STEP by Step to MBE

Rosemary Astheimer

Mechanical Engineer - NIST

Smart Connected Manufacturing Systems

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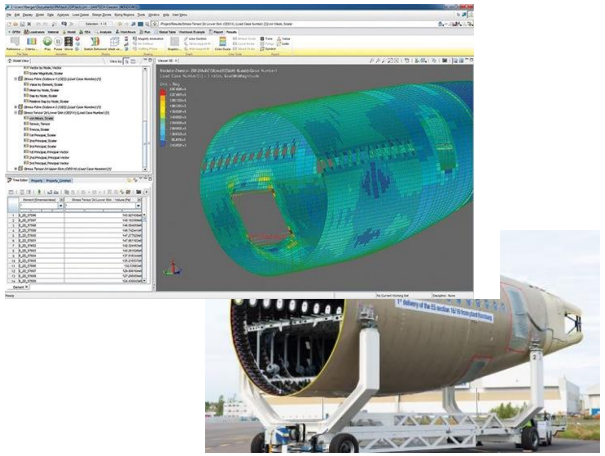
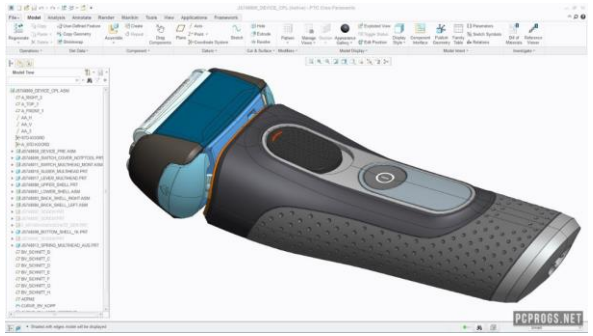
Rosemary Astheimer

Focus on Computer Aided-Design (CAD)



FiberSIM Applications Engineer – VISTAGY



Product Manager – Creo Data Exchange

PURDUE UNIVERSITY

CAD, MBD, PLM & PDM

PLM Software SIEMENS NX

SIEMENS NX CERTIFIED CAD Design Associate

ASME GD&T Technologist

QIF by DMSC

DS CATIA

V5 SPECIALIST Mechanical Designer

V5 ASSOCIATE Part Design

V5 ASSOCIATE Assembly Design

ptc creo®

DASSAULT SYSTEMES MECHANICAL DESIGN SOLIDWORKS ASSOCIATE

DS SOLIDWORKS

https://resources.sw.siemens.com/en-US/case-study-airbus-group-innovations

https://www.ptc.com/en/blogs/cad/parametric-vs-direct-modeling-which-side-are-you-on

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

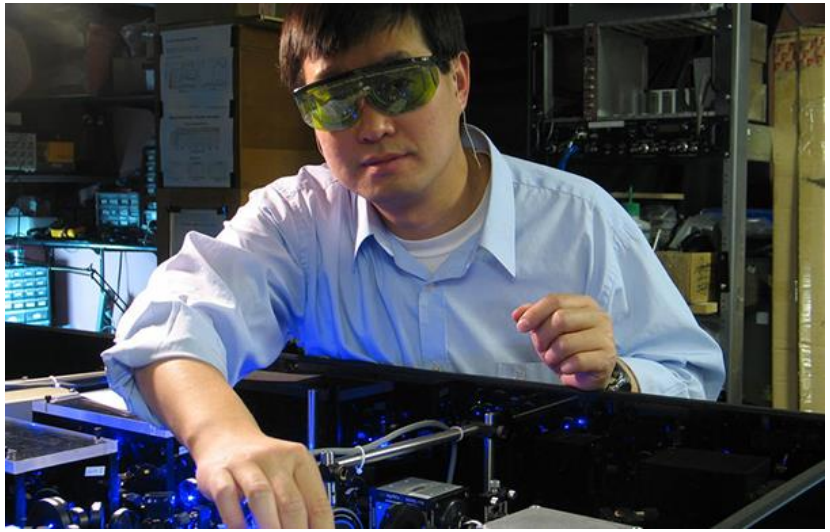
ManufacturingUSA
NATIONAL OFFICE COORDINATING 16 MANUFACTURING INSTITUTES

51
MANUFACTURING EXTENSION PARTNERSHIP CENTERS

U.S. BALDRIGE PERFORMANCE EXCELLENCE PROGRAM

NIST Mission

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

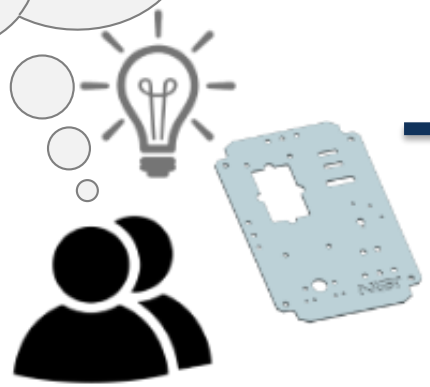
Why are we here?

The Challenge

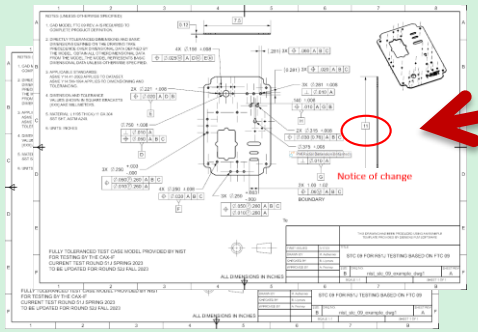
Communication!

This is a unique case

…they will figure it out



PDM



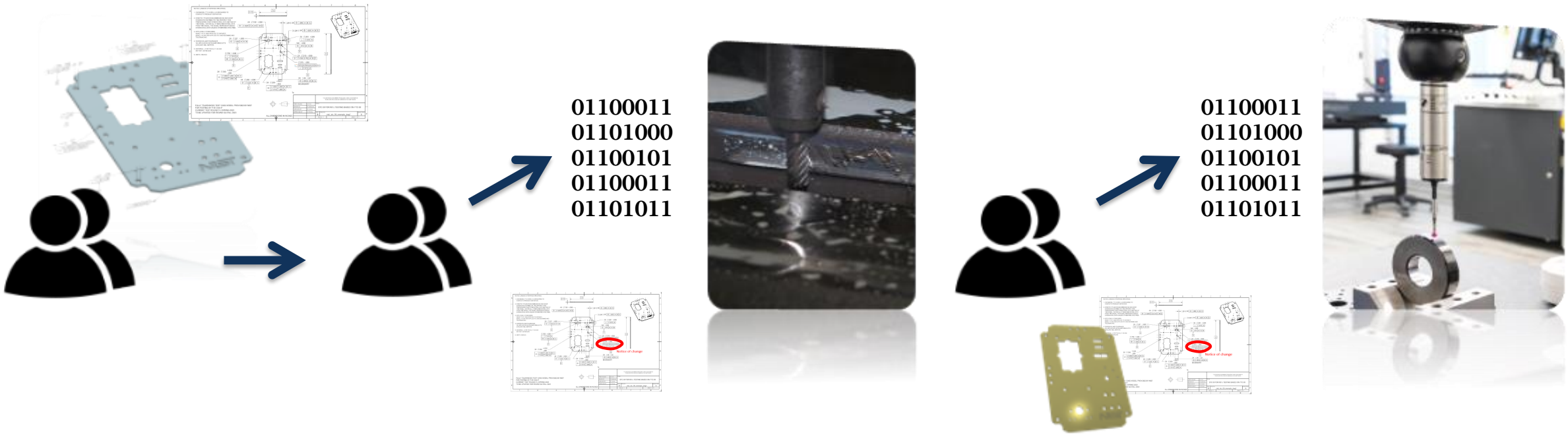
?

I've never seen that before it must be wrong.

I'll fix it.

