

# STEP by Step to MBE

Rosemary Astheimer

*Mechanical Engineer - NIST*

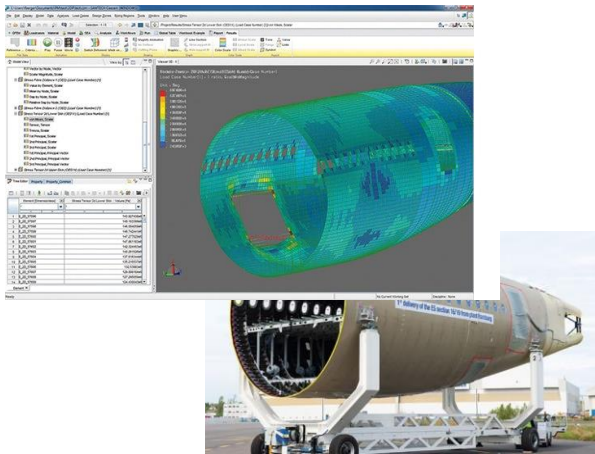
*Smart Connected Manufacturing Systems*

*rla3@nist.gov*

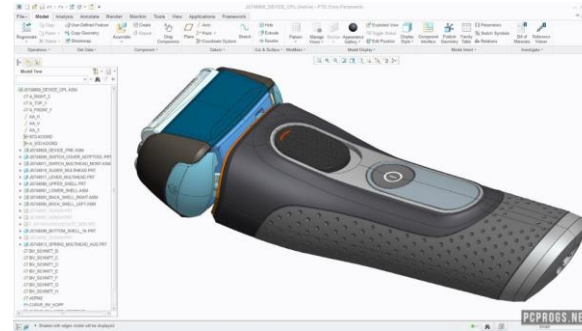
# GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023



## Focus on Computer Aided-Design (CAD)



FiberSIM Applications Engineer – VISTAGY



Product Manager – Creo Data Exchange

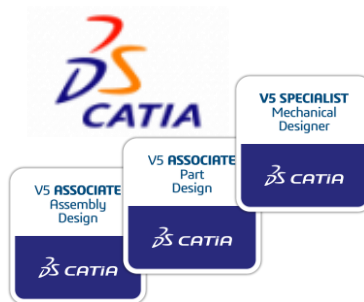
# PURDUE

UNIVERSITY

CAD, MBD, PLM & PDM



PLM Software



# NIST AT A GLANCE

National Institute of Standards and Technology



**3,400+**  
FEDERAL  
EMPLOYEES



**5**  
NOBEL PRIZES



**2 CAMPUSES**  
GAITHERSBURG, MD [HQ]  
BOULDER, CO



**3,500+**  
ASSOCIATES



**10**  
COLLABORATIVE  
INSTITUTES



**400+**  
BUSINESSES USING  
NIST FACILITIES



NATIONAL OFFICE  
COORDINATING 16  
MANUFACTURING  
INSTITUTES



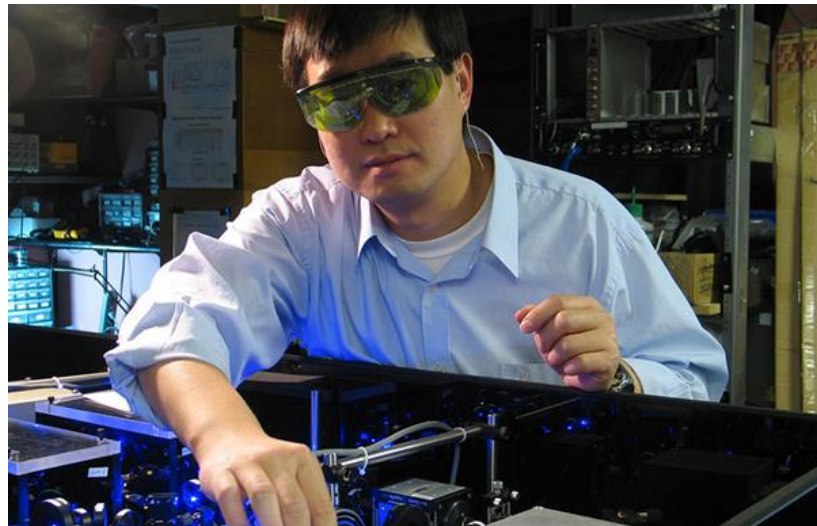
**51**  
MANUFACTURING  
EXTENSION  
PARTNERSHIP CENTERS



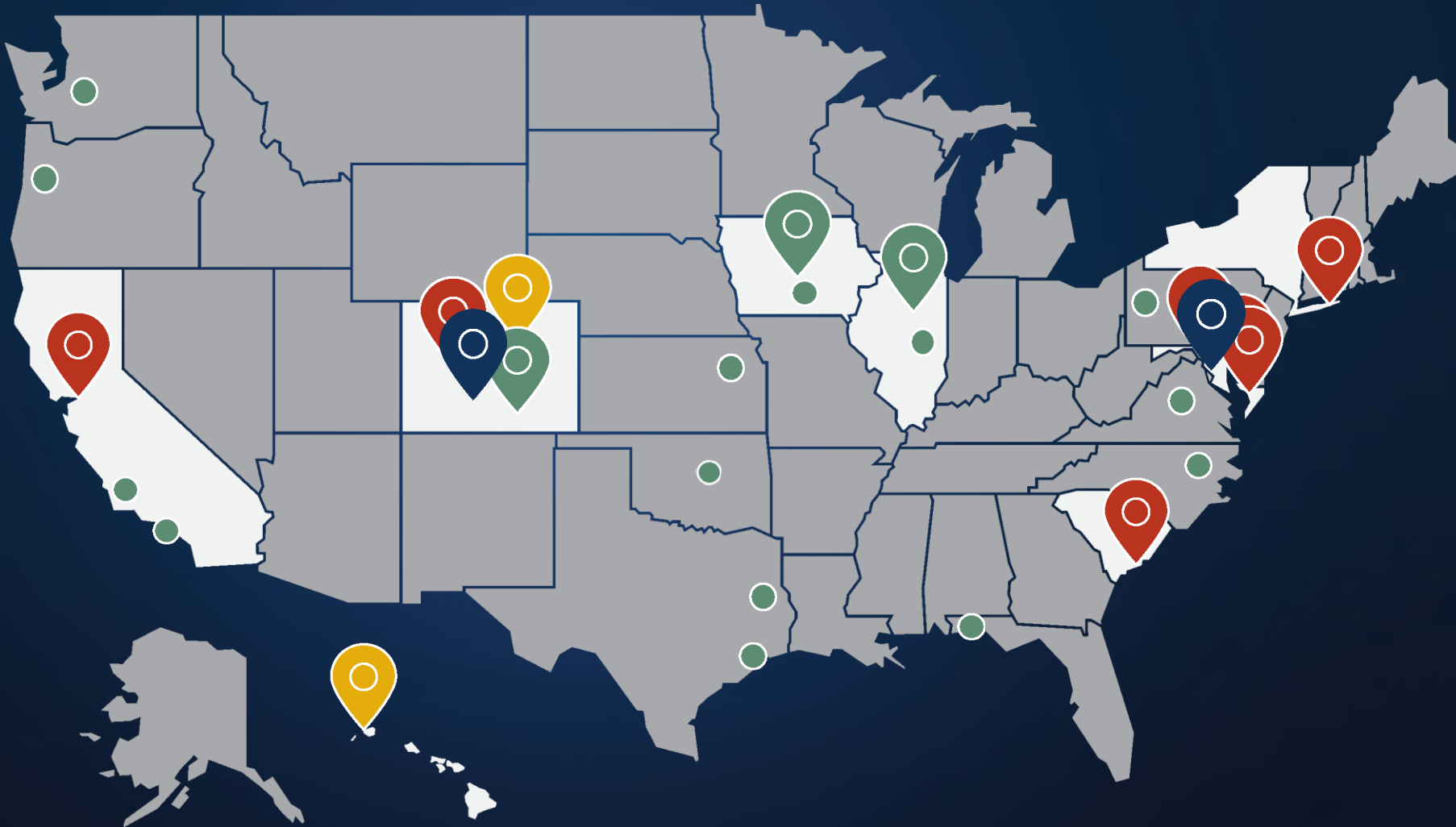
U.S. BALDRIGE  
PERFORMANCE  
EXCELLENCE  
PROGRAM



To **promote U.S. innovation and industrial competitiveness** by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life



# NIST Joint Institute and Center Locations



## NIST Campuses

- Gaithersburg, MD
- Boulder, CO



## Joint Institutes and Centers

- National Cybersecurity Center of Excellence
- Institute for Bioscience & Biotechnology Research
- Joint Institute for Quantum Computer Science
- Joint Quantum Institute
- JILA
- Hollings Marine Laboratory
- Brookhaven National Laboratory
- Joint Initiative for Metrology in Biology



