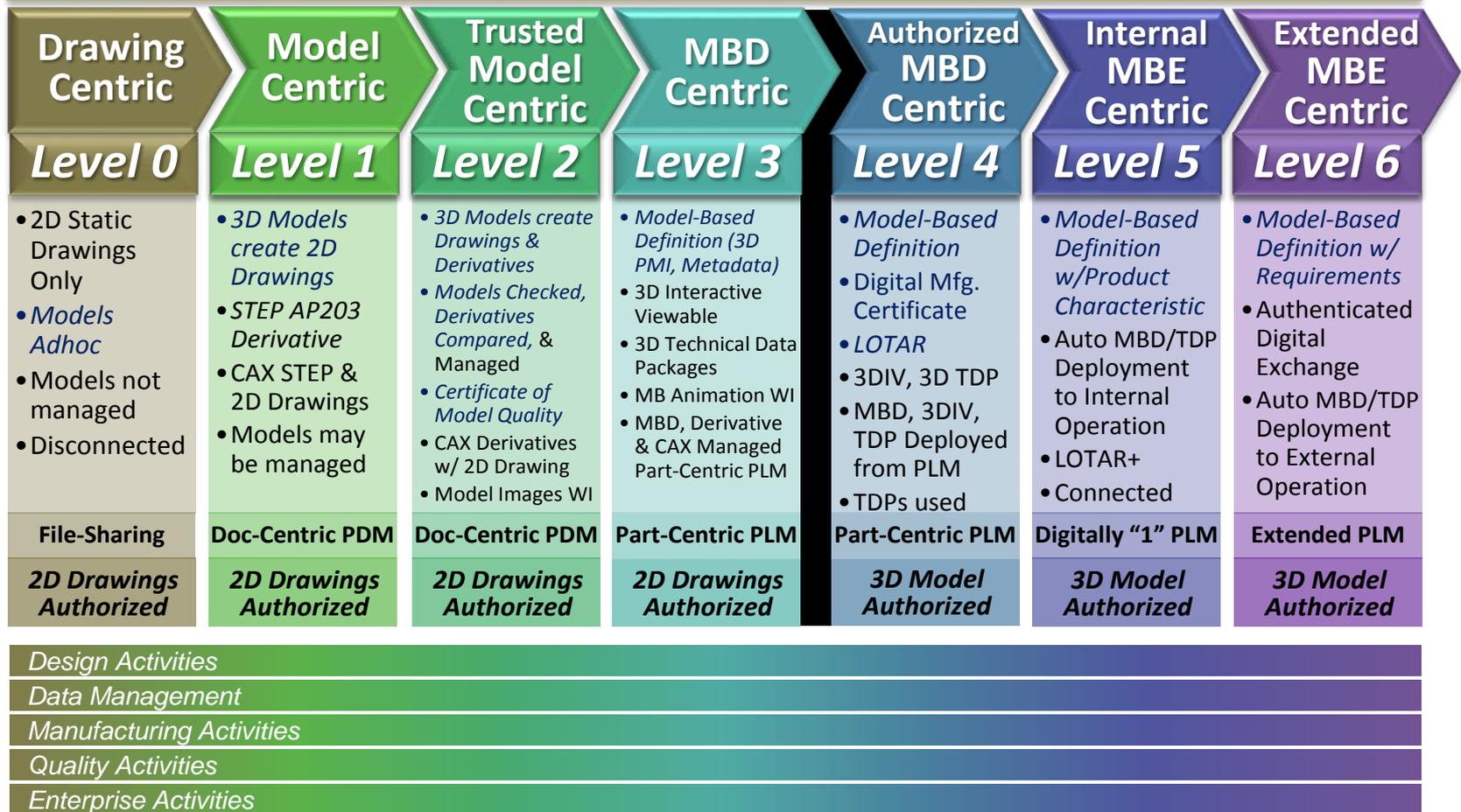
- Simulations & Analysis
- Manufacturing (Additive & Subtractive)
- Engineering & Tool Design
- Purchased Products / Procurement
- Quality's Contribution to the Enterprise
- 3D Technical Data Packages
- Visualization & Animation
- Automation via Digital Interoperability
- Extends the Enterprise



Results will benefit Product Realization and Acceptance

MBE Maturity Index*

Model-Based Enterprise 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

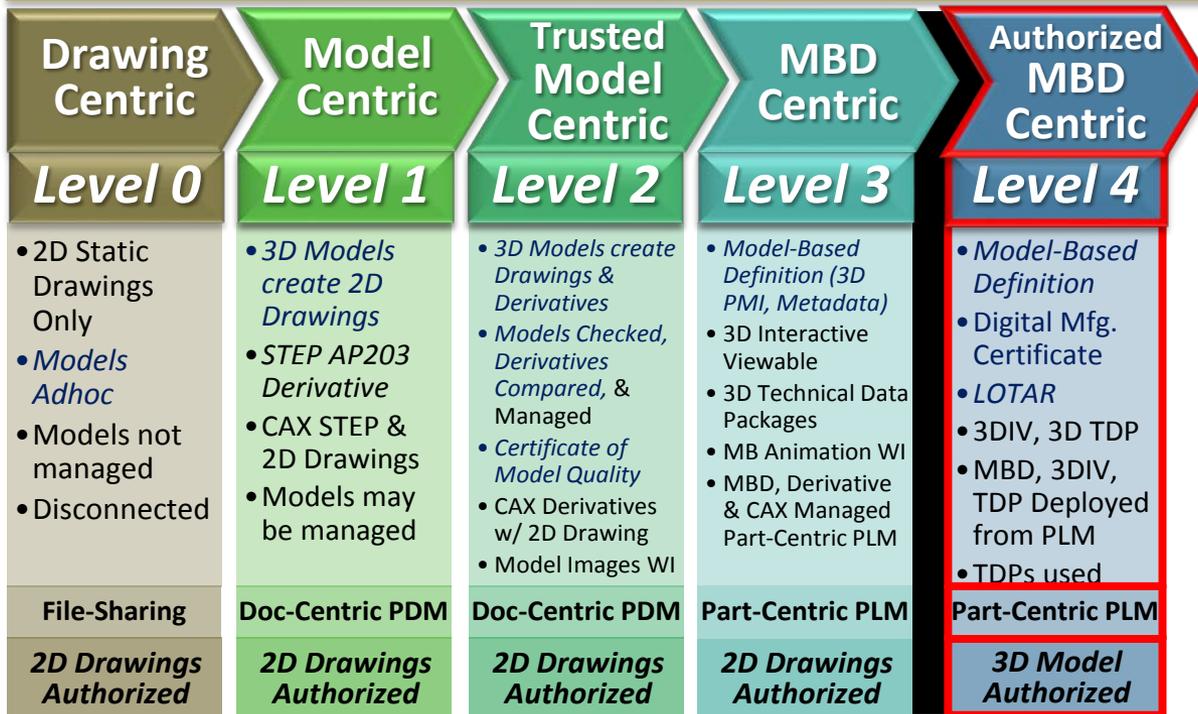
Drawing Centric	Model Centric
Level 0	Level 1
<ul style="list-style-type: none"> • 2D Static Drawings Only • <i>Models Adhoc</i> • Models not managed • Disconnected 	<ul style="list-style-type: none"> • <i>3D Models create 2D Drawings</i> • <i>STEP AP203 Derivative</i> • CAX STEP & 2D Drawings • Models may be managed
File-Sharing	Doc-Centric PDM
<i>2D Drawings Authorized</i>	<i>2D Drawings Authorized</i>

- 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?