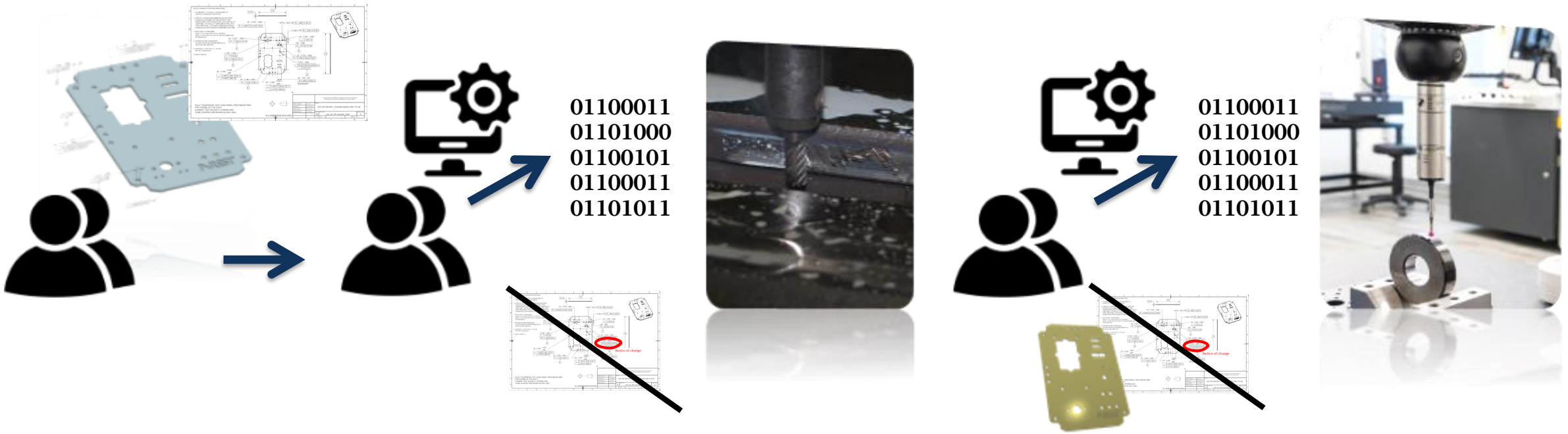
Human to human, to machine, to human, to machine

Humans make mistakes!