## Atomic Clock Signal Stations

- NIST Kauai HI WWVH
- NIST Ft. Collins CO WWV



## NIST Centers of Excellence

- Forensic Science
- Disaster Resilience
- Advanced Materials

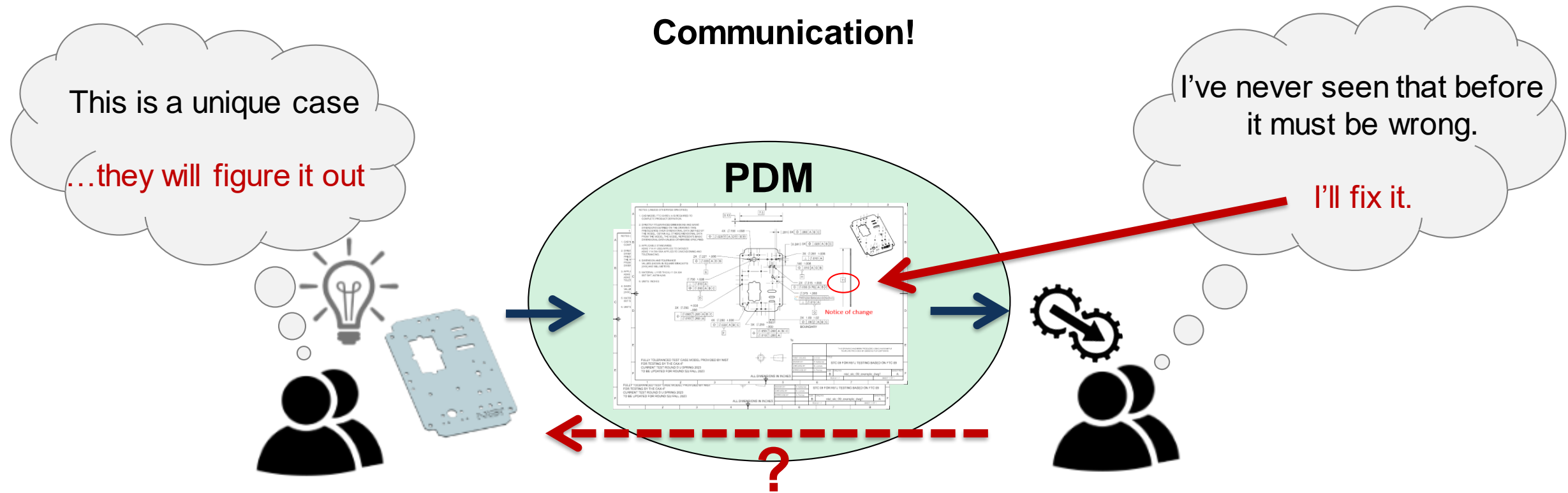


# Why are we here?



# The Challenge

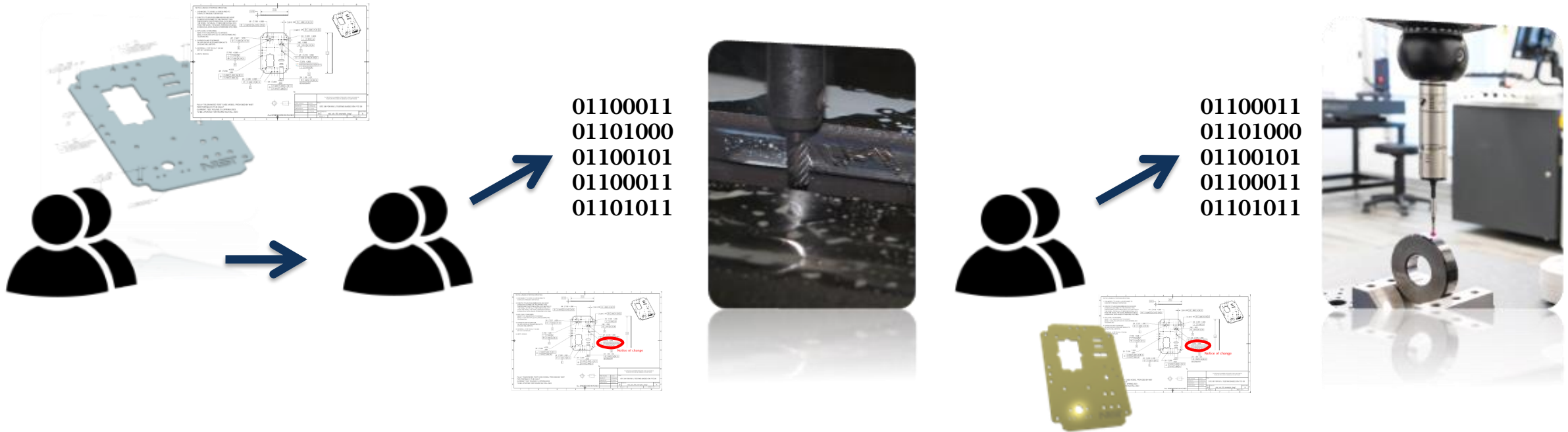
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# Human to human, to machine, to human, to machine

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## Humans make **mistakes!**

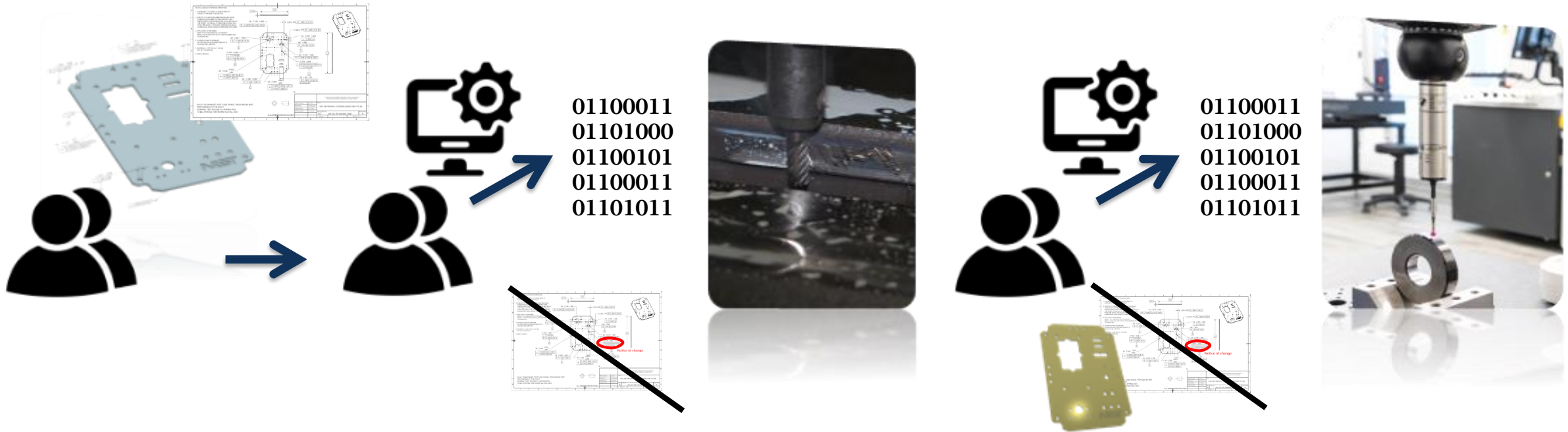




# Machine to machine, to machine

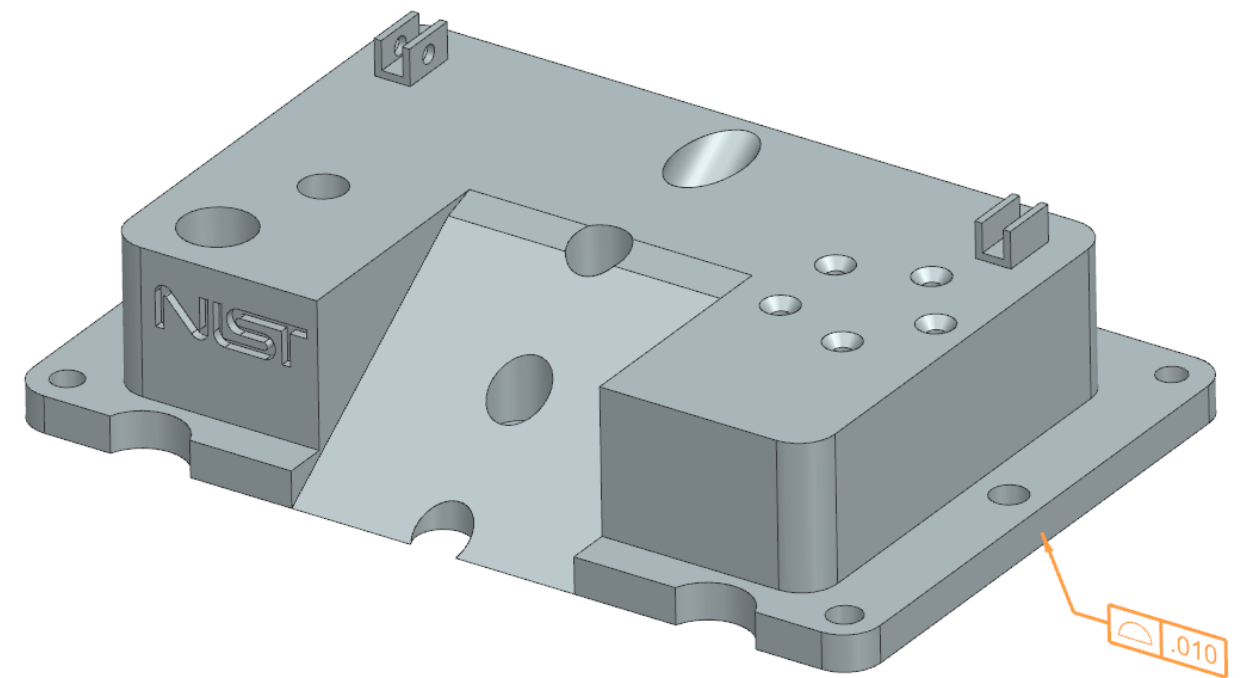
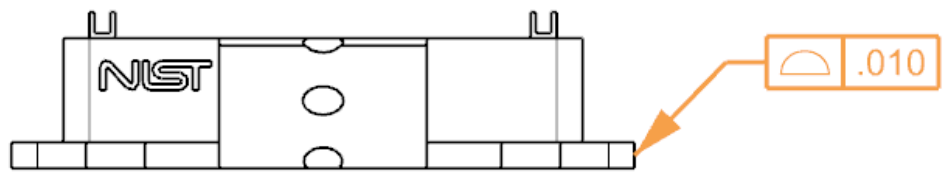
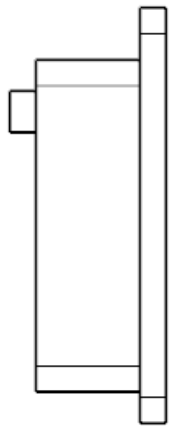
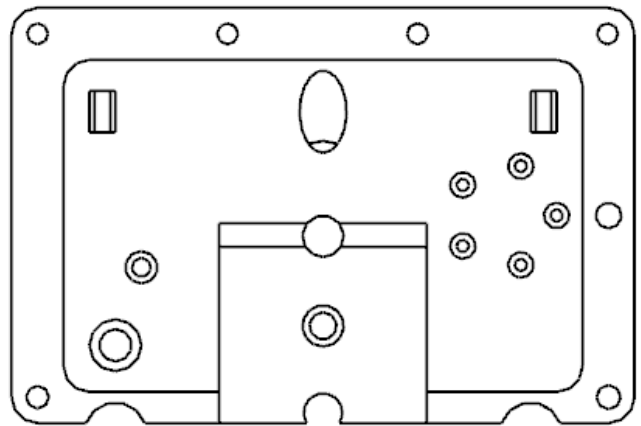
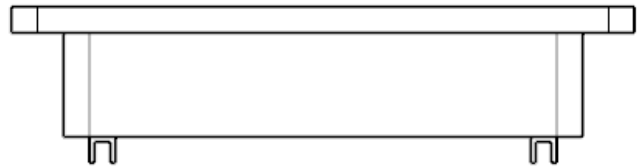
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## Humans look for mistakes