Model-Based Enterprise Maturity Index



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

MAP-R Methodology

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

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 and analysis, collaborate full-process traceability participants. This paper strategies for implement of data between various results from a study of

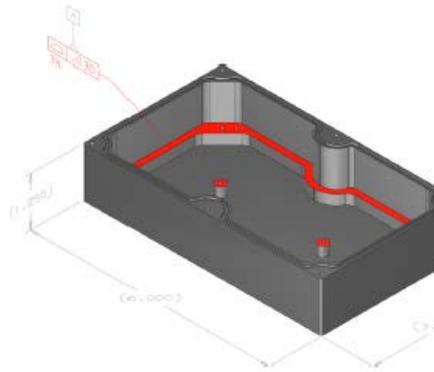


Fig. 3 Three-dimensional model of test case 1

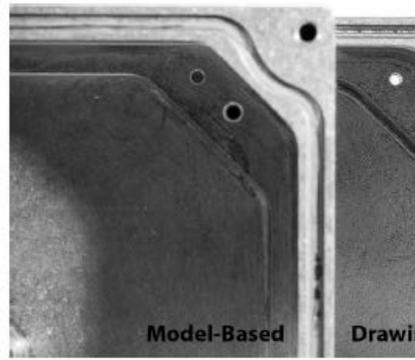
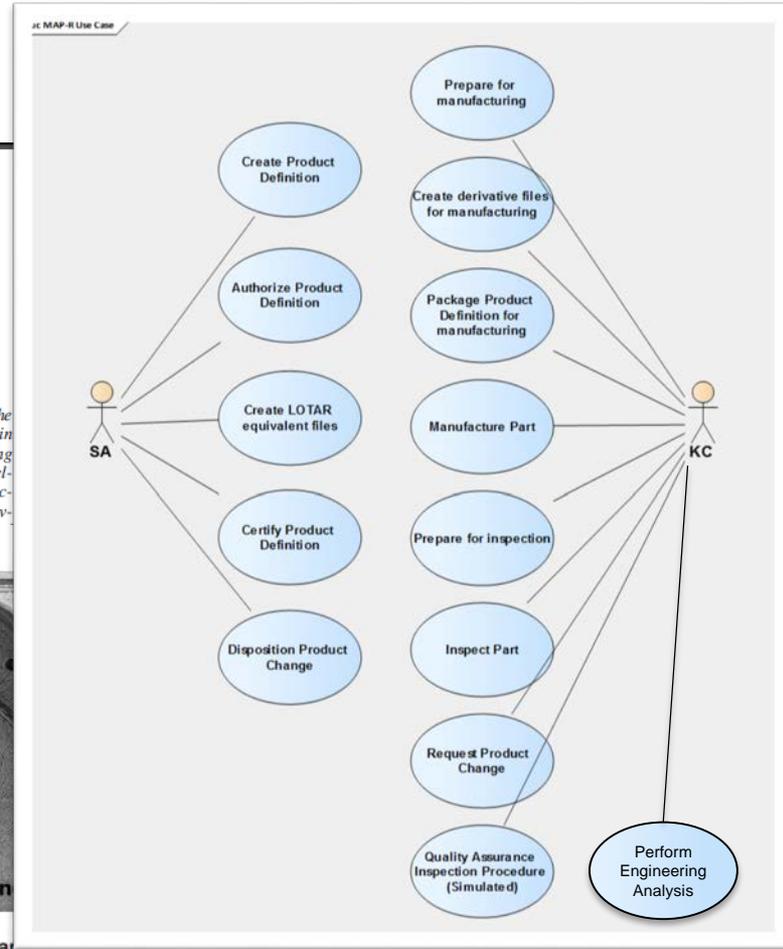


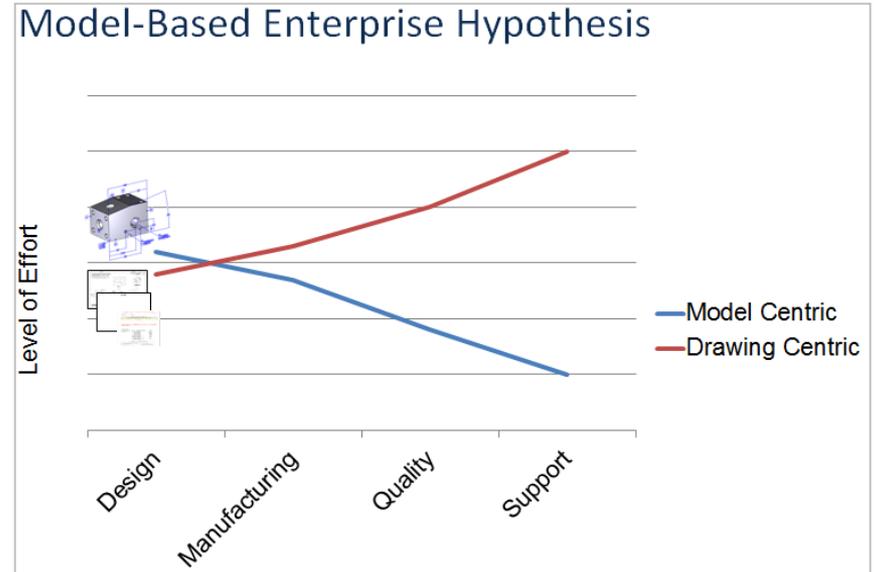
Fig. 7 Comparison of a delivered test case 1 part showing the addition of an unintended through-hole in the drawing-based part



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

- Validate 3D Models



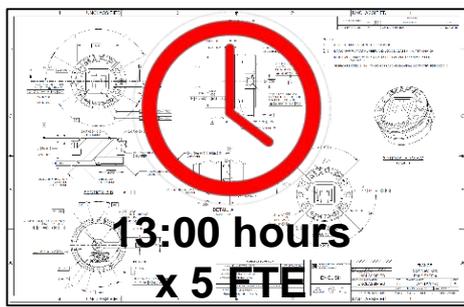
If you rely on a model, it must be a reliable model... then prove it.