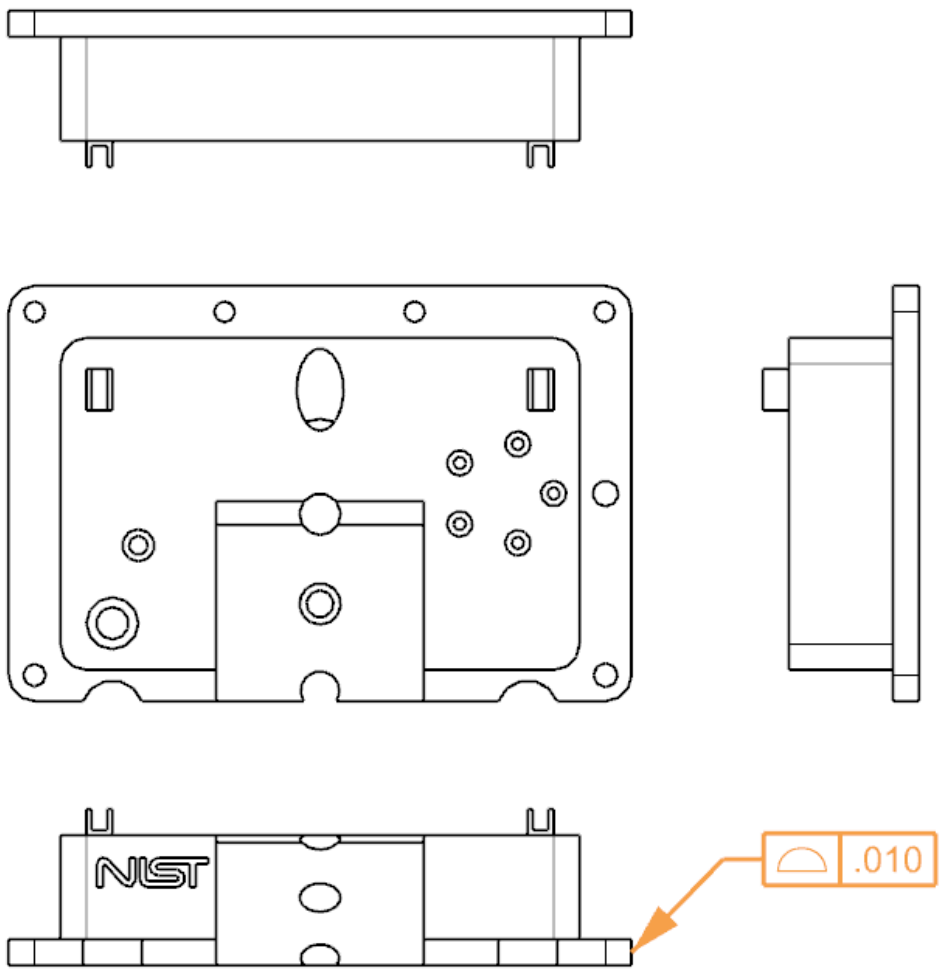


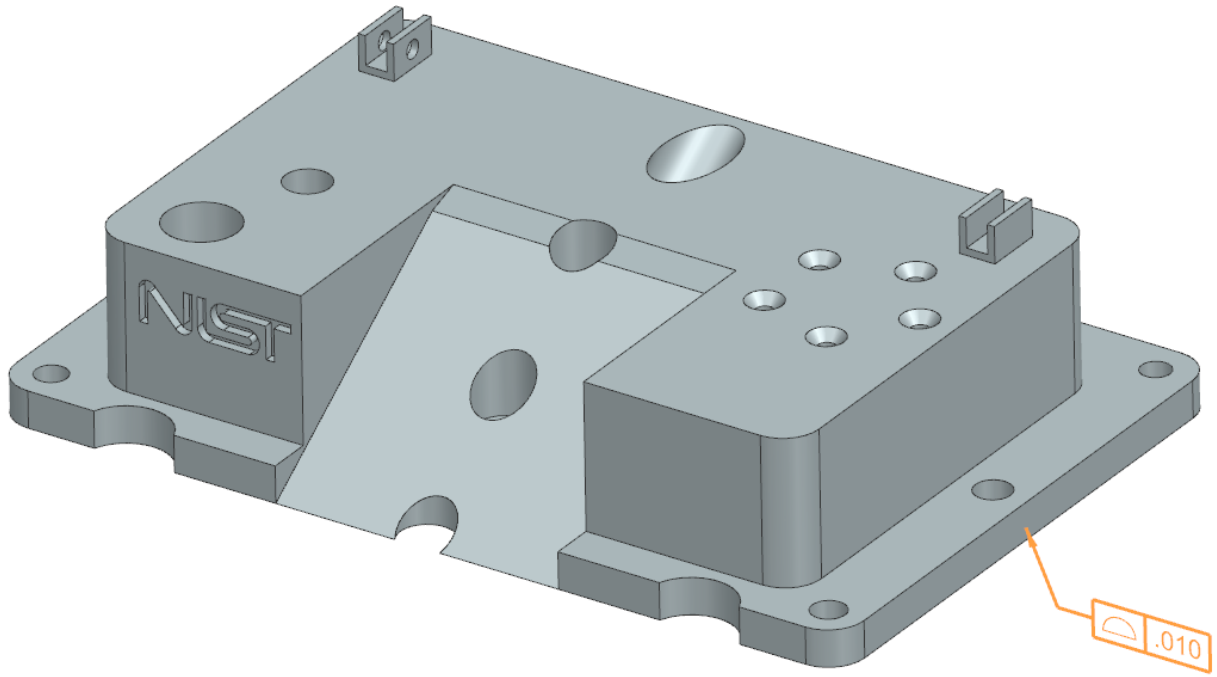
Machine to machine, to machine

Humans look for mistakes



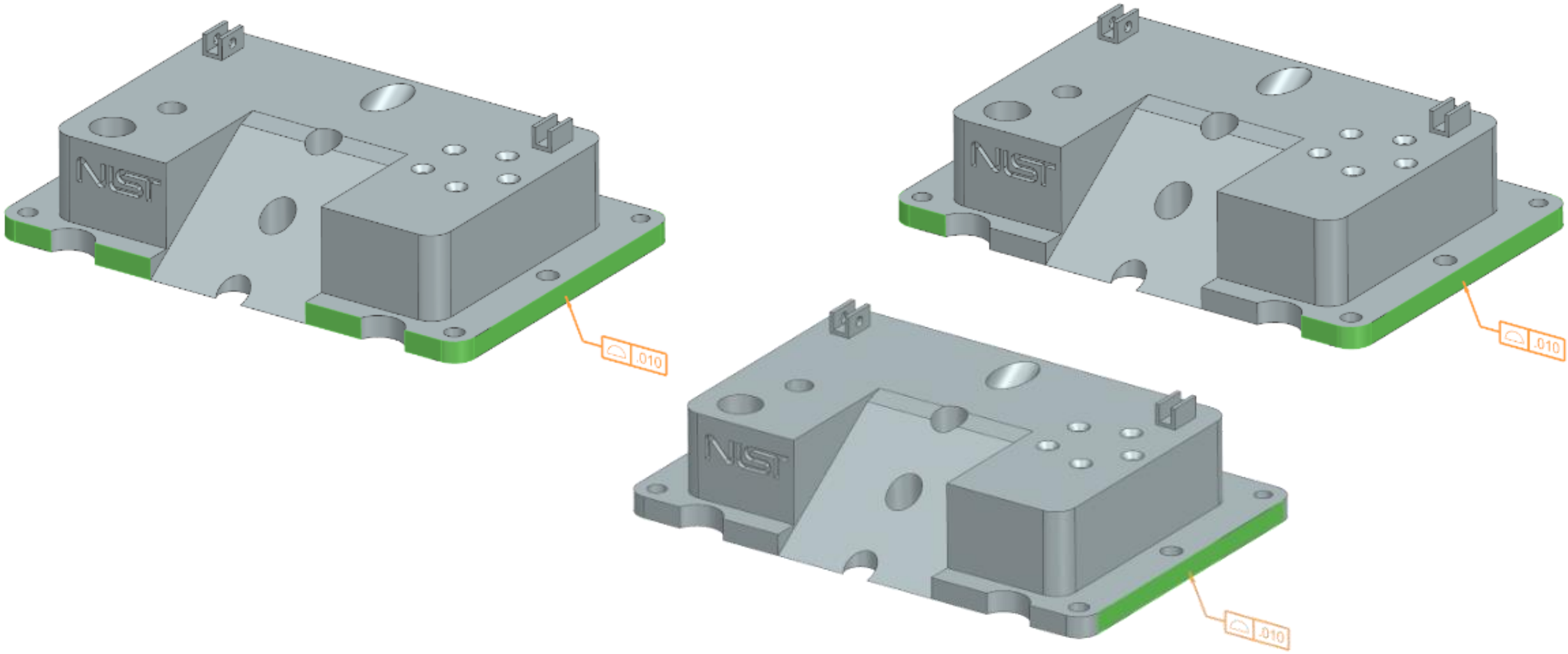
From 2D to 3D



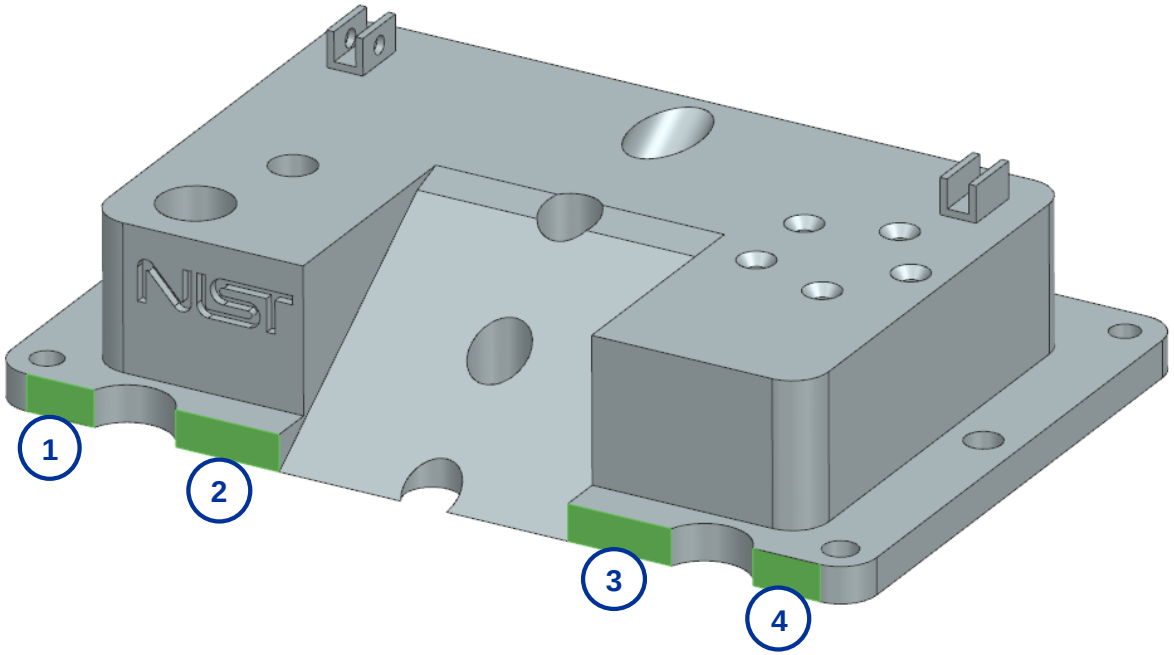


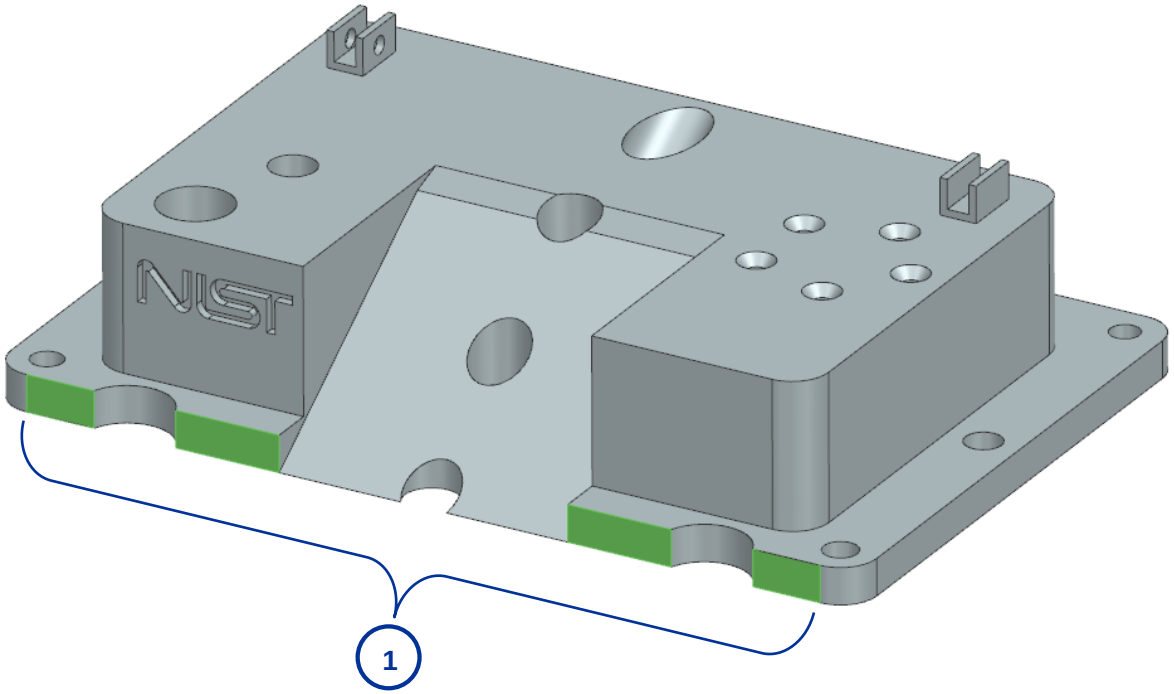
Let’s do it!

This or that… or that?



Different systems, different representations

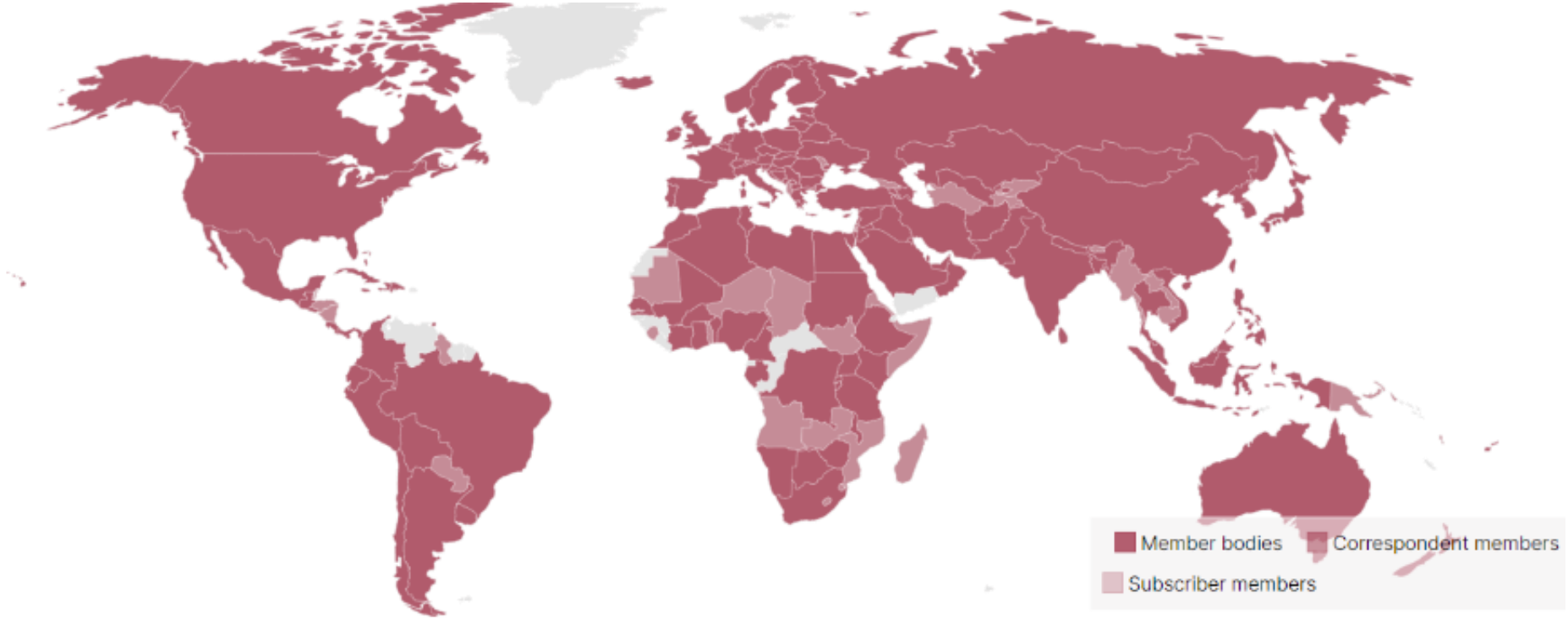




How do we handle this?