# From 2D to 3D

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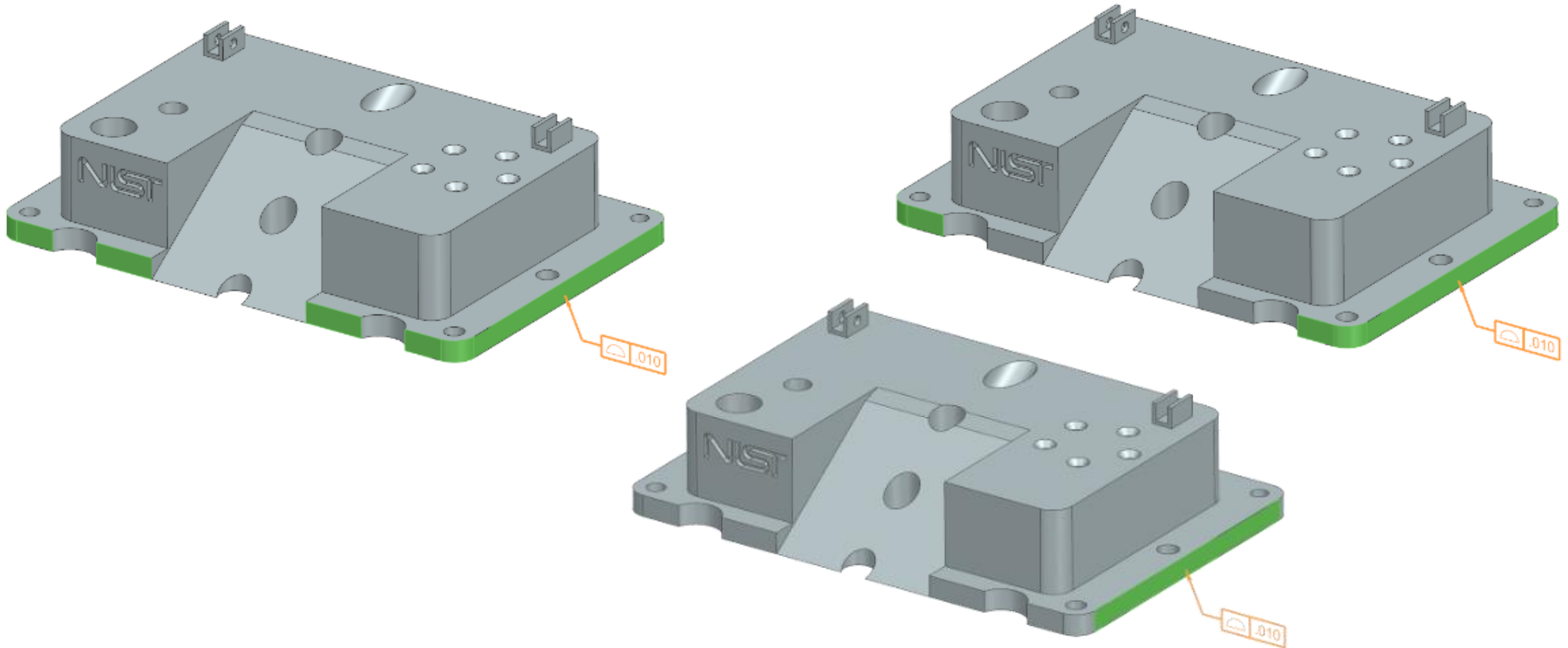
# Let's do it!

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# This or that... or that?

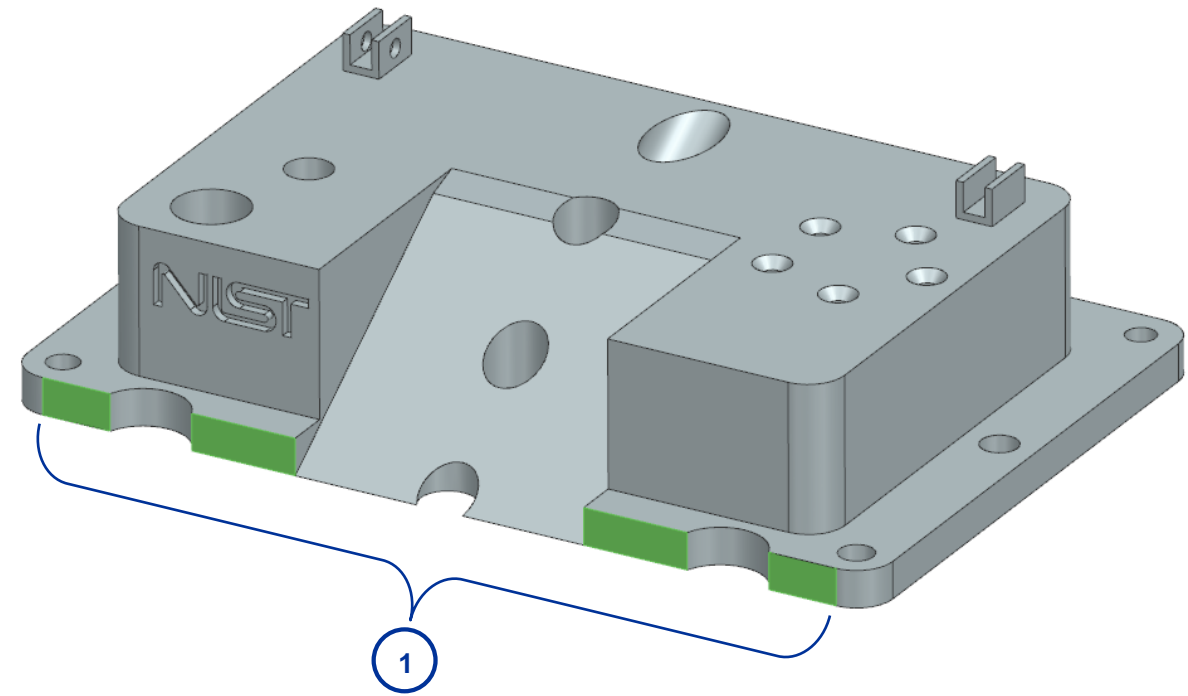
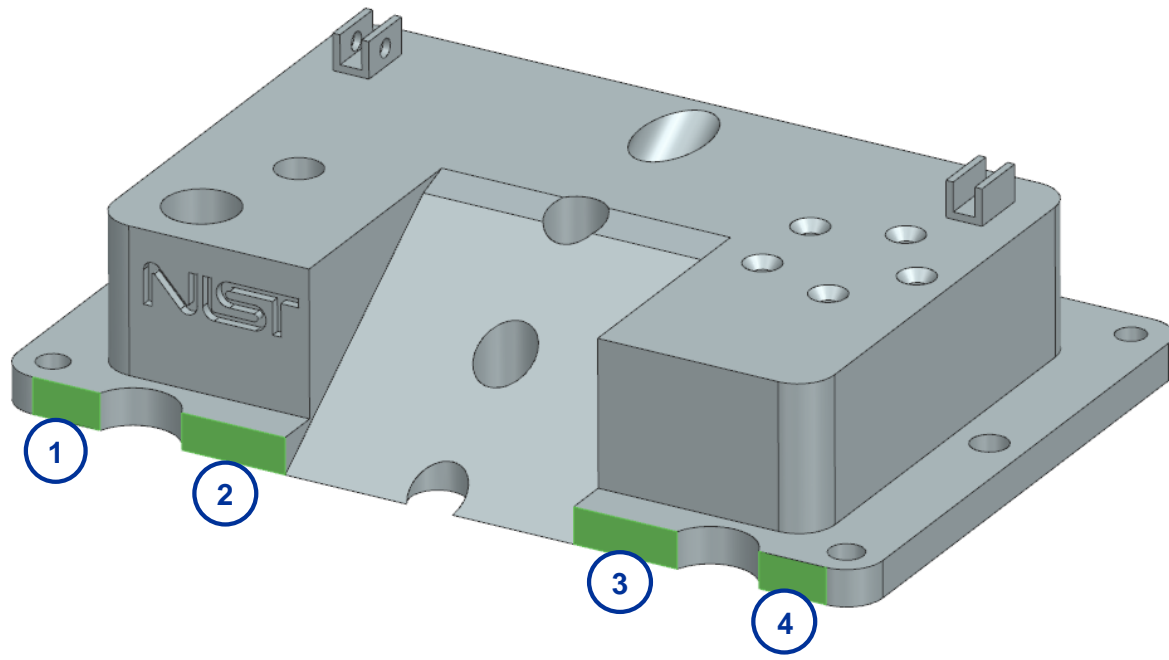
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# Different systems, different representations

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# How do we handle this?

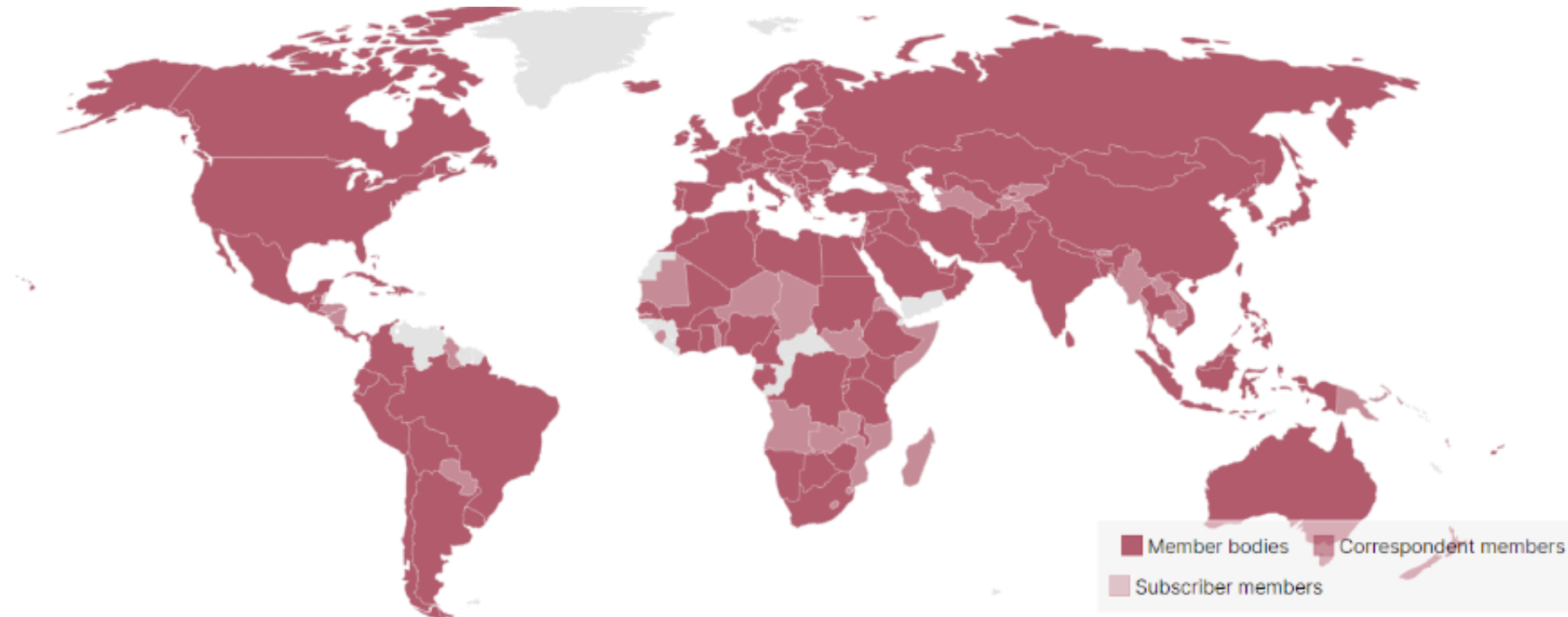
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# ISO - International Organization for Standardization