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

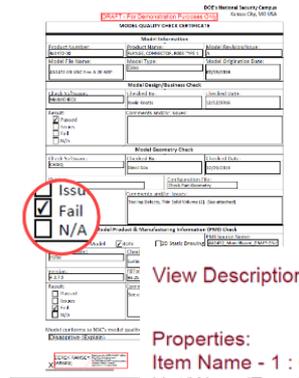
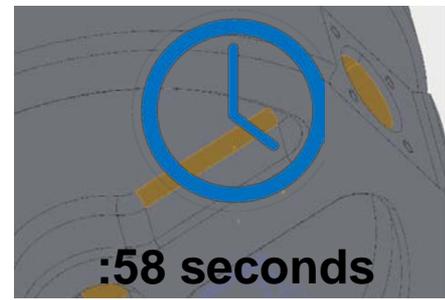


Create Certified Derivatives w.r.t. Source Model

- Example:



VS



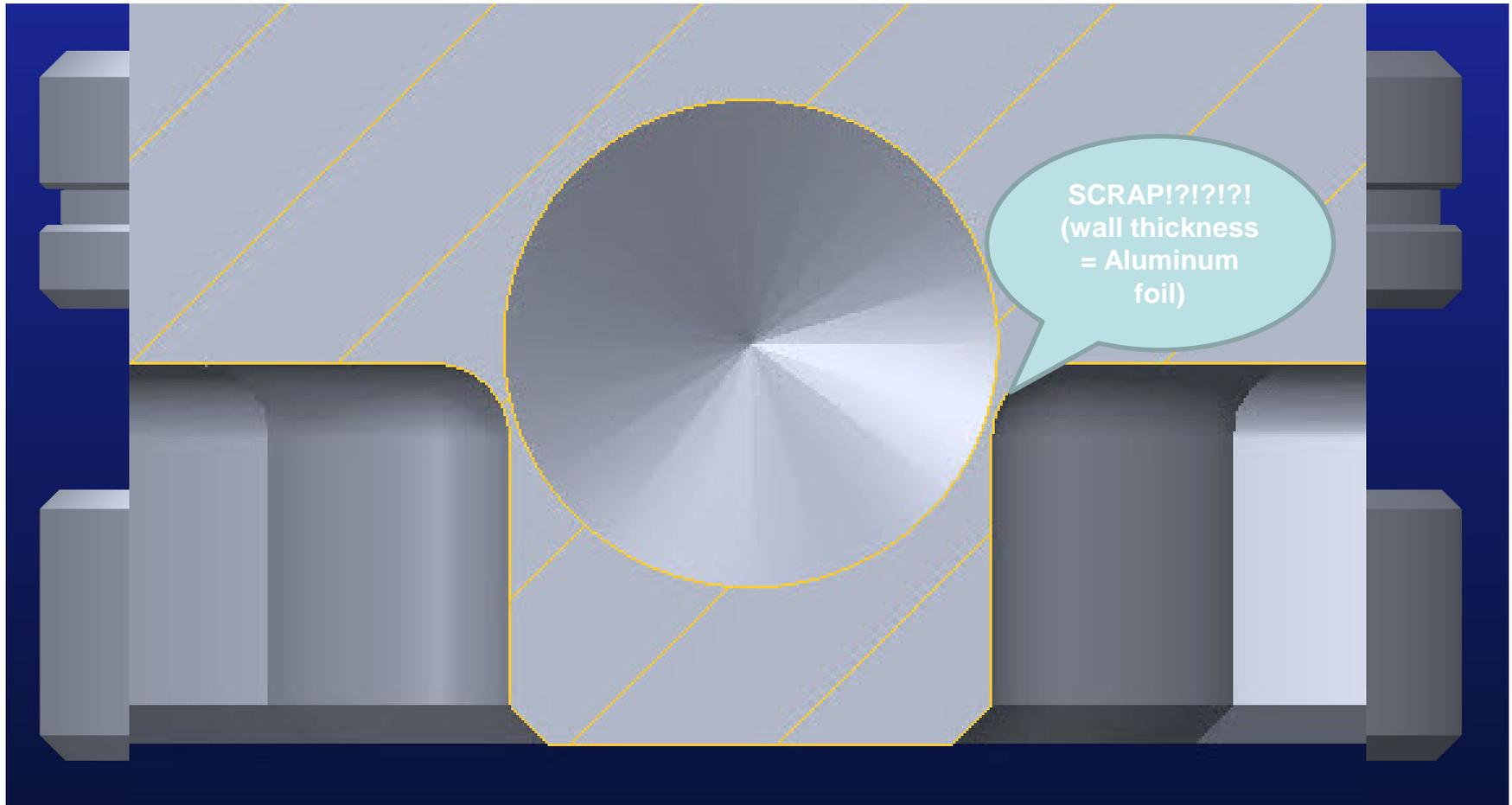
View Description: The minimum thickness of a solid is too thin

Properties:
 Item Name - 1 : 0.0108021
 Hot/Warm/Error/Total Thicknesses : 2/0/0/5
 Surface Type : Cylinder
 Target Faces : 4084-1

Drawing-Based Practice Model-Based Approach

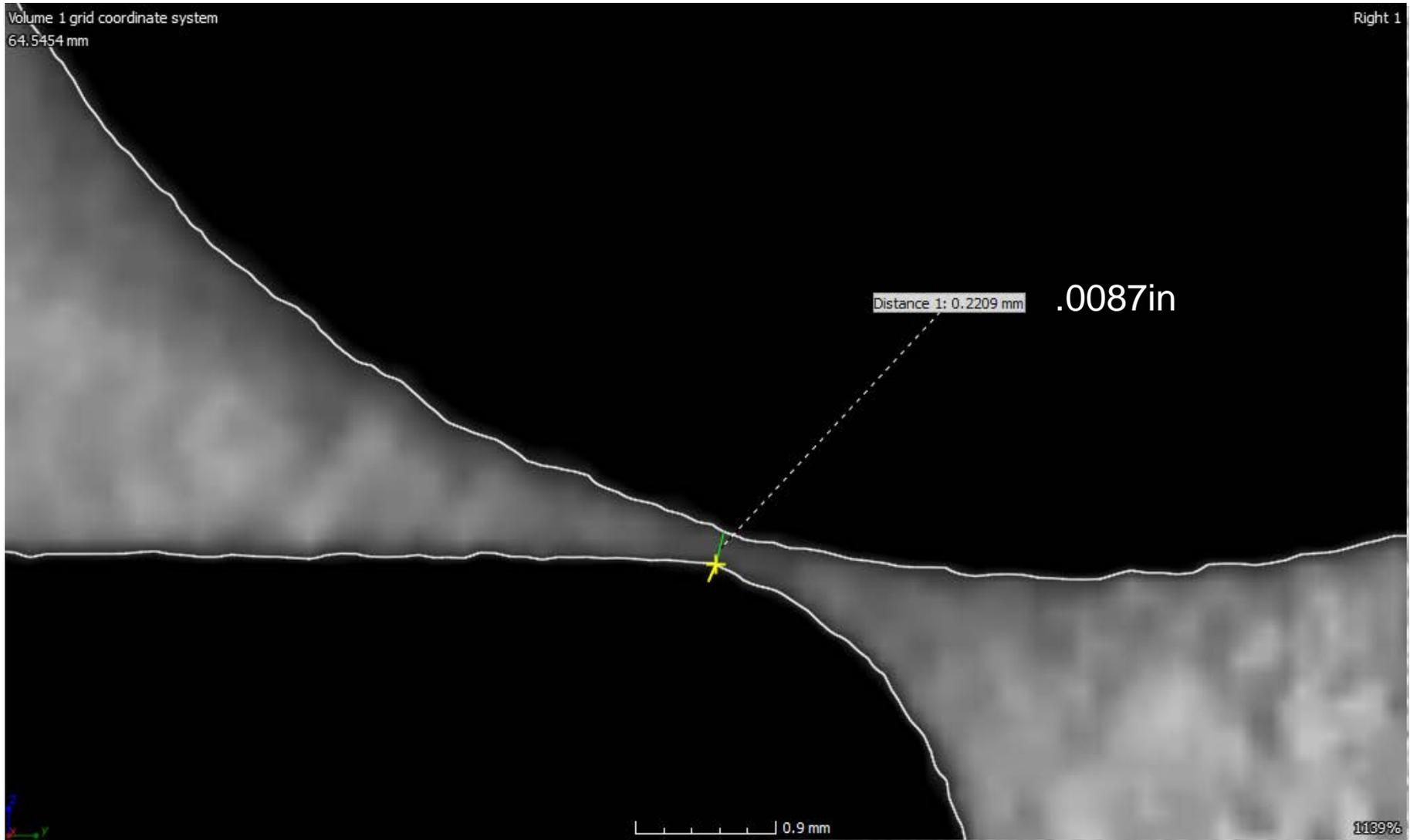
Model Validation identifies issues not easily identified in drawing reviews