ISO - International Organization for Standardization

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



https://www.iso.org/standards.html

ISO 10303 – Product Data Standards

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)**

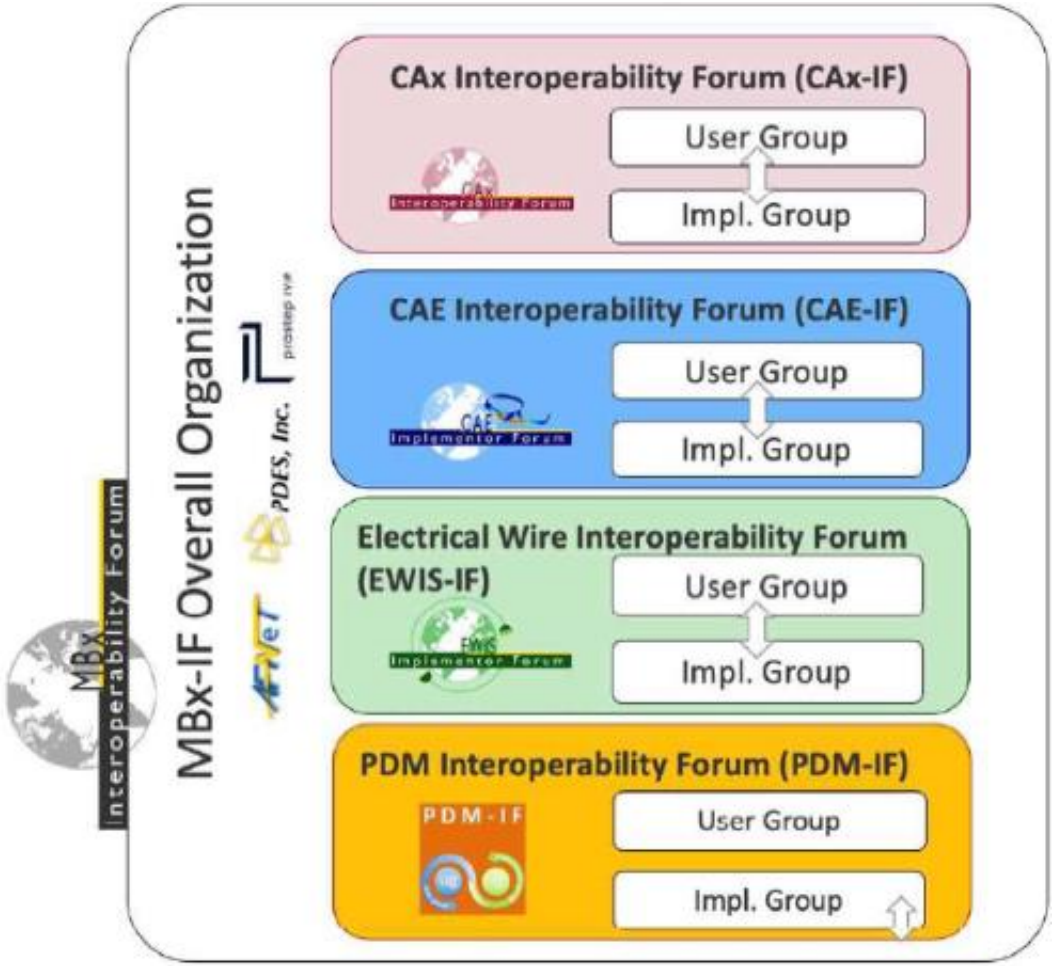
MBx-IF (Model-Based x Interoperability Forum)

AFNeT, PDES, Inc. & prostep ivip.

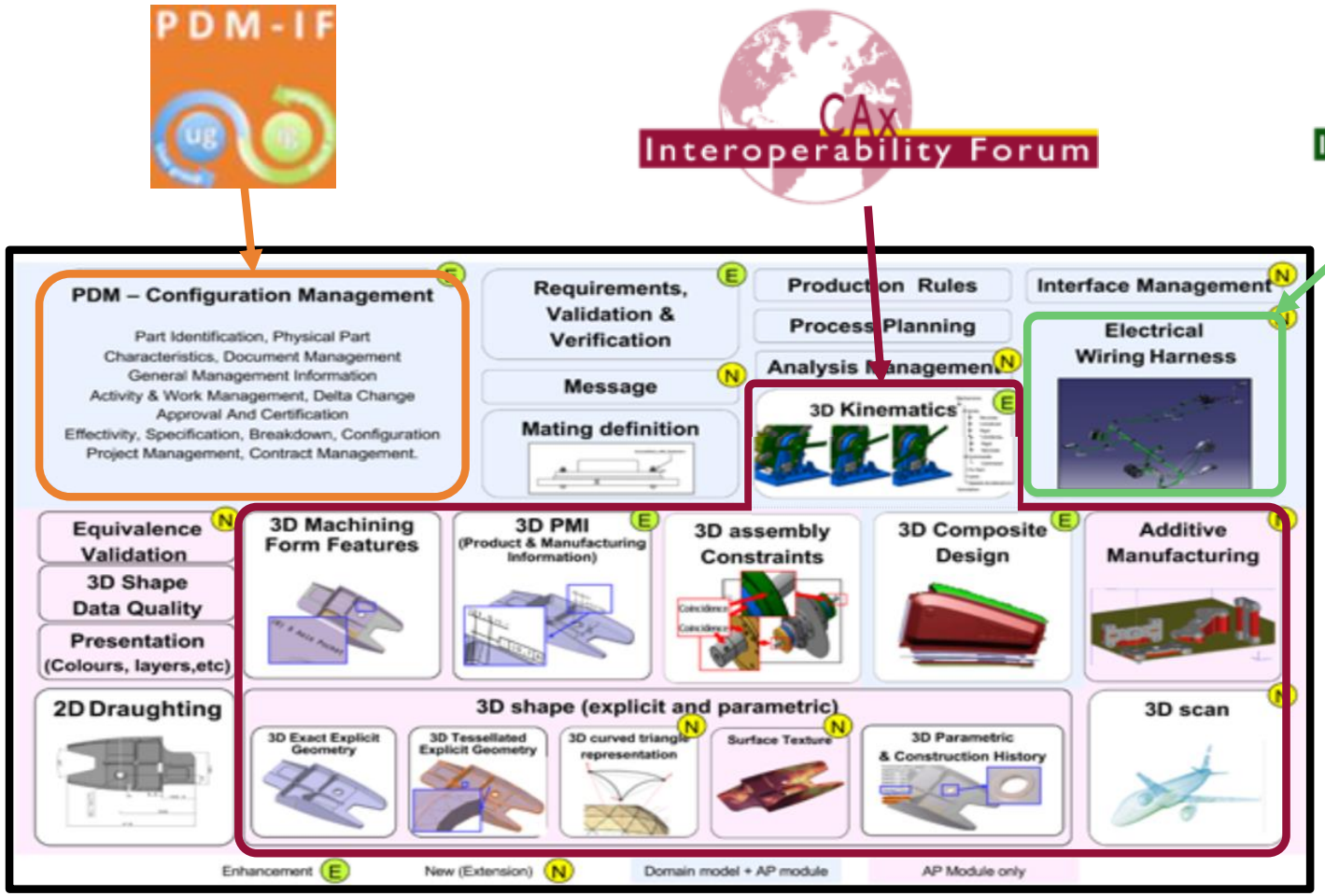
- Accelerate MBx translator development
- Ensure users' requirements are satisfied