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- **Independent, non-governmental, international organization**
- **169 member nations**
- **Volunteers share knowledge to develop standards**



# ISO 10303 – Product Data Standards

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## Application Protocols

- 10303-209:2014 Multidisciplinary **analysis** and design
- 10303-210:2021 **Electronic** assembly interconnect and packaging design
- 10303-233:2012 **Systems** Engineering
- 10303-235:2019 Engineering properties and **materials** information
- 10303-238:2022 Model-based integrated **manufacturing**
- 10303-239:2012 Product **life cycle** support
- 10303-242:2022 Managed **model-based 3D engineering**
- 10303-243:2021 For modeling and **simulation** information in a collaborative systems engineering context (MoSSEC)



# MBx-IF (Model-Based x Interoperability Forum)

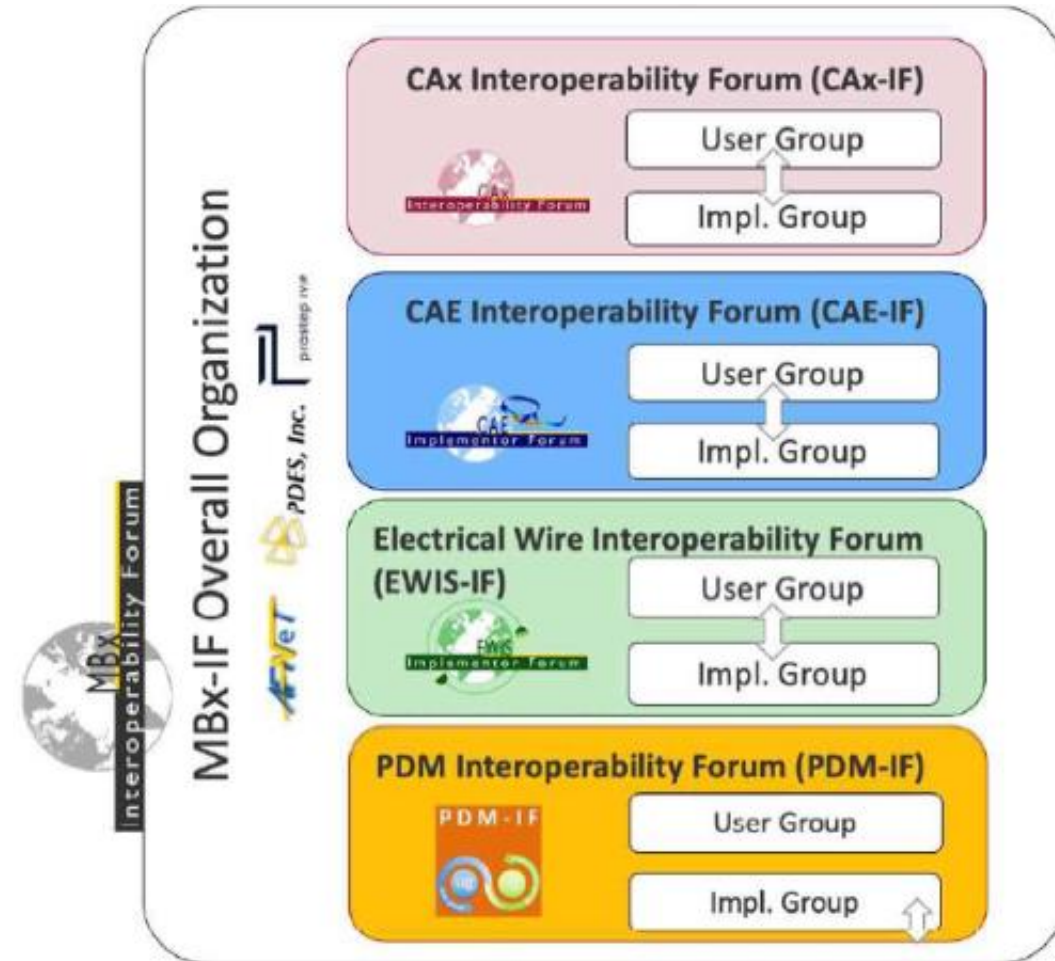
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## AFNeT, PDES, Inc. & prostep ivip.

- Accelerate MBx translator development
- Ensure users' requirements are satisfied

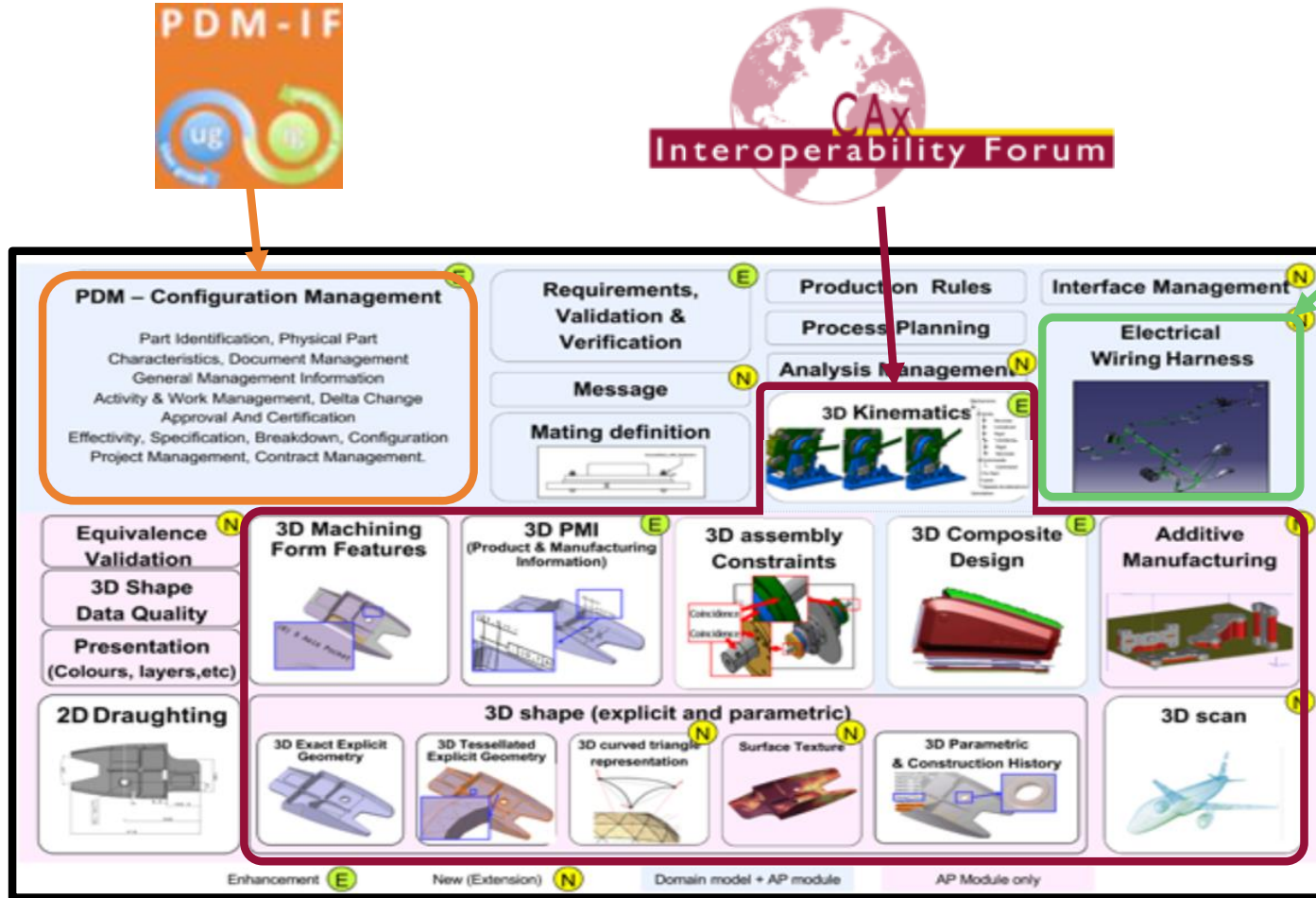
## Test standards implementations to

- Improve product quality
- Reduce time to market
- Reduce manufacturing costs
- Ease implementation of new technologies