Early Detection of Defects



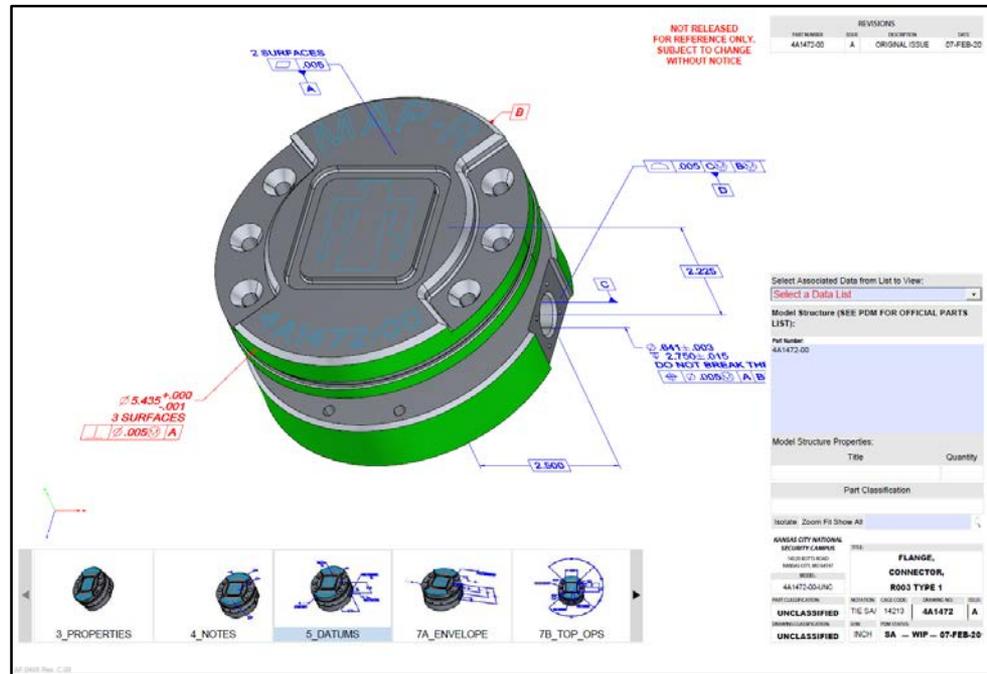
CT Scan of Interesting Area

- 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

Authorization to Baseline

Sandia PLM asmiura Submit a Service Request

CAD Document Quick Links

Products > 4A1472 FLANGE-CONNECTOR-R003 TYPE 1 > PDMLink Business Objects Recently Accessed

Actions Folder - Baselines (/Default) (14 objects)

Search in selected folder

Name ↑

- 4A1472 FLANGE-CONNECTOR-...
- Documents
- Material Lists
- Models and Drawings
- PDMLink Business Objects
- Baselines
- BOM Notes
- Change Management
- Product Templates
- Promotion Requests
- Procurement Index
- Product Structure
- Production Definitions

Folder Contents All (3 objects)

New Document New Part New Change Request New Folder Copy Add to Workspace

Number ↑	Name ↑
0000003810	4A1472-00 ISSUE A

Products > 4A1472 FLANGE-CONNECTOR-R003 TYPE 1 > PDMLink Business Objects > Baselines Recently Accessed

Managed Baseline - 0000003870 (4A1472-00 ISSUE C) Released

Details Related Objects History

Baseline Objects | Contexts

Baseline Objects All (7 objects)

Add Objects Collect Objects Remove Copy Paste Actions

Name	Number	Version	State	Last Modified
7420300-7420398_U_0_1	7420300-7420398	A.0	REL	2017-02-23 09:30 M
ALUMINUM ALLOY, 6061-T6 EXTRUDED BAR AN...	7420373-02-BULK-U...	A.1	REL	2017-02-24 09:23 M
FLANGE, CONNECTOR, R003 TYPE 1	4A1472-00-UNC	B.1	REL	2017-04-25 07:40 M
FLANGE, CONNECTOR, R003 TYPE 1	4A1472-00-UNC.ASM	C.2	REL	2017-04-28 10:39 M
ALUMINUM ALLOY, 6061-T6 EXTRUDED BAR AN...	7420373-02	A.3 (As-Designed)	REL	2017-02-24 09:23 M
FLANGE, CONNECTOR, R003 TYPE 1	4A1472-00-PRT	B.3 (As-Designed)	REL	2017-05-01 14:38 M
FLANGE, CONNECTOR, R003 TYPE 1	4A1472-00	C.1 (As-Designed)	REL	2017-05-01 14:45 M

(0 objects selected)

Contexts (0 objects)

Search | Browse

Navigator

Search | Browse

Navigator

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



CAGE CODE 14213 9925020
PAGE 1 OF 11

UNCLASSIFIED Page 2 of 2

DRAWING LIST				Drawing Information PART DEFINING MODEL
Dwg No	Iss	Loc	Drawing Title	
4A1472	00	A	SA	FLANGE, CONNECTOR, R003 TYPE 1

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 NU
9925020-00

DISTRIBUTION

Callout: PART DEFINING MODEL
(1) Insert "NON"

SPEC IS AUTHORIZED
REFER TO AER FOR

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: [redacted]
Title: [redacted]
Date: [redacted]
Derived From: N/A
Source Date: N/A

UNCLASSIFIED

MBE Level 3 – Model-Based Definition

3D Technical Data Package

- Manufacturing Authority
- PDF Container



This 3D Technical Data Package (TDP) is:
*****UNCLASSIFIED*****

The information conveyed in this TDP is to be used for its intended purposes only. Contents of this 3D TDP shall not be used in any weapon or weapon related product, associated with any current or future weapon program, nor with any trainer items or ancillary equipment associated with such a program.

