ISO 10303 - STEP

model-based before model-based was cool

Model-Based Enterprise Summit

MxD April 16, 2024

NIST COMMUNICATIONS TECHNOLOGY LABORATORY

Allison Barnard Feeney

Outline

ISO TC 184/SC 4 Industrial data

STEP 101

STEP today

Your tax dollars at work

- Composite Structures
- Hybrid Brep Modeling
- UUID in STEP EXPRESS models
- Interoperability testing support
- EasyEXPRESS
- CAx Interoperability Testing Support

Questions?

ISO TC 184/SC 4 Industrial Data

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ISO TC 184/SC 4 Industrial Data

- ISO 10303: Product data representation and exchange
- ***STEP**: **ST**andard for the **E**xchange of **P**roduct model data*

SC 4 Industrial Data

801 Published 43 In development 22 Participating countries 12 Observing countries

Active SC4 Standards

ISO 8000 - Data Quality
ISO 10303 - Product data representation and exchange
ISO 15926 - Integration of life-cycle data for process plants including oil and gas production facilities
ISO 17506 - COLLADA digital asset schema specification for 3D visualization of industrial data
ISO 23247 - Digital Twin manufacturing framework
ISO 23301 - STEP Geometry Services
ISO 23952 - Quality information framework (QIF) — An integrated model of manufacturing quality information
ISO 24464 - Visualization elements of digital twins
ISO 29002 - Exchange of characteristic data

SC4 Organizational Structure

ISO/TC 184/SC 4/AG 0	Change management advisory group
ISO/TC 184/SC 4/AG 2	Implementation Forum
ISO/TC 184/SC 4/AG 3	Core terminology for industrial data
ISO/TC 184/SC 4/AHG 3	UUID management for industrial data
ISO/TC 184/SC 4/JWG 16	Joint with ISO/IEC JTC 1/SC 24 & ISO/TC 171/SC 2 WG: Formats for visualization and other derived forms of product data
ISO/TC 184/SC 4/JWG 24	Joint with IEC SC3D WG: Use of IEC CDD for ISO data dictionaries and ontologies
ISO/TC 184/SC 4/PPC	Policy and planning committee
ISO/TC 184/SC 4/QC	Quality committee
ISO/TC 184/SC 4/TF 1	ISO 10303 SMRL architecture innovation
ISO/TC 184/SC 4/TF 2	SC 4 reference model for industrial data
ISO/TC 184/SC 4/TF 3	SC 4 Common change process
ISO/TC 184/SC 4/WG 3	Oil, Gas, Process and Power
ISO/TC 184/SC 4/WG 11	Implementation methods and conformance methods
ISO/TC 184/SC 4/WG 12	STEP product modelling and resources
ISO/TC 184/SC 4/WG 13	Industrial Data Quality
ISO/TC 184/SC 4/WG 15	Digital manufacturing
ISO/TC 184/SC 4/WG 21	SMRL Validation Team
ISO/TC 184/SC 4/WG 22	Reference data validation team
ISO/TC 184/SC 4/WG 23	Vocabulary validation team
ISO/TC 184/SC 4/WG 25	ISO CDD Validation Team
ISO/TC 184/SC 4/WG 26	Ontology-based interoperability NEW!