Test standards implementations to

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

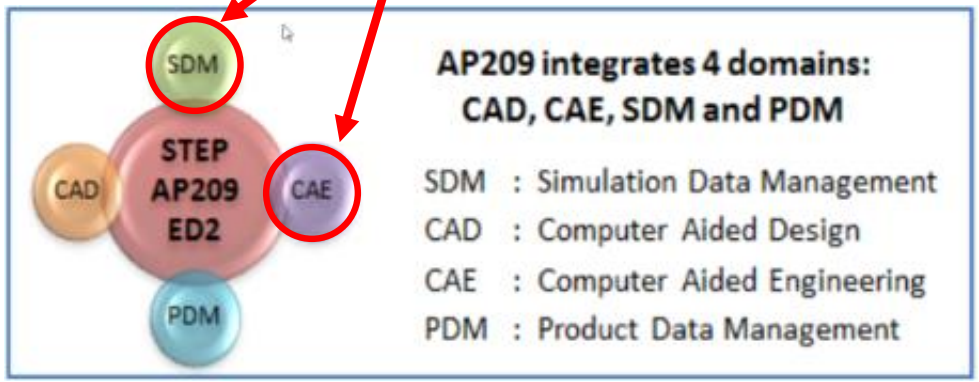


Relationship of Interoperability Forums to STEP



Overview of the scope of AP242 edition 3

Inactive



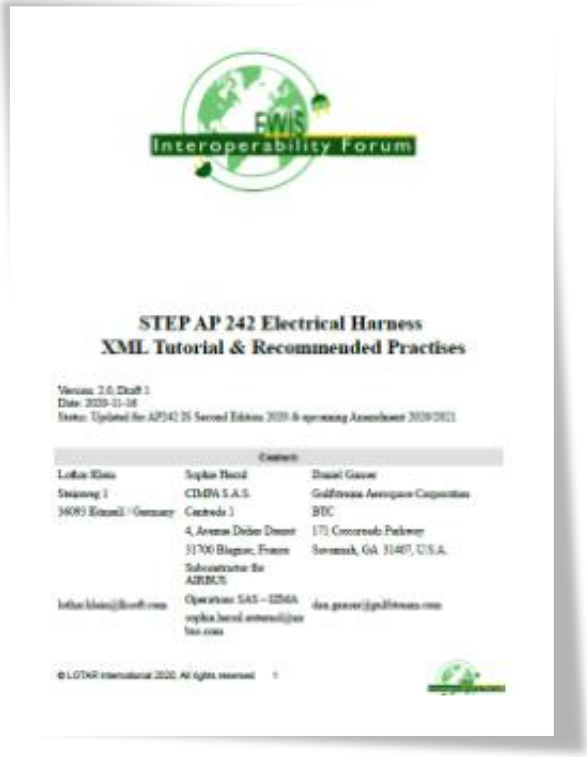
AP209 includes the AP242 module, taking benefits of the STEP modular architecture

Recommended Practices

Fundamental for testing implementations in various domains

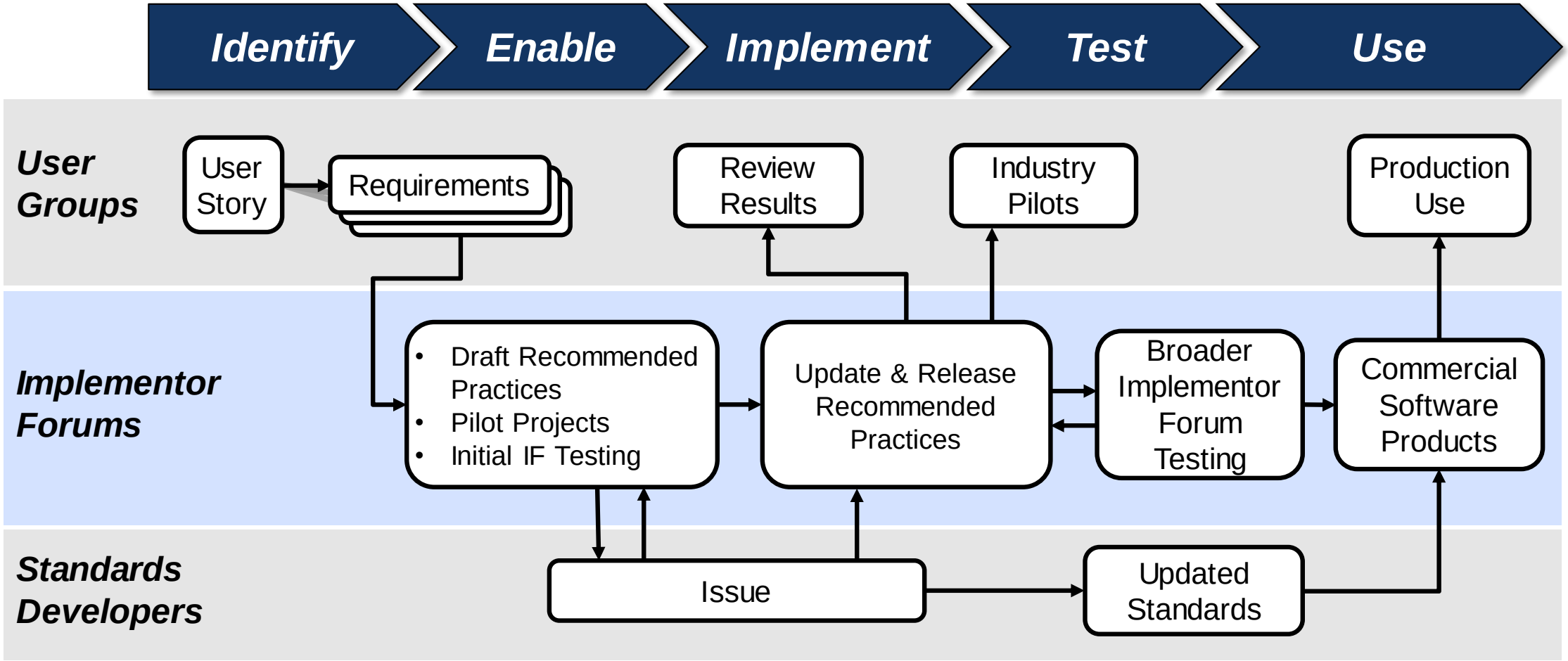
https://www.mbx-if.org/cax/cax_recommPractice.php

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



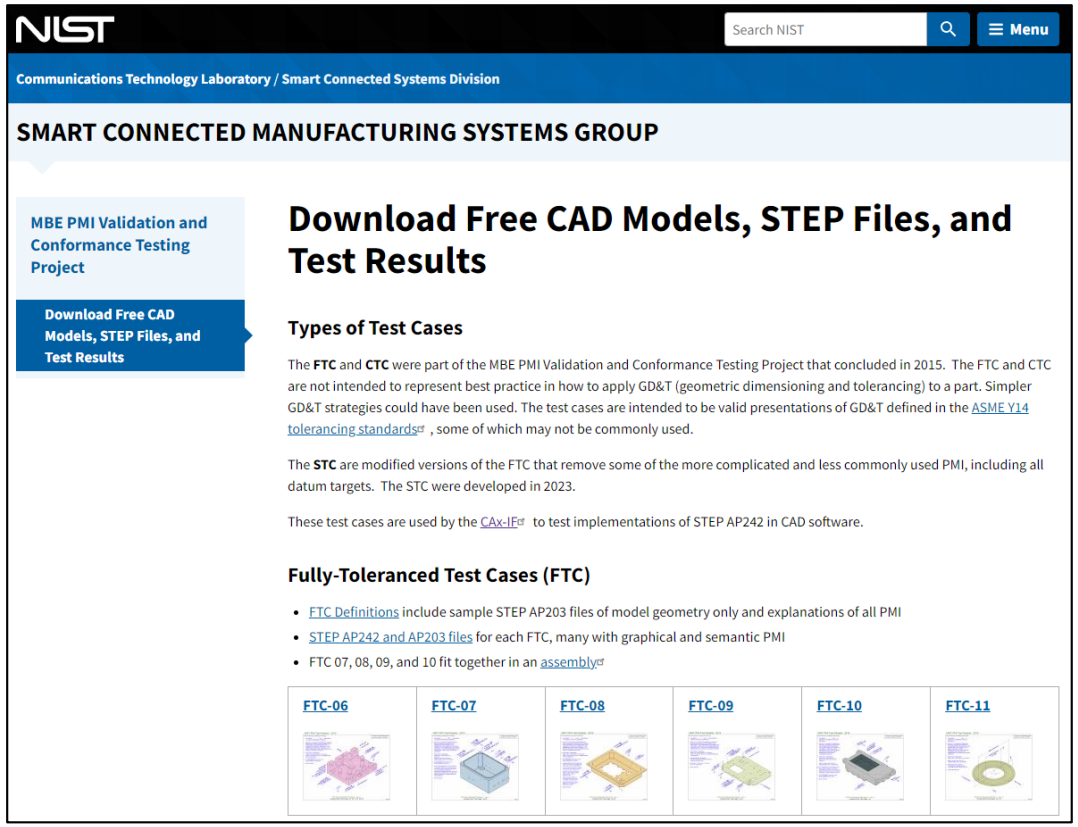
https://www.mbx-if.de/ewis/ewis_recommPractice.php