This 3D TDP is intended to be used to progress the maturation of Model-Based Enterprise (MBE), specifically model-based definition, manufacturing, quality, and inspection capabilities.

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Do you agree to the terms of use?

Name	Description
4A1472_3DVI_A.pdf	3DVI PRC PDF
4A1472-00-unc_A.sat	ACIS Derivative Model
4A1472-00-unc_A.x_t	Parasolid Derivative Model
4A1472-00-unc_AP203_A.stp	STEP AP203 Derivative Model
Derivative Model Equivalency_C	Certificate of Model Equivalency
Derivative Model Equivalency_D	Certificate of Model Equivalency
Derivative Model Equivalency_S	Certificate of Model Equivalency
Intro to 3DVI's.pdf	3DVI User Guide
MNF4A1472_A_Manifest.xls	TDP Manifest

3D TECHNICAL DATA PACKAGE COVERSHEET (v0.4b)

14520 Botts Road
Kansas City, MO 64147

TDP ID: TDP4A1472 TDP REV: A CAGE CODE: 14061 TDP LEVEL: Conceptual Development Production

PRODUCT NUMBER: 4A1472 PRODUCT NAME: FLANGE, CONNECTOR, R003 TYPE 1 BASELINE REV/ISSUE: B DATE PREPARED: 4/18/17

TDP PURPOSE: Contains the models, documents, reports, and certificates that supports the fabrication and acceptance of product for the Model Authorized Product Realization (MAP-R) project. CLASSIFICATION: Unclassified EXPORT CONTROL: N/A

1. DELIVERABLE DATA PRODUCTS (✓ all that apply and complete as applicable)

TYPE	FORM	TYPE	CERTIFIED
<input checked="" type="checkbox"/> 3D Design Models	<input type="checkbox"/> Native	PTC Creo SolidWorks Siemens NX Other (Specify)	<input type="checkbox"/>
	<input checked="" type="checkbox"/> Derivative	<input checked="" type="checkbox"/> STEP (.stp) AP203 <input checked="" type="checkbox"/> Parasolid (.x_t) <input type="checkbox"/> Stereolithography (.stl) <input type="checkbox"/> Quality Information Framework (.qif) <input type="checkbox"/> Additive Manufacturing File (.amf) <input checked="" type="checkbox"/> ACIS (.sat) <input type="checkbox"/> Other (Specify)	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/> 3D Interactive Viewable	<input checked="" type="checkbox"/> 3D Annotated PRC PDF (ISO 14739)	<input type="checkbox"/> Other (Specify)	<input type="checkbox"/>
<input type="checkbox"/> 2D Static Drawing	PTC Creo SolidWorks DOCUMENT PDF (ISO 32000 BASIC)	Siemens NX Other (Specify)	TIFF
<input type="checkbox"/> SUPPLEMENTAL DATA	<input type="checkbox"/> Analysis	CAD/CAM FEA (Specify)	FBTol Other (Specify)
	<input type="checkbox"/> Associated Lists	Bill of Materials (BoM) Bill of Characteristics (BoC)	Other (Specify)
	<input type="checkbox"/> References	Internal References 9900000 Other (Specify)	9919100 Applicable References TBD Other (Specify)
	<input type="checkbox"/> Viewables	UNIVERSAL 3D PDF (ECMA-363) CreoView eDrawings	MBDVideo Photo Other (Specify)

2. OTHER TAILORING (attach additional sheets as necessary)

3. 3D VIEWABLE (Click on area to manipulate)

Printed / downloaded copies of this document are uncontrolled for use.

3D Viewable Navigation
• Rotate - Left Click • Pan - Ctrl+Left Click • Zoom - Mouse Wheel

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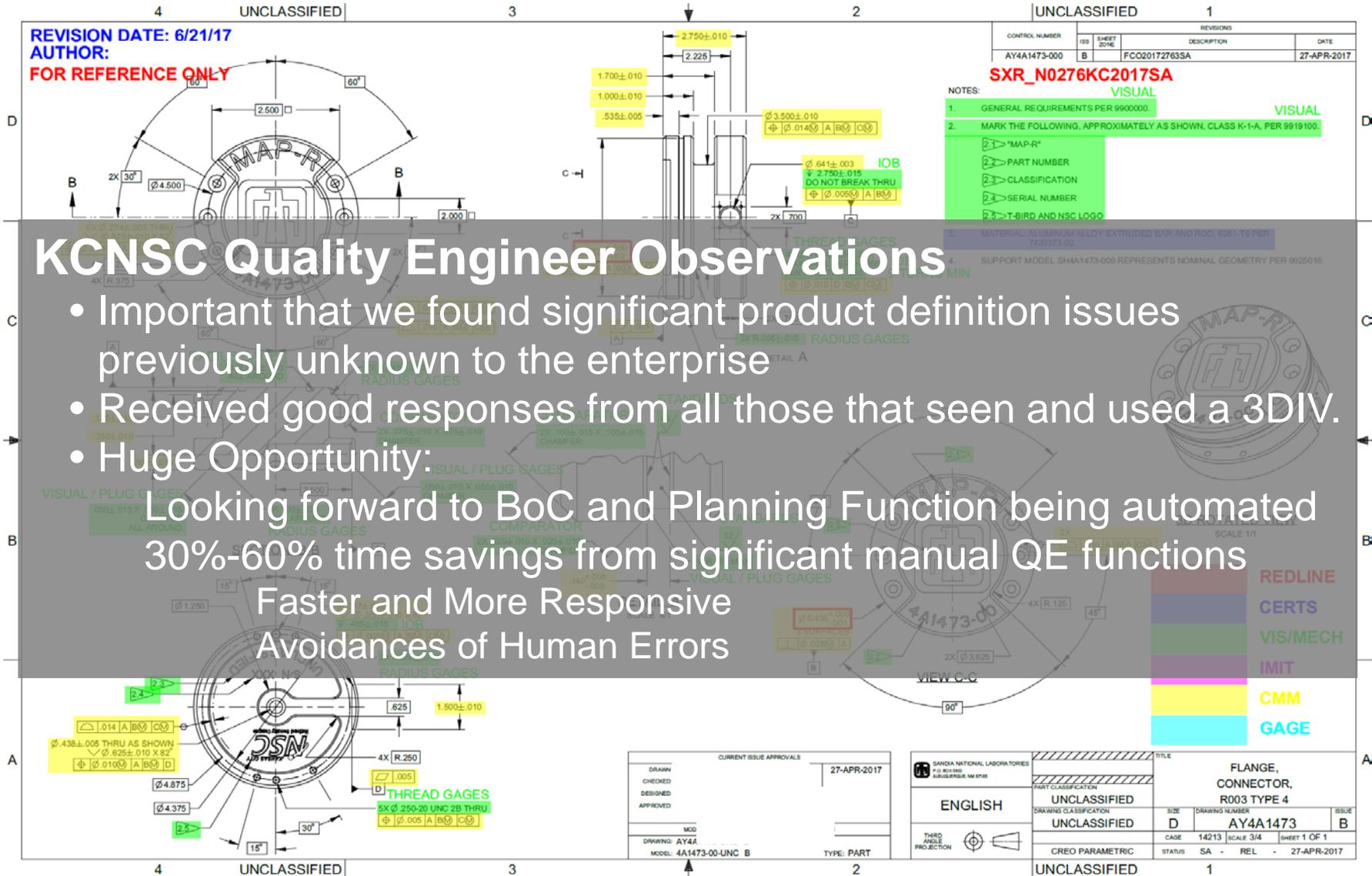
Mechanical Piece-Part