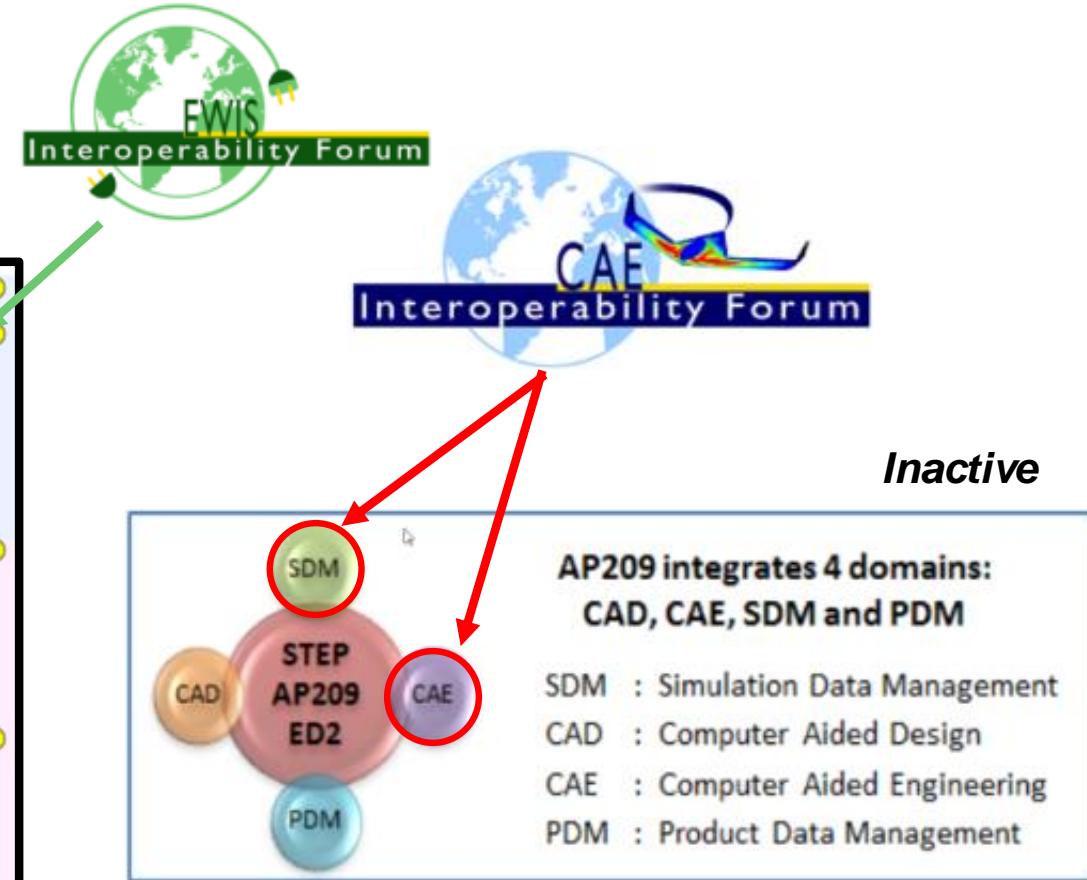


# Relationship of Interoperability Forums to STEP

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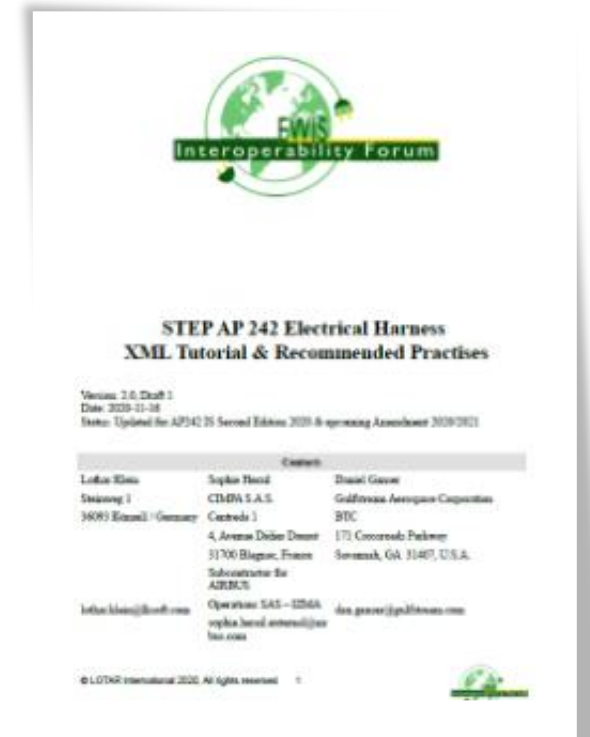
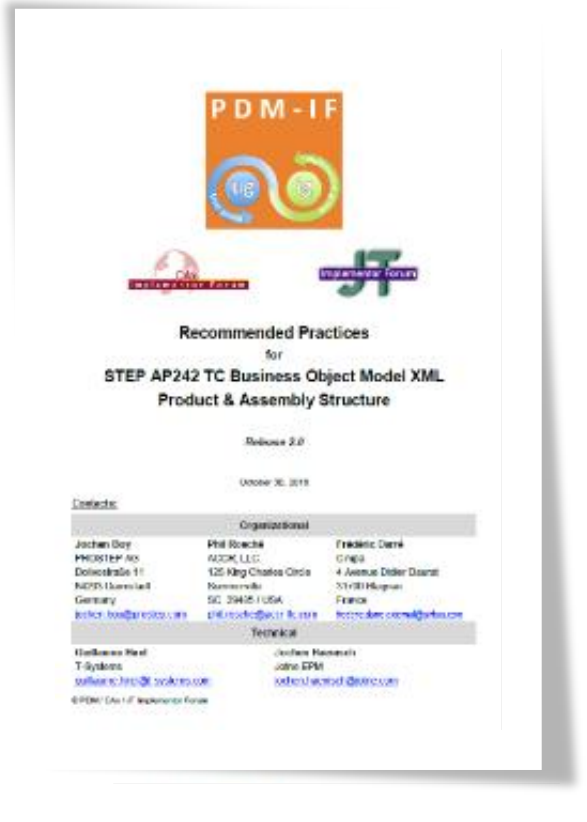
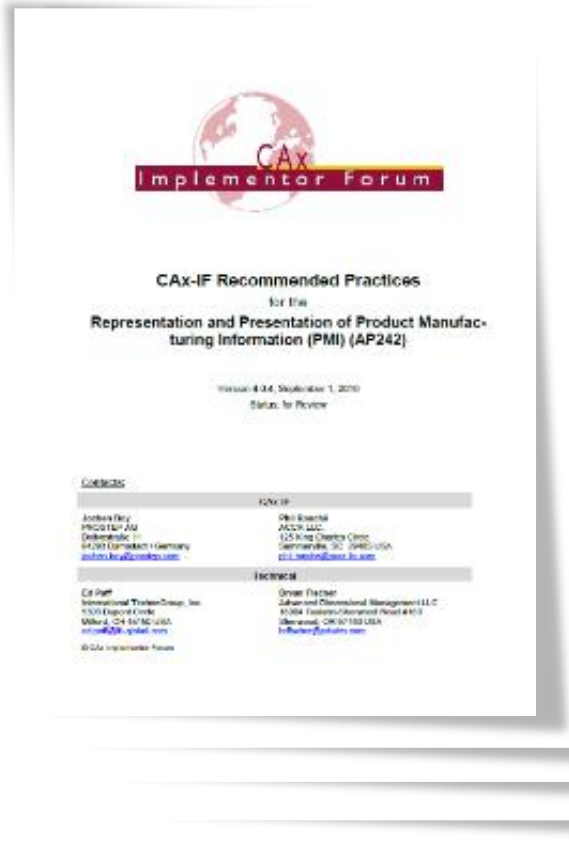


Overview of the scope of AP242 edition 3



AP209 includes the AP242 module, taking benefits of the STEP modular architecture

## Fundamental for testing implementations in various domains



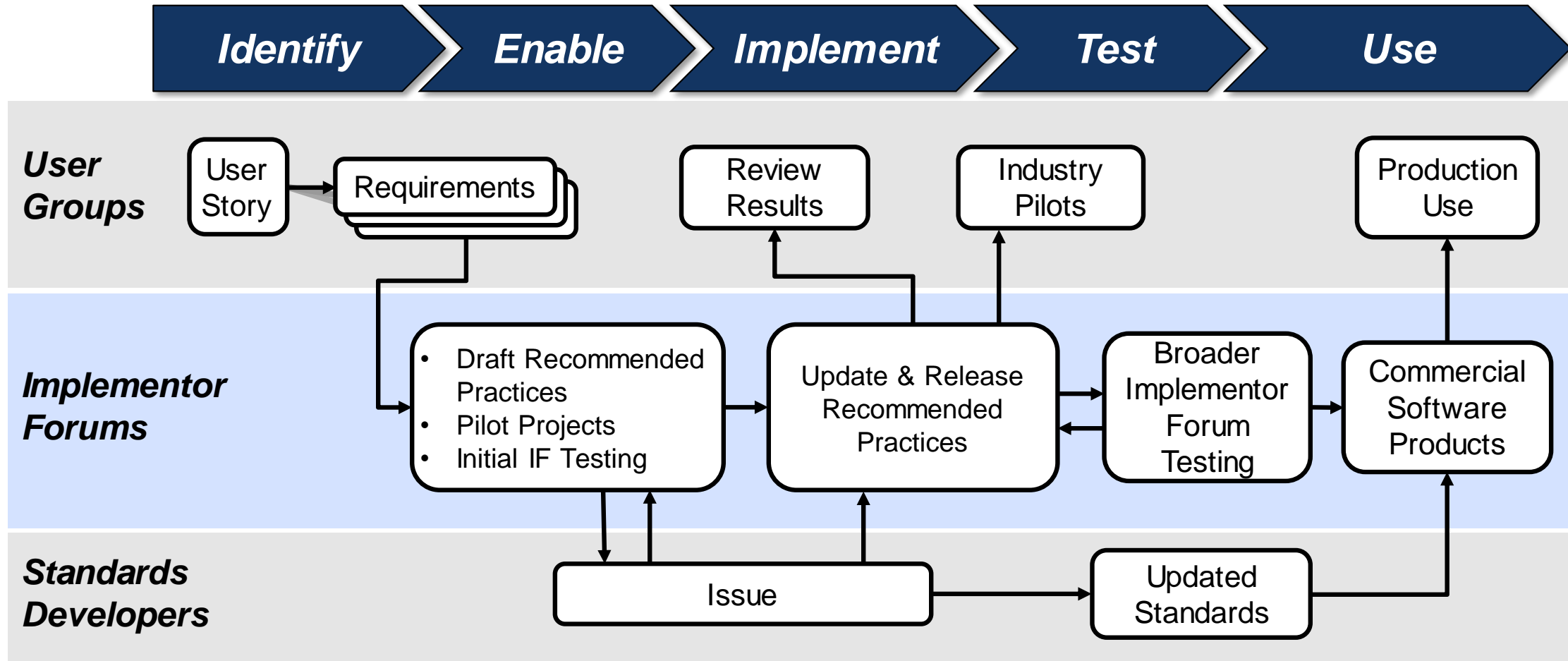
[https://www.mbx-if.org/cax/cax\\_recommPractice.php](https://www.mbx-if.org/cax/cax_recommPractice.php)

<http://www.pdm-if.org/recommended-practices1>

[https://www.mbx-if.de/ewis/ewis\\_recommPractice.php](https://www.mbx-if.de/ewis/ewis_recommPractice.php)

# MBx-IF role between Users, Implementors, and Developers

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# CAX-IF (Computer Aided x Interoperability Forum)

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- NIST developed models
- Translated by and exchanged between vendors

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Communications Technology Laboratory / Smart Connected Systems Division

**SMART CONNECTED MANUFACTURING SYSTEMS GROUP**

**Download Free CAD Models, STEP Files, and Test Results**

MBE PMI Validation and Conformance Testing Project

Download Free CAD Models, STEP Files, and Test Results

**Types of Test Cases**

The **FTC** and **CTC** were part of the MBE PMI Validation and Conformance Testing Project that concluded in 2015. The FTC and CTC are not intended to represent best practice in how to apply GD&T (geometric dimensioning and tolerancing) to a part. Simpler GD&T strategies could have been used. The test cases are intended to be valid presentations of GD&T defined in the [ASME Y14 tolerancing standards](#), some of which may not be commonly used.