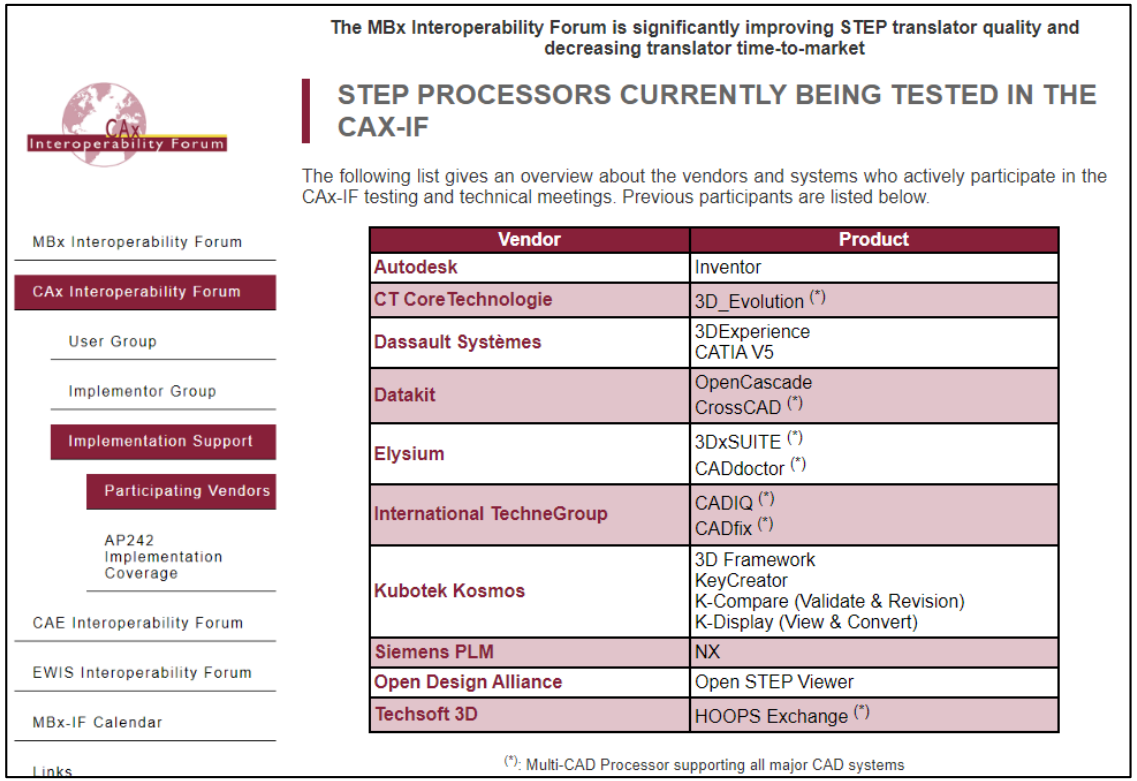
MBx-IF role between Users, Implementors, and Developers



CAx-IF (Computer Aided x Interoperability Forum)