KCNSC's 3D Manufacturing Technical Data Package Example!

Drawing Based – NC Programming



KCNSC QE's Inspection Planning



KCNSC Quality Engineer Observations

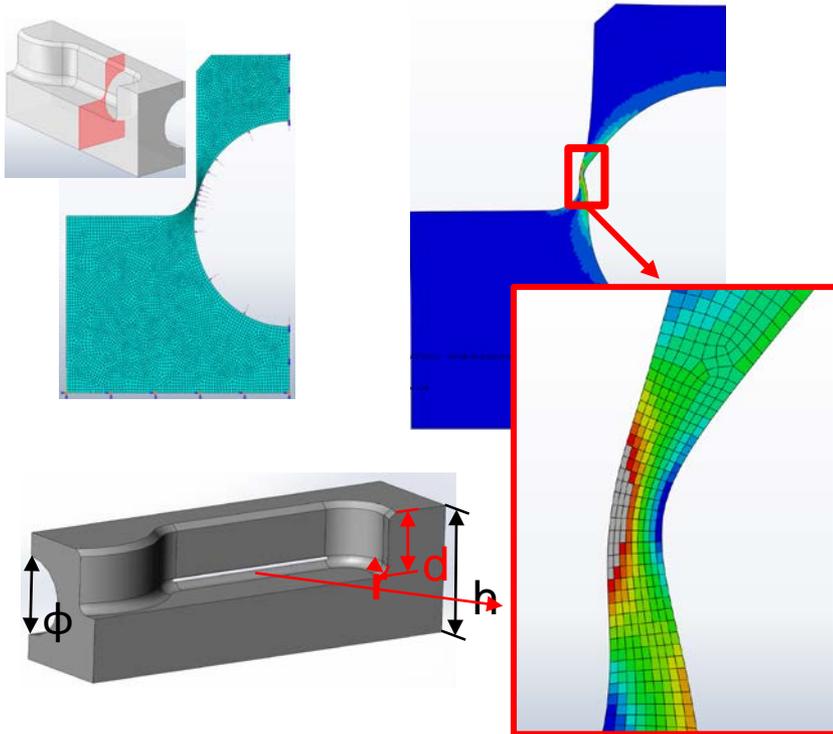
- Important that we found significant product definition issues previously unknown to the enterprise
- Received good responses from all those that seen and used a 3DIV.
- Huge Opportunity:

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

Perform Engineering Analysis

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

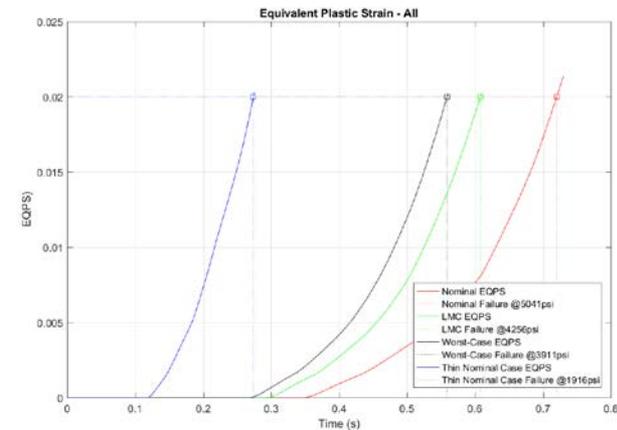
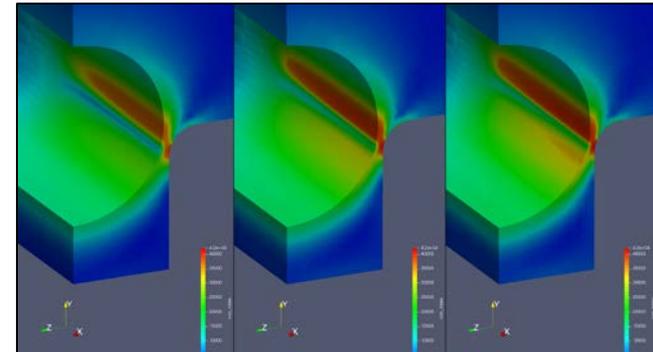


Time Spent: 50 hrs.

Time Spent on Model Prep: 31.5 hrs.

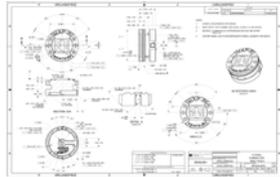
Time Spent Analyzing: 18.5 hrs.