The **STC** are modified versions of the FTC that remove some of the more complicated and less commonly used PMI, including all datum targets. The STC were developed in 2023.

These test cases are used by the [CAX-IF](#) to test implementations of STEP AP242 in CAD software.

**Fully-Toleranced Test Cases (FTC)**

- [FTC Definitions](#) include sample STEP AP203 files of model geometry only and explanations of all PMI
- [STEP AP242 and AP203 files](#) for each FTC, many with graphical and semantic PMI
- FTC 07, 08, 09, and 10 fit together in an [assembly](#)

FTC-06    FTC-07    FTC-08    FTC-09    FTC-10    FTC-11

The MBx Interoperability Forum is significantly improving STEP translator quality and decreasing translator time-to-market

**STEP PROCESSORS CURRENTLY BEING TESTED IN THE CAX-IF**

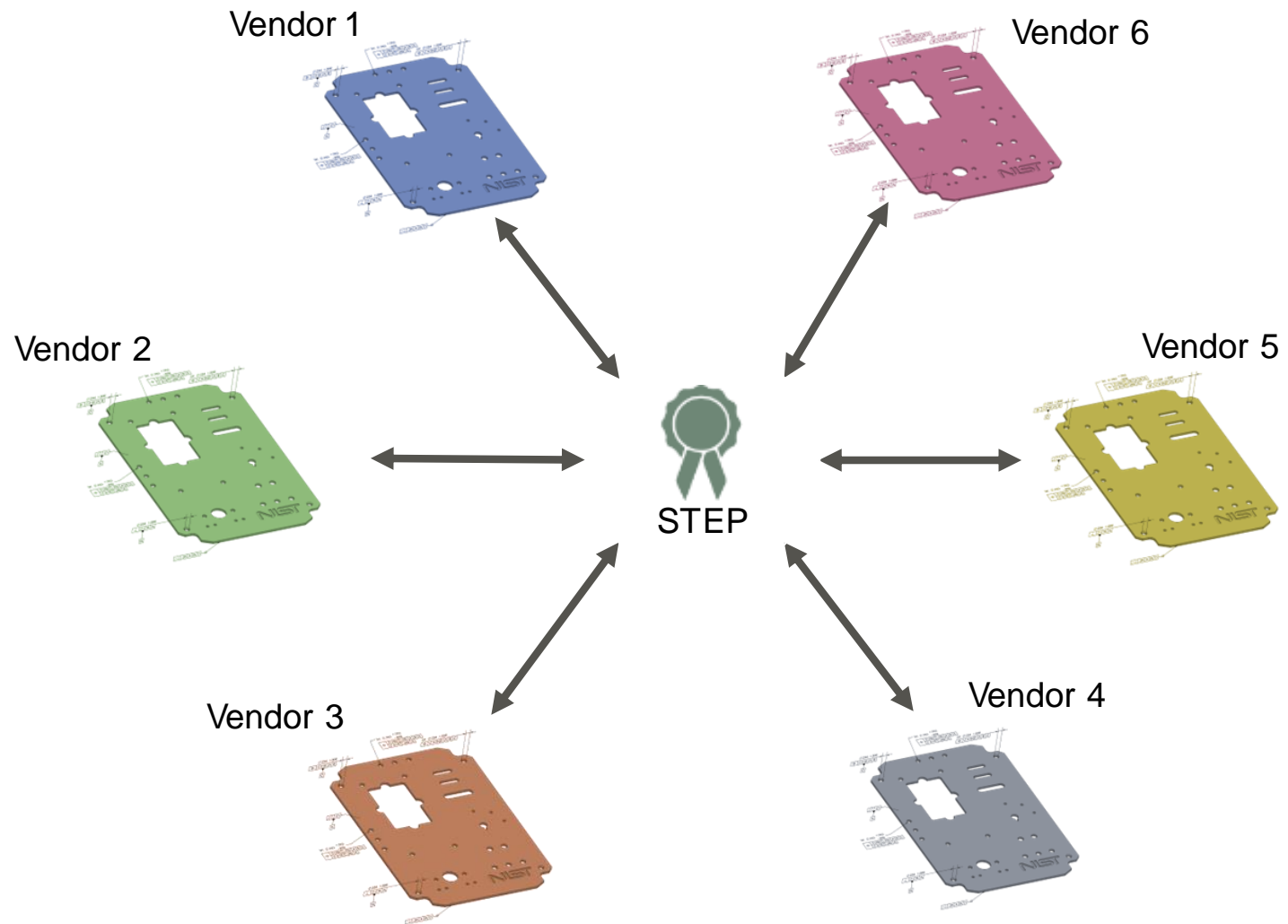
The following list gives an overview about the vendors and systems who actively participate in the CAX-IF testing and technical meetings. Previous participants are listed below.

Vendor	Product
Autodesk	Inventor
CT Core Technologie	3D_Evolution (*)
Dassault Systèmes	3DEXPERIENCE CATIA V5
Datakit	OpenCascade CrossCAD (*)
Elysium	3DxSUITE (*) CADdoctor (*)
International TechneGroup	CADIQ (*) CADfix (*)
Kubotek Kosmos	3D Framework KeyCreator K-Compare (Validate & Revision) K-Display (View & Convert)
Siemens PLM	NX
Open Design Alliance	Open STEP Viewer
Techsoft 3D	HOOPS Exchange (*)

(\*): Multi-CAD Processor supporting all major CAD systems

# Testing of STEP implementation

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# NIST STEP File Analyzer (SFA) and Viewer

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- **Analyzes STEP files**
  - Conformance to CAx-IF Recommended Practices
  - Checks for basic file format errors
- **Generates spreadsheet**
  - All entities and attributes
  - Product Manufacturing Information (PMI)
- **Browser based viewer**
  - Geometry, graphical PMI, saved view viewpoints, section view
  - Finite element analysis model, cloud of points validation property, point clouds
- **Bill of Materials of parts and assemblies**

<https://go.usa.gov/yccx>

# NIST STEP File Analyzer & Viewer User Interface

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STEP File Analyzer and Viewer 5.0

File Websites Examples Help

Status Generate More

```
datum_feature
datum_reference_compartment
datum_reference_element
datum_system
dimensional_characteristic_representation
dimensional_characteristic_representation
flatness_tolerance
(geometric_tolerance_with_datum_reference)(geometric_toleranc
(geometric_tolerance_with_datum_reference)(position_toleranc
(geometric_tolerance_with_datum_reference)(surface_profile
(geometric_tolerance_with_defined_area_unit)(straightnes
(geometric_tolerance_with_defined_area_unit)(straightnes
perpendicularity_tolerance
symmetry_tolerance
tessellated_annotation_occurrence
property_definition
composite_group_shape_aspect
shape_aspect
value_format_type_qualifier
Adding PMI Representation Coverage worksheet
Expected PMI: 95%
Processing time: 22.0 seconds
```

Generate Spreadsheet and View

STEP File Analyzer and Viewer 5.0

File Websites Examples Help

Status Generate More

**Generate**

Spreadsheet  CSV Files  View  Part Only  BOM  Syntax Checking  Log File  Open Output

**Process**

Common  Measure  Geometry  Kinematics  Quality  All

Presentation  Shape Aspect  Coordinates  Composites  Constraint  Reset

Representation  Tolerance  Features  AP242

User-Defined List:

**Analyzer**

Validation Properties

AP242 PMI Representation (Semantic PMI)

PMI Presentation (Graphical PMI)

Presentation Coverage

Inverse Relationships and Backwards References

**Viewer**

Part Geometry  Edges  Sketch  Normals

Quality:  Low  Normal  High

Graphical PMI  Saved View Viewpoints

PMI Color:  From File  Black  By View  Random

AP242 Tessellated Part Geometry  Wireframe

AP209 Finite Element Model  Boundary conditions

Loads  Scale loads  Displacements  No vector tail

**Open STEP File in App**

Tree View (for debugging)   Include Geometry  Include styled\_item

Generate Spreadsheet and View

**NIST** NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

nlist\_stc\_10\_asme1.stp AP242e2 2023-06-29T09:48

Viewpoint: Front 1 (SFA)  
Part: nlist\_stc\_10\_asme1

**NIST Test Case Drawing**

Part Geometry

Sketch Geometry

Edges

**Saved View Graphical PMI**  
(PageDown to switch Saved Views)

MBD\_A (Default)

MBD\_B

MBD\_C

MBD\_D

MBD\_E

**Transparency**

Bounding Box  
Min: 0.007 0. 0.  
Max: 157.99 31. 75.

Origin

**Background Color**

White  Blue  Gray  Black

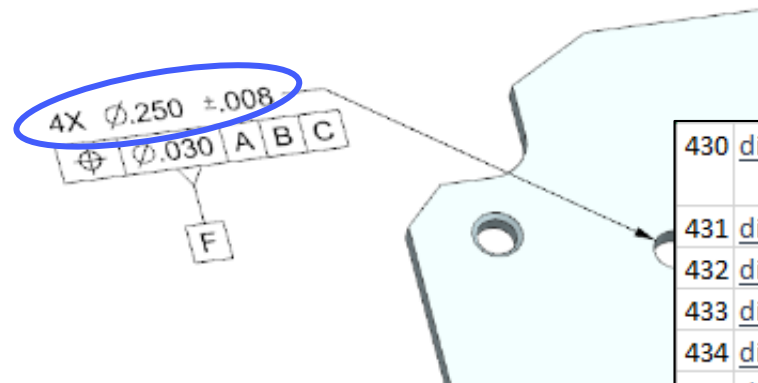
PageDown for Viewpoints. Key 'r' to restore, 'a' to view all. Use the mouse in 'Examine Mode' to rotate, pan, zoom.