- **NIST developed models**
- **Translated by and exchanged between vendors**



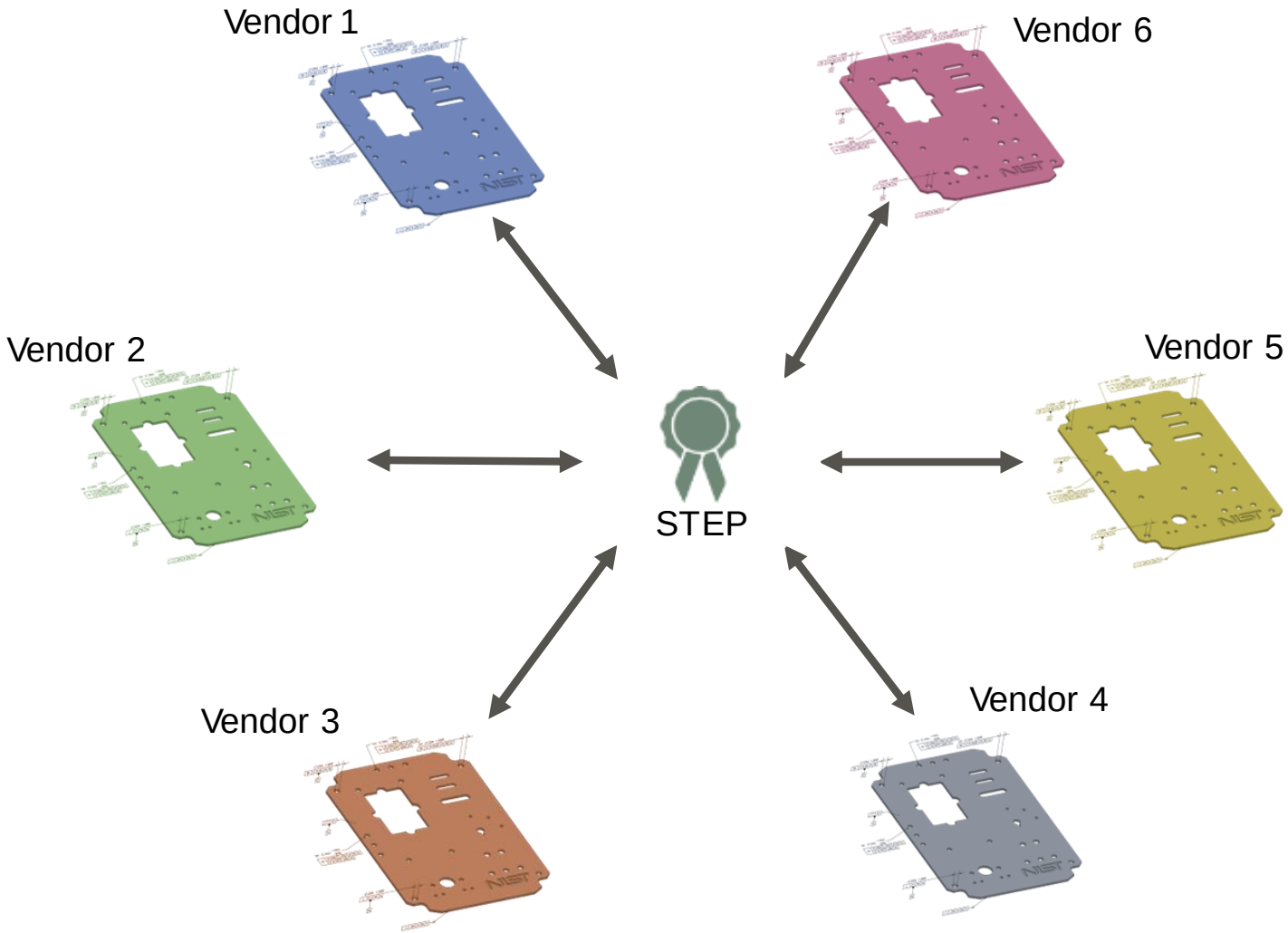


https://go.usa.gov/mGVm

GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023

https://www.mbx-if.org/cax/cax_vendors.php

Testing of STEP implementation

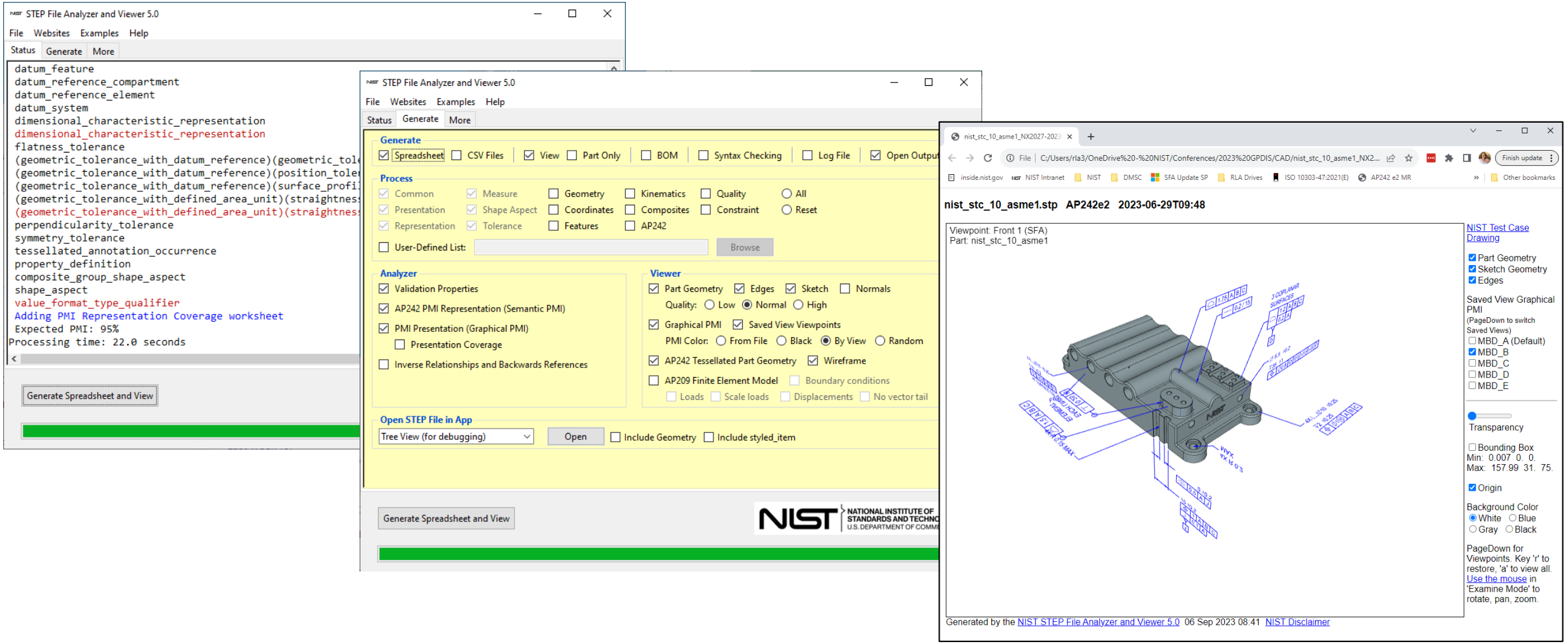


NIST STEP File Analyzer (SFA) and Viewer

- **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

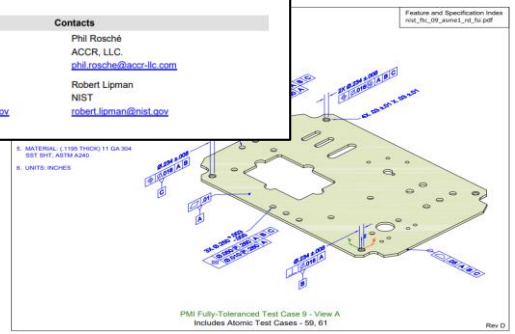
NIST STEP File Analyzer & Viewer User Interface

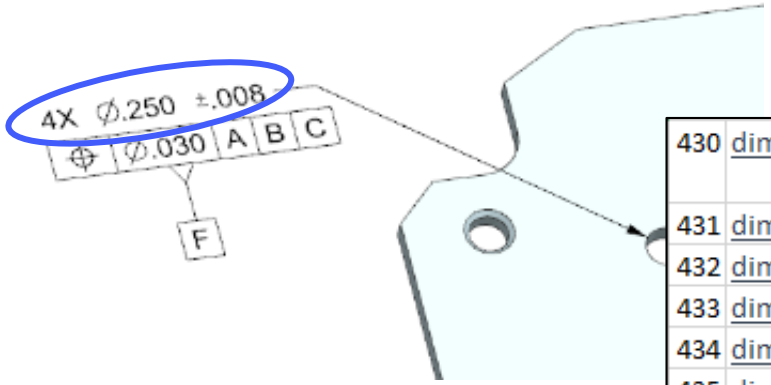


https://doi.org/10.1016/j.cad.2015.04.002

SFA reporting of semantic PMI Entities

- **Semantic PMI Summary Worksheet**





430	dimensional_characteristic_representation	3X ⌀0.250 +0.003 -.000
431	dimensional_characteristic_representation	2X ⌀0.221 ± 0.008
432	dimensional_characteristic_representation	(0.281)
433	dimensional_characteristic_representation	3X ⌀0.281 ± 0.008
434	dimensional_characteristic_representation	4X R0.125
435	dimensional_characteristic_representation	2X ⌀0.250 ± 0.008
436	dimensional_characteristic_representation	⌀0.375 ± 0.008
437	dimensional_characteristic_representation	4X ⌀0.156 ± 0.008
438	dimensional_characteristic_representation	0.140 ± 0.008
439	dimensional_characteristic_representation	1.00 ± 0.02

ID	dimension	representation	Dimensional Tolerance	dimension ... ifier (Sec. 5.1.1, 5.1 ype 2 5.3)	Associated Geometry (Sec. 5.1.1, 5.1.5)
435	dimensional_size 454	shape_dimension_representation 473	2X ⌀0.250 ± 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

- **2,114 files tested since 1999**

CAx Interoperability Forum

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

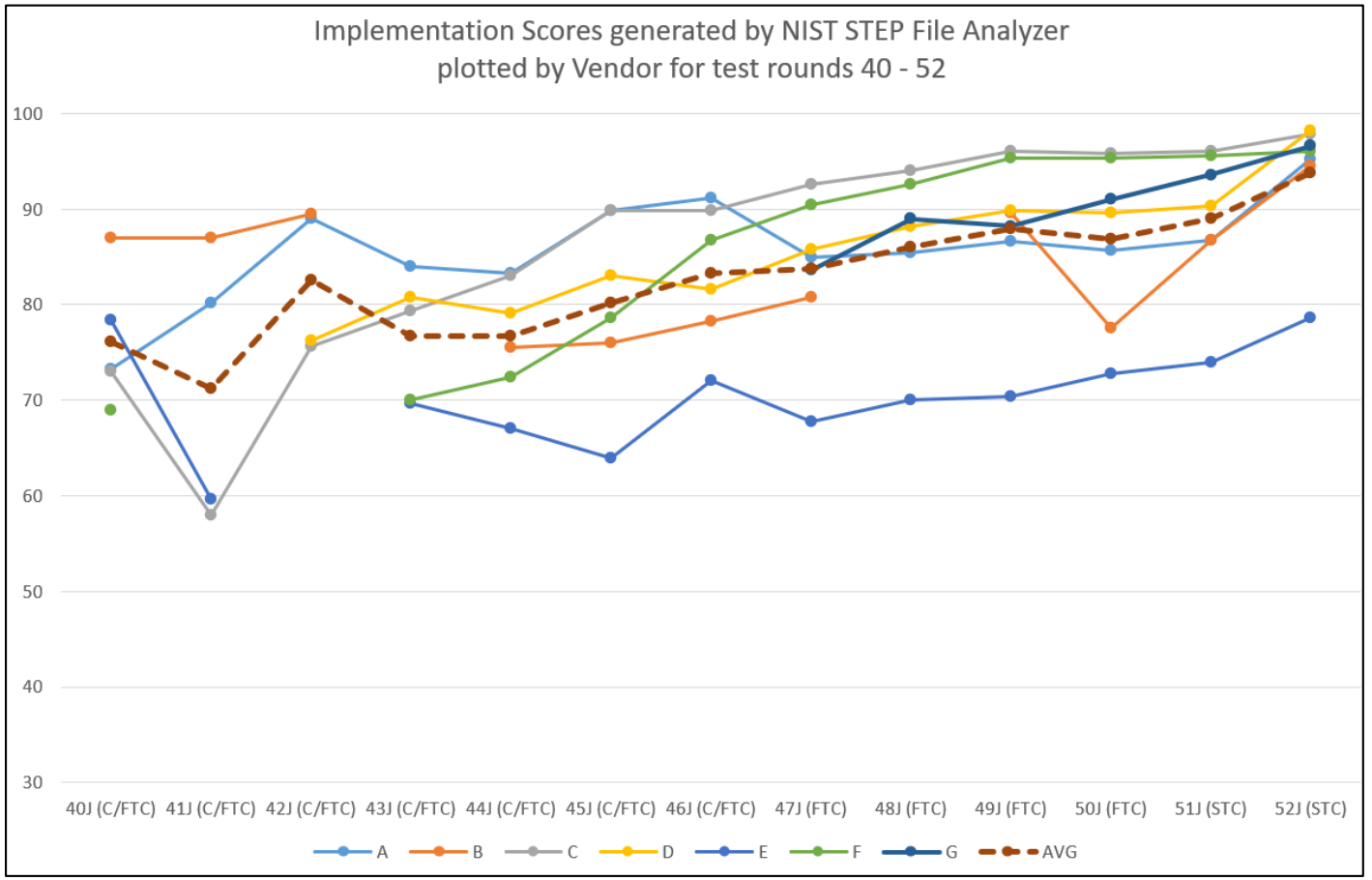
Models Tested in Current Round

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!

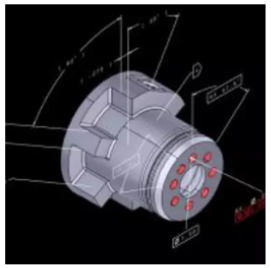
Ongoing Projects & Research

- **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

NIST | Search NIST | Menu

Communications Technology Laboratory / Smart Connected Systems Division

SMART CONNECTED MANUFACTURING SYSTEMS GROUP



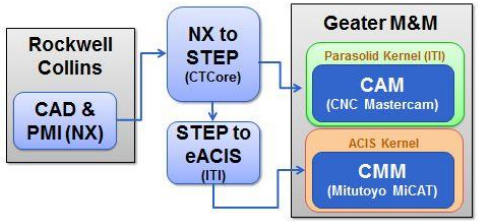
Enabling the Digital Thread for Smart Manufacturing

- 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.)