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

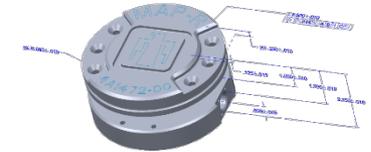
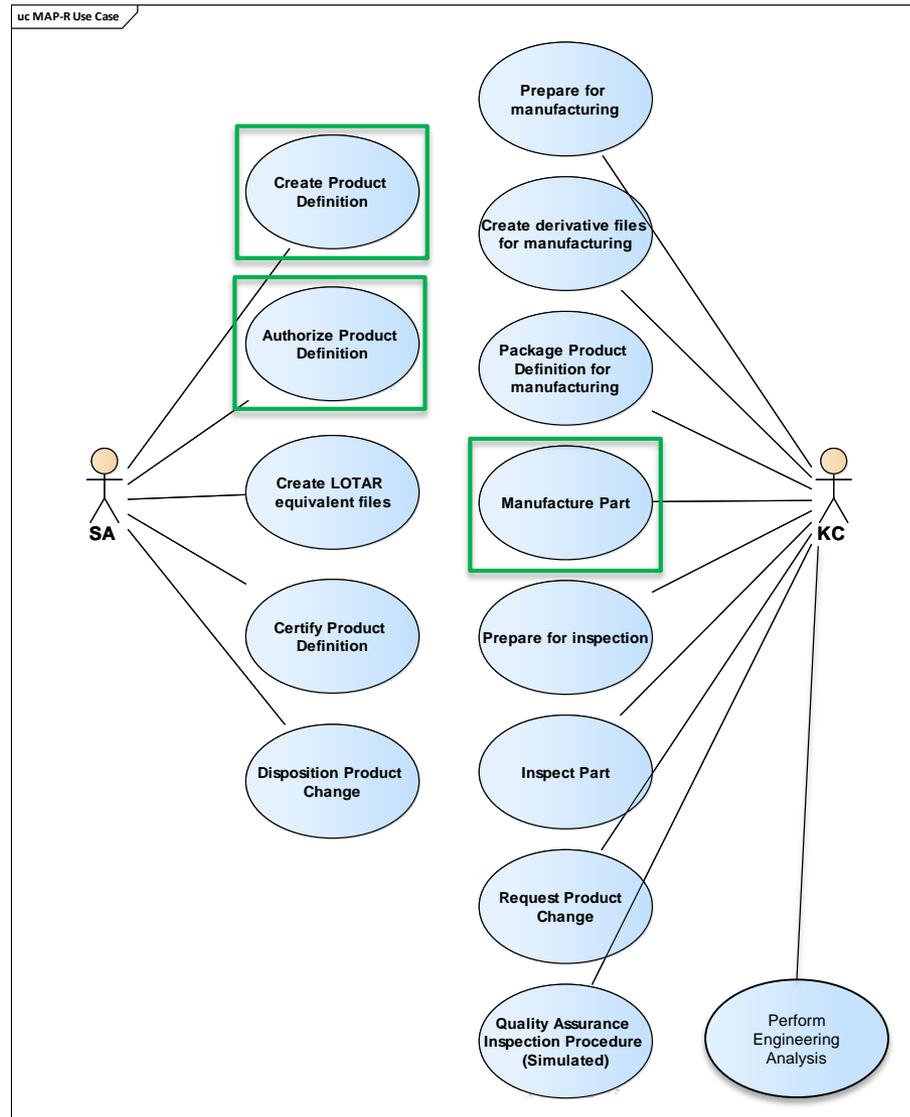


Use *ACIS* model from 3DTDP
Time Spent: 12.2 hrs.

MAP-R Project Status



Drawing-Based
All Use Cases
Completed



Model-Based
All Use Cases
Completed

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.

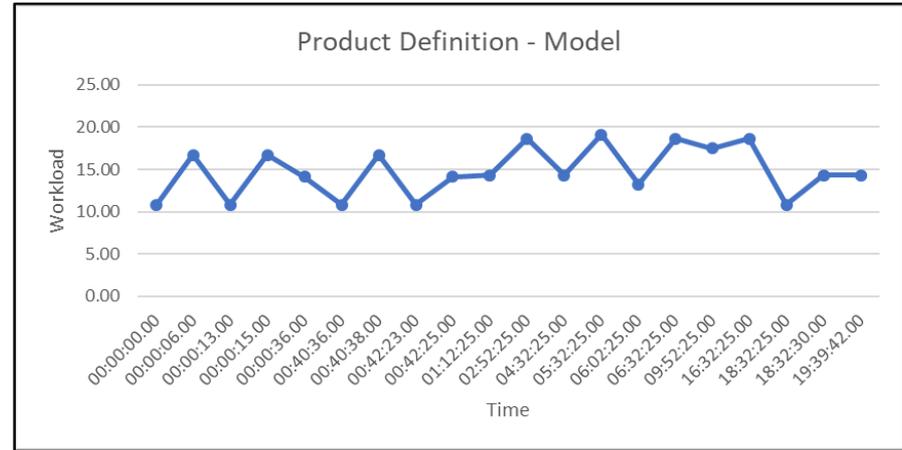
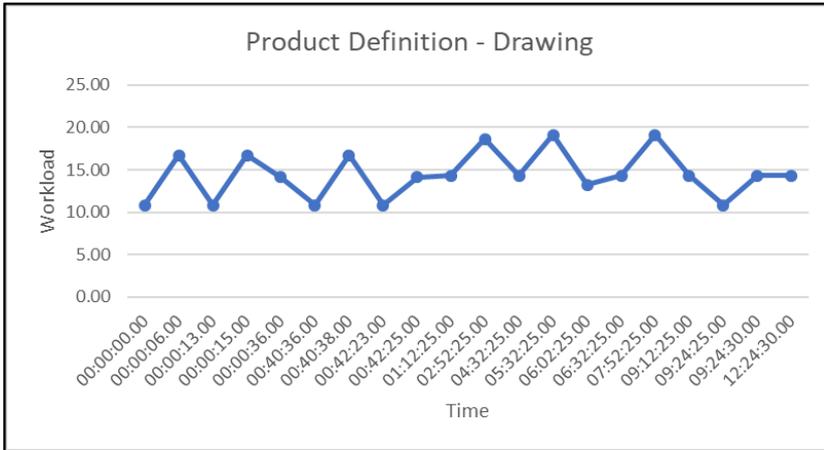
■ Workload Levels:

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

Create Product Definition



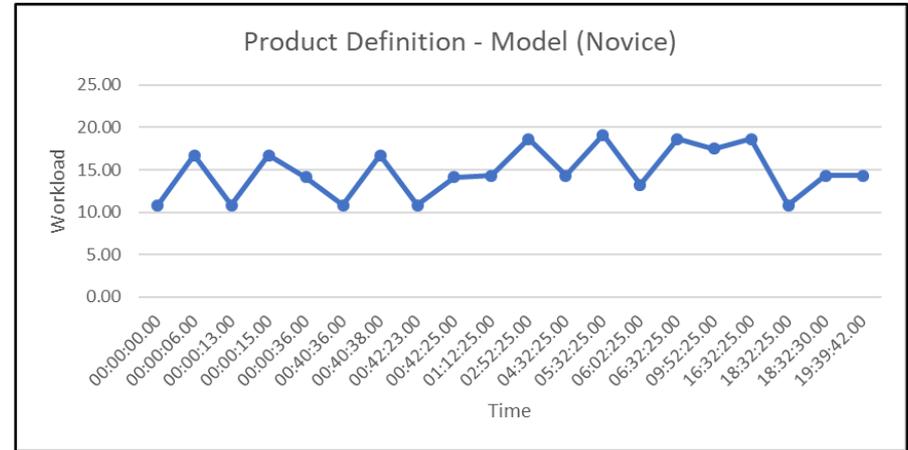
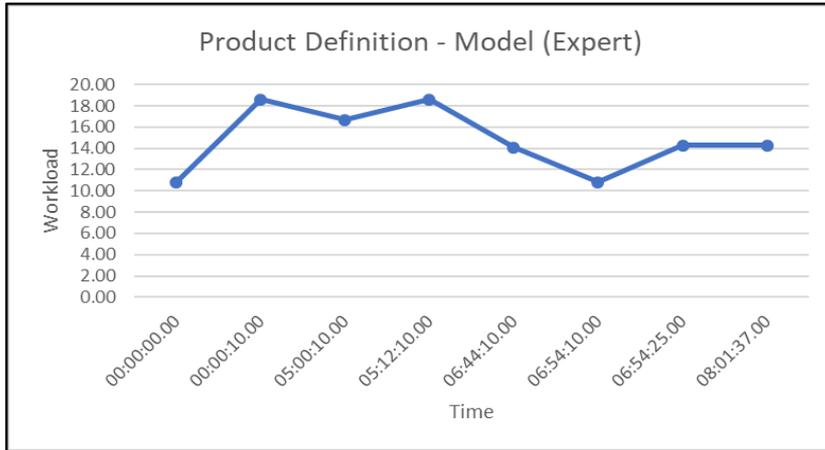
Time at Load		
Low 0-14	Med 15-18	High 19-21
8:52:17	0:02:13	3:30:00