Generated by the NIST STEP File Analyzer and Viewer 5.0 06 Sep 2023 08:41 NIST Disclaimer

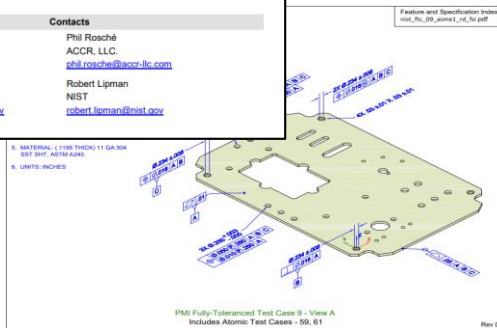
# SFA reporting of semantic PMI Entities

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## • Semantic PMI Summary Worksheet



430	<u>dimensional characteristic representation</u>	3X $\varnothing.250 +0.003$ -0.000
431	<u>dimensional characteristic representation</u>	2X $\varnothing.221 \pm 0.008$
432	<u>dimensional characteristic representation</u>	(0.281)
433	<u>dimensional characteristic representation</u>	3X $\varnothing.281 \pm 0.008$
434	<u>dimensional characteristic representation</u>	4X R0.125
435	<u>dimensional characteristic representation</u>	2X $\varnothing.250 \pm 0.008$
436	<u>dimensional characteristic representation</u>	$\varnothing0.375 \pm 0.008$
437	<u>dimensional characteristic representation</u>	4X $\varnothing.156 \pm 0.008$
438	<u>dimensional characteristic representation</u>	0.140 $\pm 0.008$
439	<u>dimensional characteristic representation</u>	1.00 $\pm 0.02$



ID	dimension	representation	Dimensional Tolerance	dimension (Sec. 5.1.1, 5.3) type 2 (5.3)	Associated Geometry (Sec. 5.1.1, 5.1.5)
435	dimensional_size 454	shape_dimension_representation 473	2X $\varnothing.250 \pm 0.008$	diameter	(2) cylindrical_surface 2086 2088 (2) advanced_face 4520 4522 (2) shape_aspect 1149 1150 (1) composite_group_shape_aspect 1230



# CAX-IF Test Round Results

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- 2,114 files tested since 1999



The MBx Interoperability Forum is significantly improving STEP translator quality and decreasing translator time-to-market

MBx Interoperability Forum

CAX Interoperability Forum

User Group

Implementor Group

CAX Test Rounds

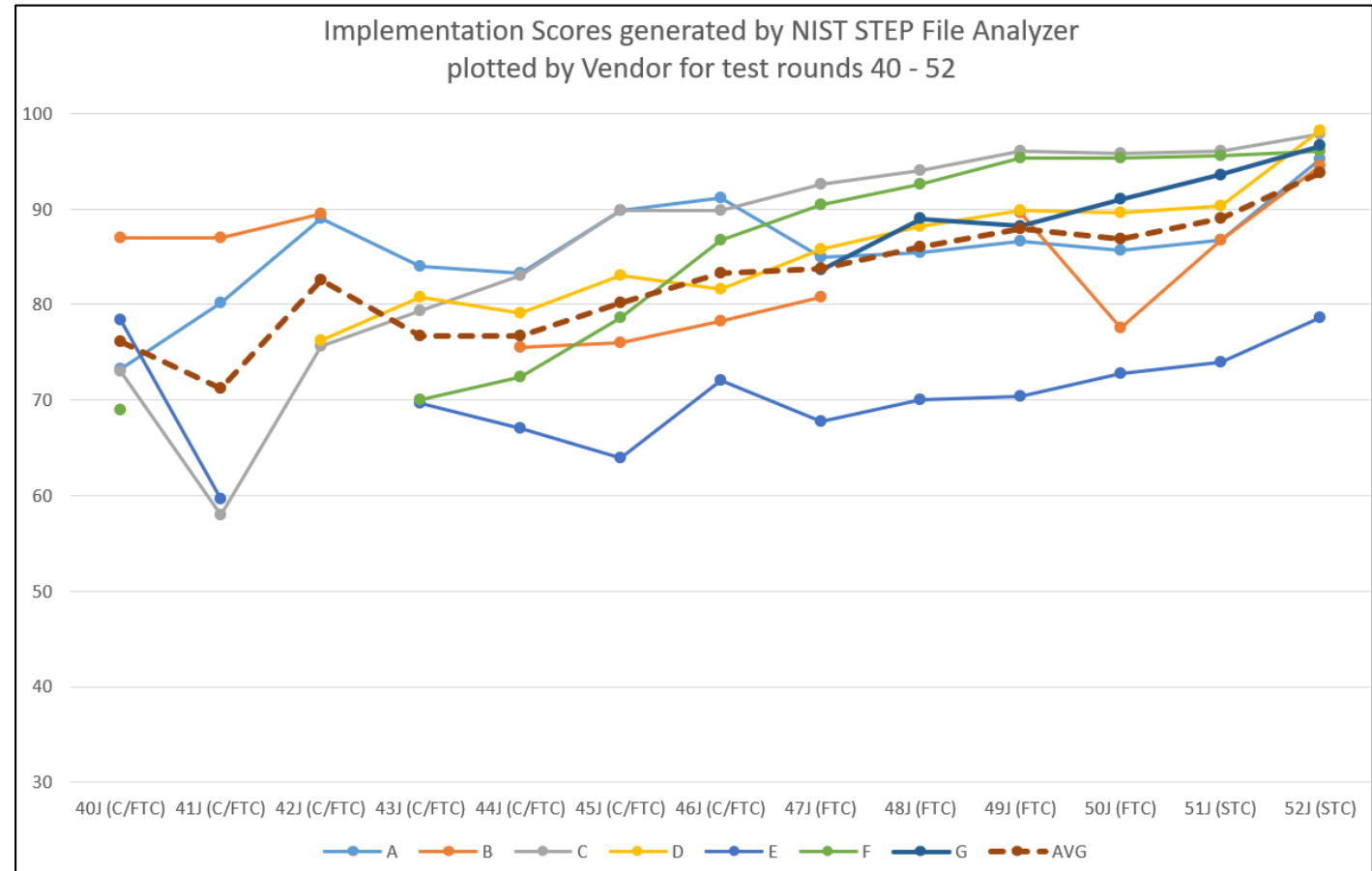
Models Tested in Current Round

CAX Recommended Practices

EXPRESS Schemas

## CAX TEST ROUNDS

52J - Summer 2023	Scope & Schedule	Test Suite (v1.1, PDF)
51J - Winter 2022/23	Scope & Schedule	Test Suite (v1.2, PDF)
50J - Summer 2022	Scope & Schedule	Test Suite (v1.1, PDF)
49J - Winter 2021/22	Scope & Schedule	Test Suite (v1.1, PDF)
48J - Summer 2021	Scope & Schedule	Test Suite (v1.1, PDF)
47J - Winter 2020/21	Scope & Schedule	Test Suite (v1.1, PDF)
46J - Summer 2020	Scope & Schedule	Test Suite (v1.2, PDF)
45J - Winter 2019/20	Scope & Schedule	Test Suite (v1.3, PDF)
44J - Summer 2019	Scope & Schedule	Test Suite (v1.1, PDF)
43J - Winter 2018/19	Scope & Schedule	Test Suite (v1.1, PDF)
42J - Summer 2018	Scope & Schedule	Test Suite (v1.3, PDF)
41J - Winter 2017/18	Scope & Schedule	Test Suite (v1.1, PDF)
40J - Summer 2017	Scope & Schedule	Test Suite (v1.3, PDF)
39J - Winter 2016/17	Schedule	Test Suite (v1.2, PDF)
38J - Summer 2016	Schedule	Test Suite (v1.0, PDF)
37J - Winter 2015/16	Schedule	Test Suite (v1.0, PDF)
3J - Winter 1999/2000		Test Suite (v2.0, PDF)
2J - Fall 1999		Test Suite (v2.0, PDF)
1J - Spring 1999		Test Suite (v2.0, PDF)



Nice job!



# Ongoing Projects & Research

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- **Interoperability Tools**

- Benefit on the receiving side
- CAD to CAM/CMM needs alignment

- **Standards**

- Incomplete PMI coverage
- Updated to recommend practices

- **Processes**

- Significant improvement in cycle time
- Designers need education

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Communications Technology Laboratory / Smart Connected Systems Division

## SMART CONNECTED MANUFACTURING SYSTEMS GROUP

### Design to Manufacturing and Inspection (D2MI)

The Design to Manufacturing and Inspection project demonstrated the feasibility and development of CAD-to-CAM and CAD-to-CMM tools taking advantage of the 3D data interoperability groundwork previously established with CAD-to-CAD. The enhanced interoperability will significantly

- reduce and/or eliminate recreation of part design data,
- reduced cycle time and cost,
- reduce risk of downstream error introduction,
- increased part yield, and
- generate higher quality products.

The information flow (shown below) utilizes a CAD model with PMI that is translated from native CAD to STEP. The STEP file was then imported by the CAM system, which uses a Parasolid kernel. In addition, the STEP file was ported to an extended version of ACIS that was imported by the CMM system, which uses an ACIS kernel.

The project tasks included:

- Proof-of-Concept demonstrator for transport of PMI downstream to manufacturing and First Article Inspections (FAI)
- Identify Metrics for analyzing As-Is and To-Be processes
- Collect Metrics results for As-Is and To-Be processes and determine Return On Investment (ROI)
- Identify technology and data gaps and roadblocks in the To-Be process

The project was a collaborative effort by a team comprised of NIST, ITI TranscenData, Rockwell Collins, CT CoreTechnologie, Advanced Collaboration Consulting Resources LLC, CNC Software Inc., Mitutoyo America Corp., and Geater Machining and Manufacturing, Co.

**Enabling the Digital Thread for Smart Manufacturing**

- MBE PMI Validation and Conformance Testing
- **Design to Manufacturing and Inspection (D2MI)**
- Validation for Downstream Computer-Aided Manufacturing and Coordinate Metrology Processes
- Tolerancing Standards and Associated Modeling Challenges
- Testing the Digital Thread (PDES, Inc.)