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.

https://www.nist.gov/ctl/smart-connected-systems-division/smart-connected-manufacturing-systems-group/enabling-digital-0

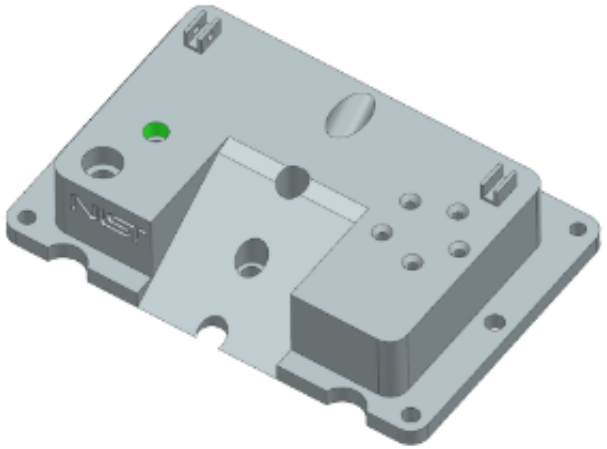
ISO 10303 Working Groups

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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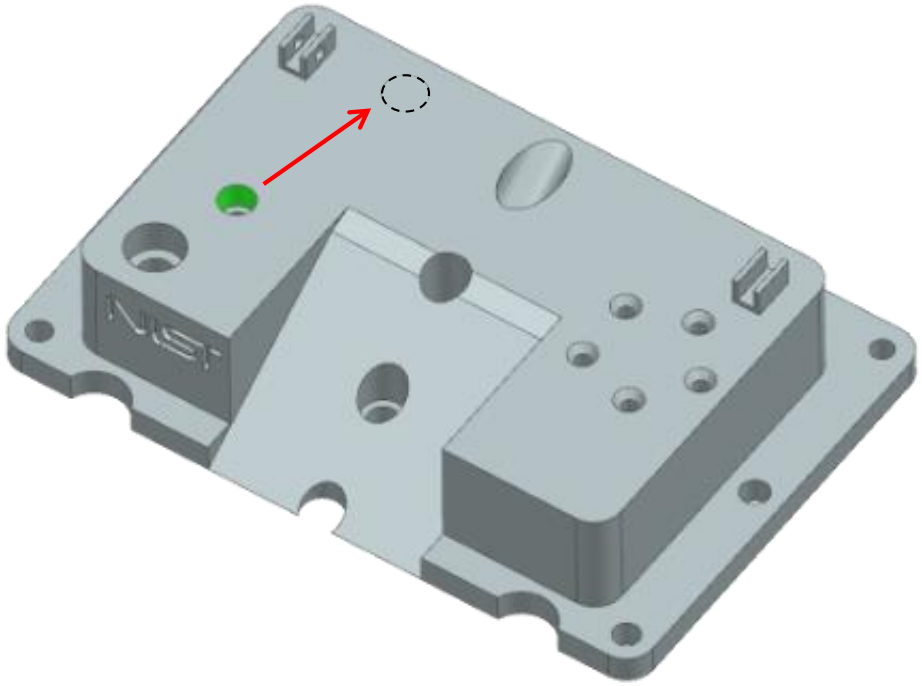
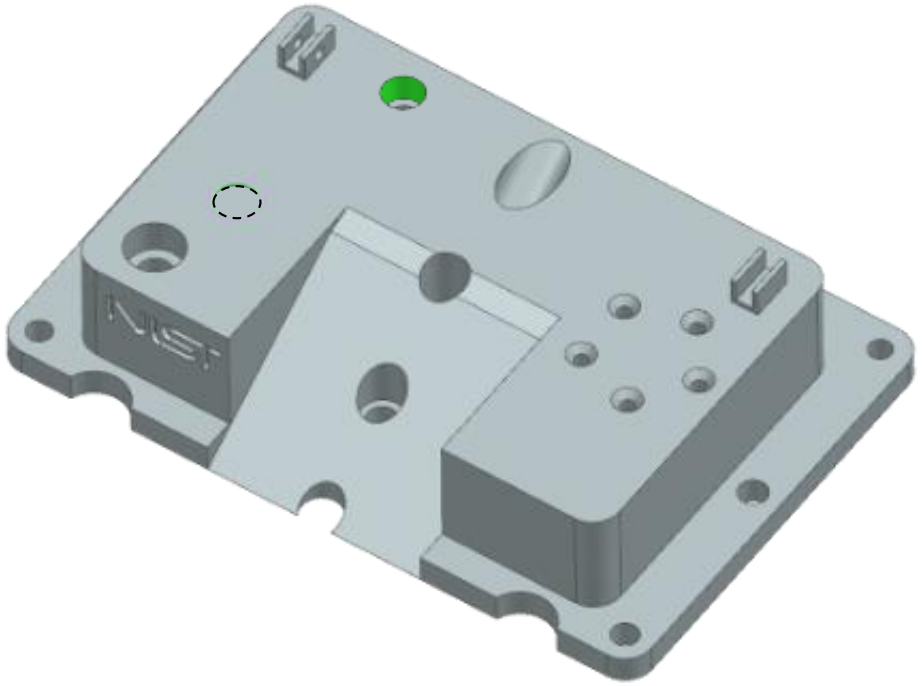
Current Investigation

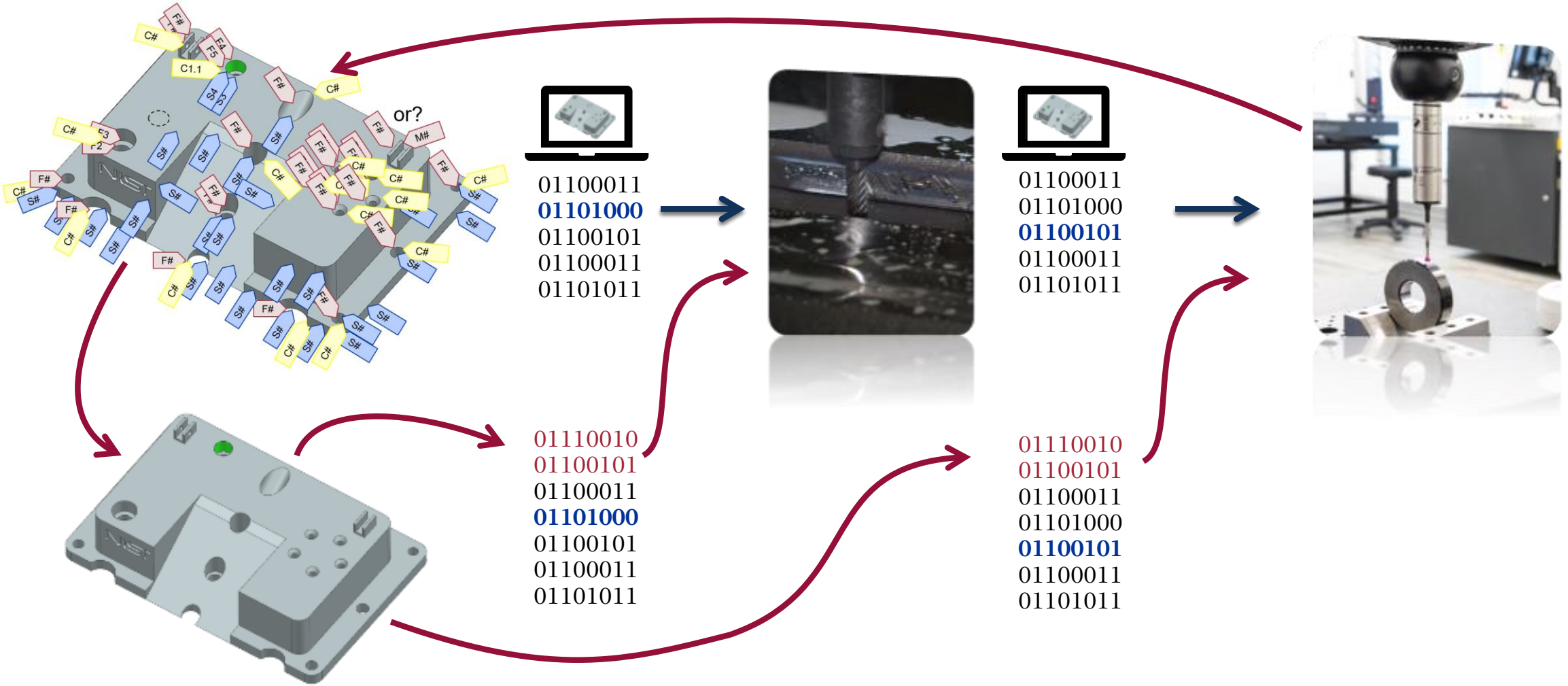
Tracking information throughout the lifecycle





Universal Unique Identifiers

Universal Unique Identifiers (UUID)



Take aways

ISO 10303 Strengths

- **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

- **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

- **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

- **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

STEP by Step to MBE

Rosemary Astheimer

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Smart Connected Manufacturing Systems

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