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

Total Time 12:24:05

Total Time 19:39:42

Create Product Definition (Novice vs. Expert)



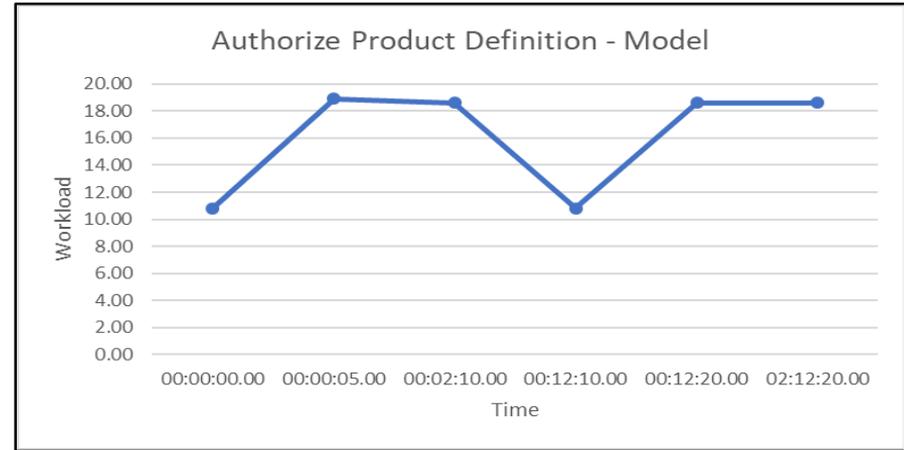
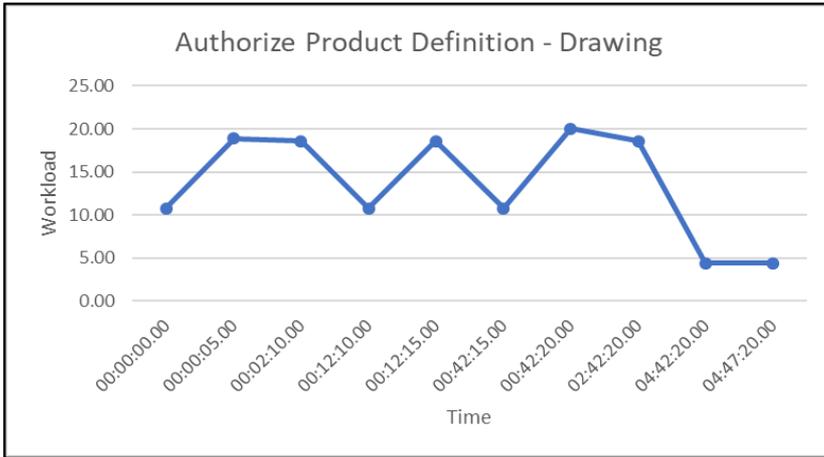
Time at Load		
Low 0-14	Med 15-18	High 19-21
1:17:37	0:12:00	6:32:00

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

Total Time 8:01:37

Total Time 19:39:42

Authorize Product Definition



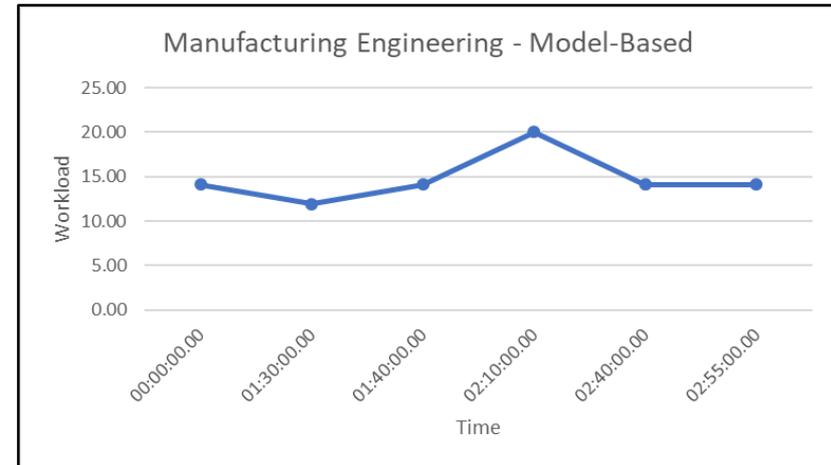
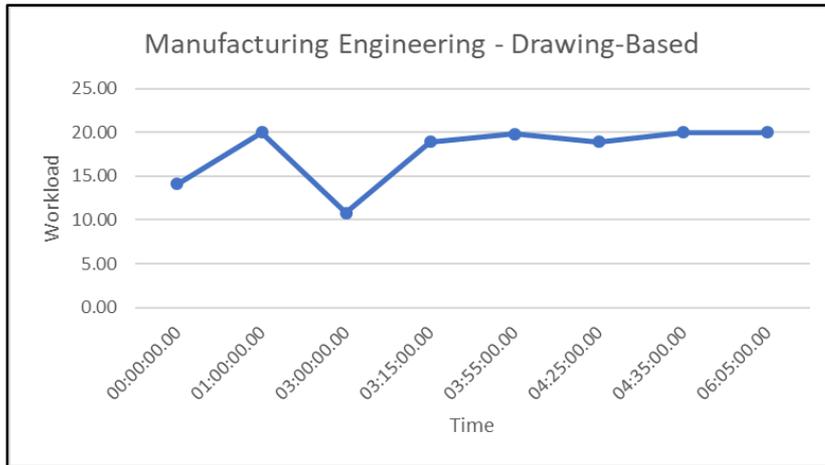
Time at Load		
Low 0-14	Med 15-18	High 19-21
0:05:15	0:00:00	4:42:05

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

Total Time 4:47:20

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