# ISO 10303 Working Groups

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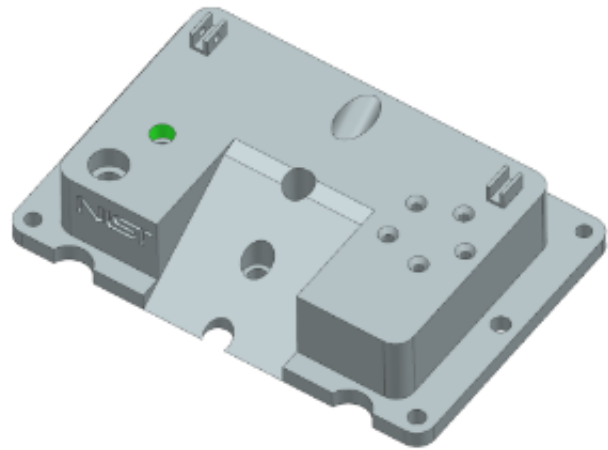
## Technical Committee 184, Subcommittee 4 – Industrial Data

- **WG 12** - STEP product modeling and resources
- **WG 15** - Digital Manufacturing
- **JWG 16** - Visualization of Data
- **TF1** – STEP Module Resource Library
- **TF2** - Reference model for industrial data (machine-readable standards)
- **AHG 3** - UUID management (Digital twin identifiers)

WG - Working Group  
JWG – Joint Working Group  
TF – Task Force  
AHG – Ad Hoc Group

# Passing of data from system to system

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01100011  
01101000  
01100101  
01100011  
01101011



01100011  
01101000  
01100101  
01100011  
01101011

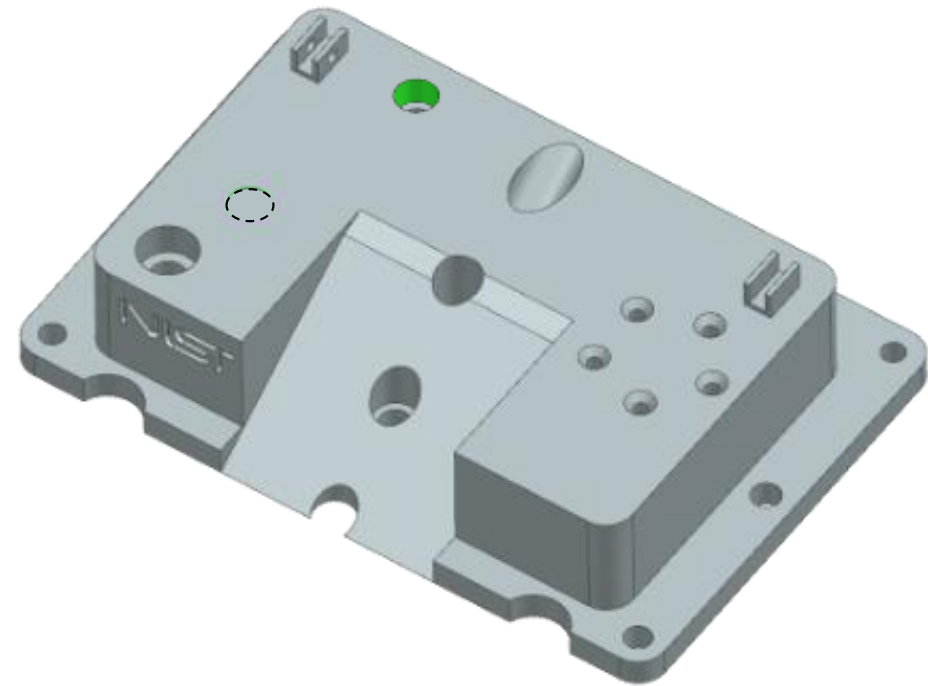
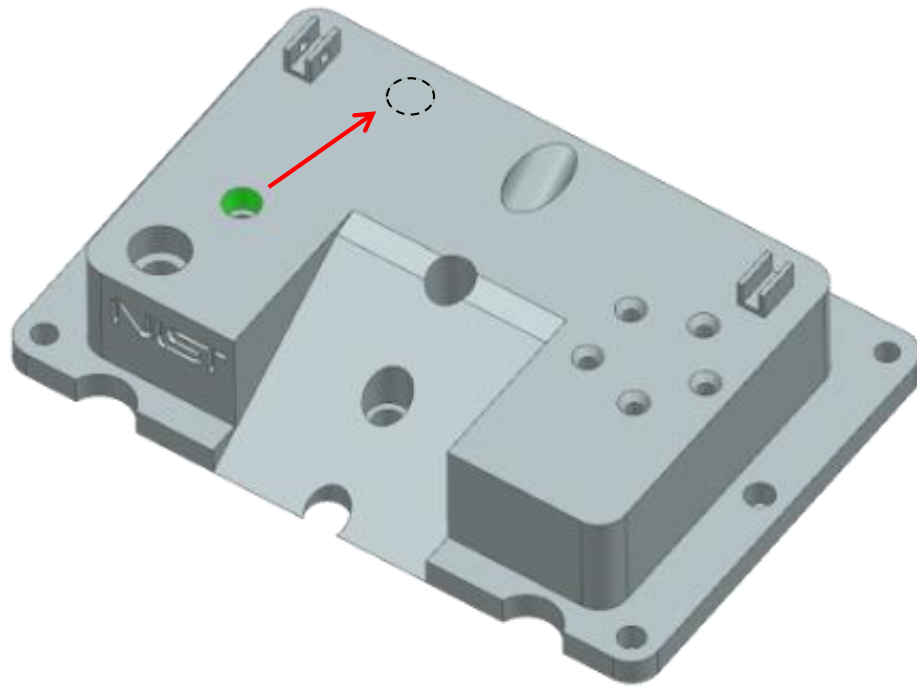




# Current Investigation

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## Tracking information throughout the lifecycle



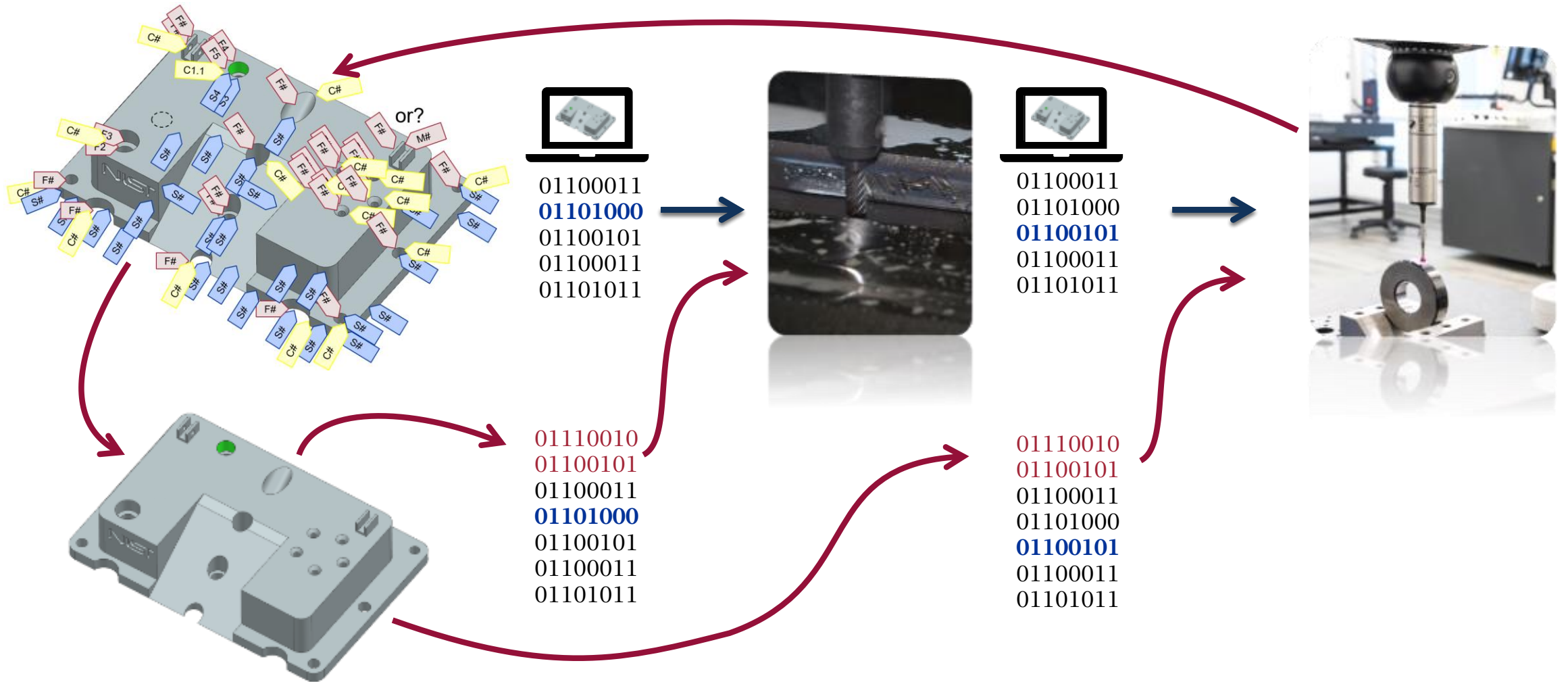
# Universal Unique Identifiers

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# Universal Unique Identifiers (UUID)

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# ISO 10303 Strengths

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- **Long history of accurate interoperability**
- **Product data repurposing and reuse**
  - CAM automation of manufacturing
  - CMM automation of inspection planning
- **LOTAR (Long Term Archival and Retrieval) International**
  - OEMs, suppliers, PDES, prostep ivip, and solution providers in aerospace and defense
  - Concluded STEP is very stable for archival (>70 years) complying with NAS/EN 9300
- **Widely implemented**
  - File exchanges - hundreds of millions annually
  - Savings through improved interoperability - \$ billions annually



# ISO 10303 Challenges

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- **STEP lacks geometric modeling formalism**
  - Unable to reconcile CAX data across domains
- **Mapping semantic PMI and metadata**
  - Continuous evolution of standard
- **Downstream representations are not fit for purpose**
  - Derived from other representations
- **Persistent IDs are required for traceability**
  - Improved redesign done faster
- **Implementations lag behind standards development**

# Findings from NIST Economic Impact Assessments

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- **Smart manufacturing technology infrastructure**
  - Conservative - could save manufacturers \$57.4 billion annually
  - Benefits would persist
- **Barriers to innovation - Increased cost of R&D with uncertain ROI**
  - Diminishes the incentive to invest
  - Trusted third-party standards and performance data let adopters know what they are buying at various cost points
  - Public institution support is needed
- **Investments in public-private manufacturing consortia needed**
  - Open platforms and marketplaces where small players can innovate
  - Support for those platforms requires investments in consortia and technology-extension services.

# Findings from NIST Economic Impact Assessments

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- **Technology infrastructure for small enterprises**
  - Decrease the cost of software and implementation and increase adoption
  - Cloud-based smart manufacturing could make big data and analytics more accessible
- **Technology infrastructure needs are vast and often interrelated**
  - Unbalanced investment, closing some technical gaps, leaving other needs unmet
  - Likely fail to fully realize the economic impact

# Progress is being made

Global Product Data Interoperability Summit | 2023



# STEP by Step to MBE

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# GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023