STEP 101

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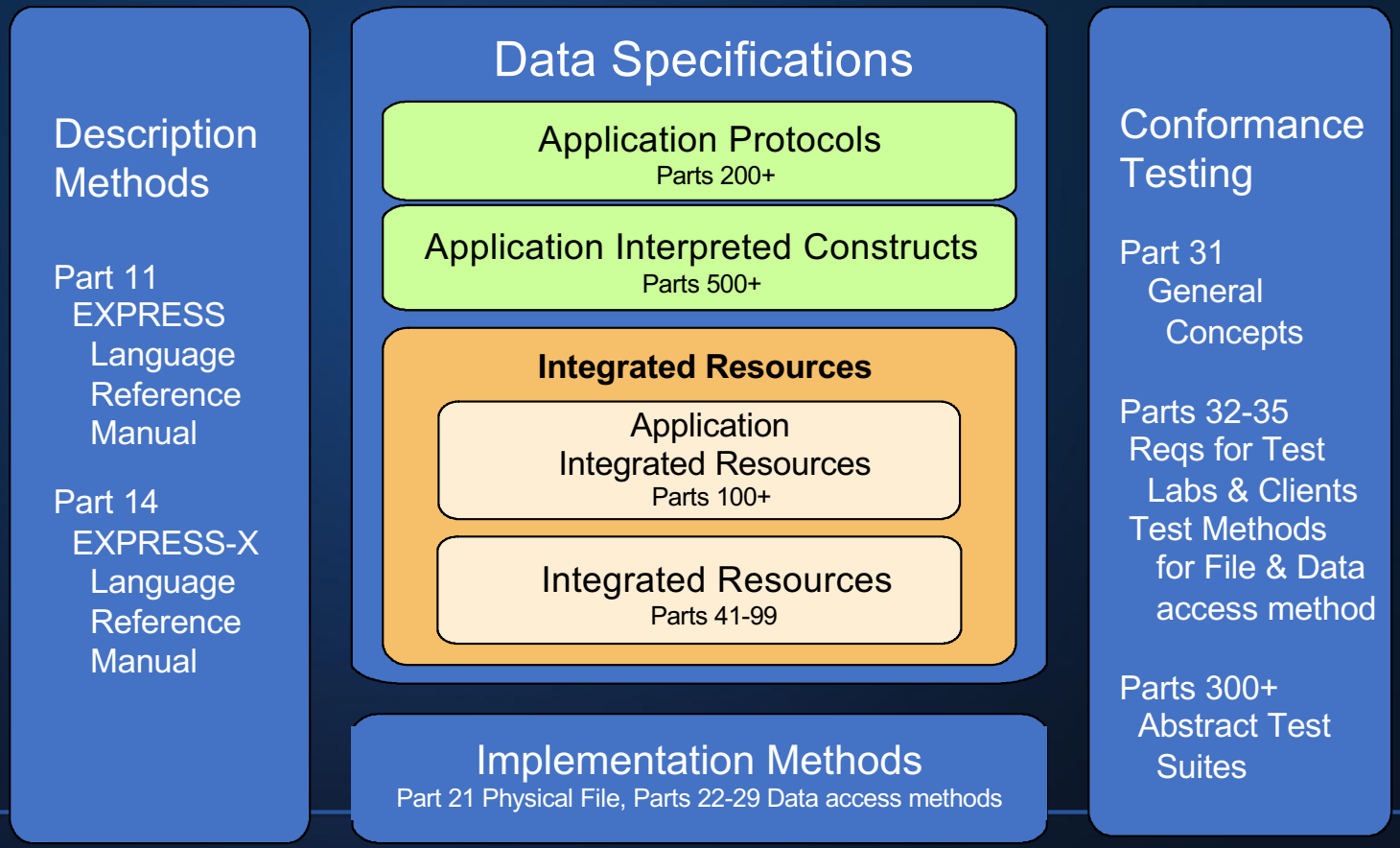
STEP – Designed to be Model-Based (in the 80s)

"ISO 10303 is an International Standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the lifecycle of a product, independent from any particular system. The nature of this description makes STEP suitable not only for neutral file exchange, but also as a basis for implementing, sharing product databases, and archiving ."

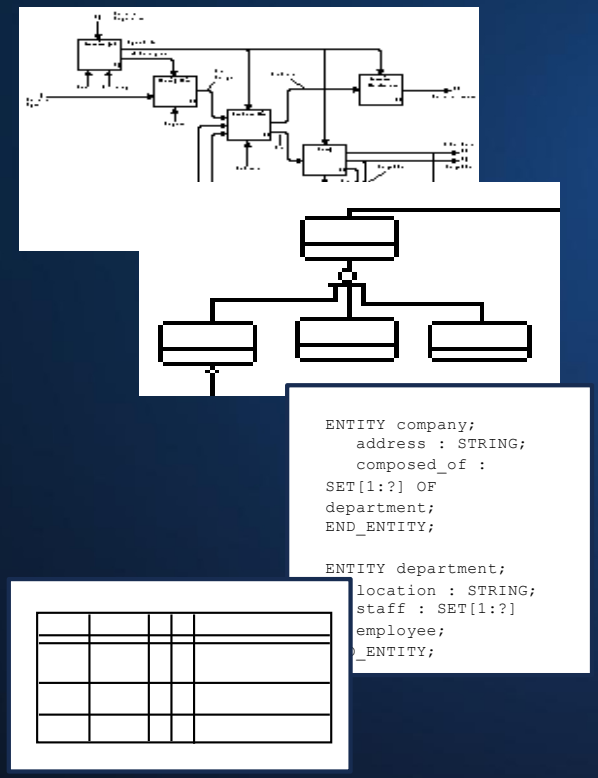
Key criteria

- STEP's large scope necessitates subdivision into Parts
- STEP is completely driven by industrial requirements.
- A formal data definition language is necessary (but not sufficient) for unambiguous definition of data.
- Separate data specifications from implementation methods.
- Conformance testing methods are built into the STEP architecture.

STEP Architecture (Classic)



Application Protocol Development



- ## Application Activity Model (AAM)

  A model that describes activities within the boundaries established by application context. This is a requirements gathering and scoping mechanism.

- ## Application Reference Model (ARM)

  A model that describes the information requirements and constraints for an application domain. The model uses application-specific terminology and rules that are familiar to domain experts.

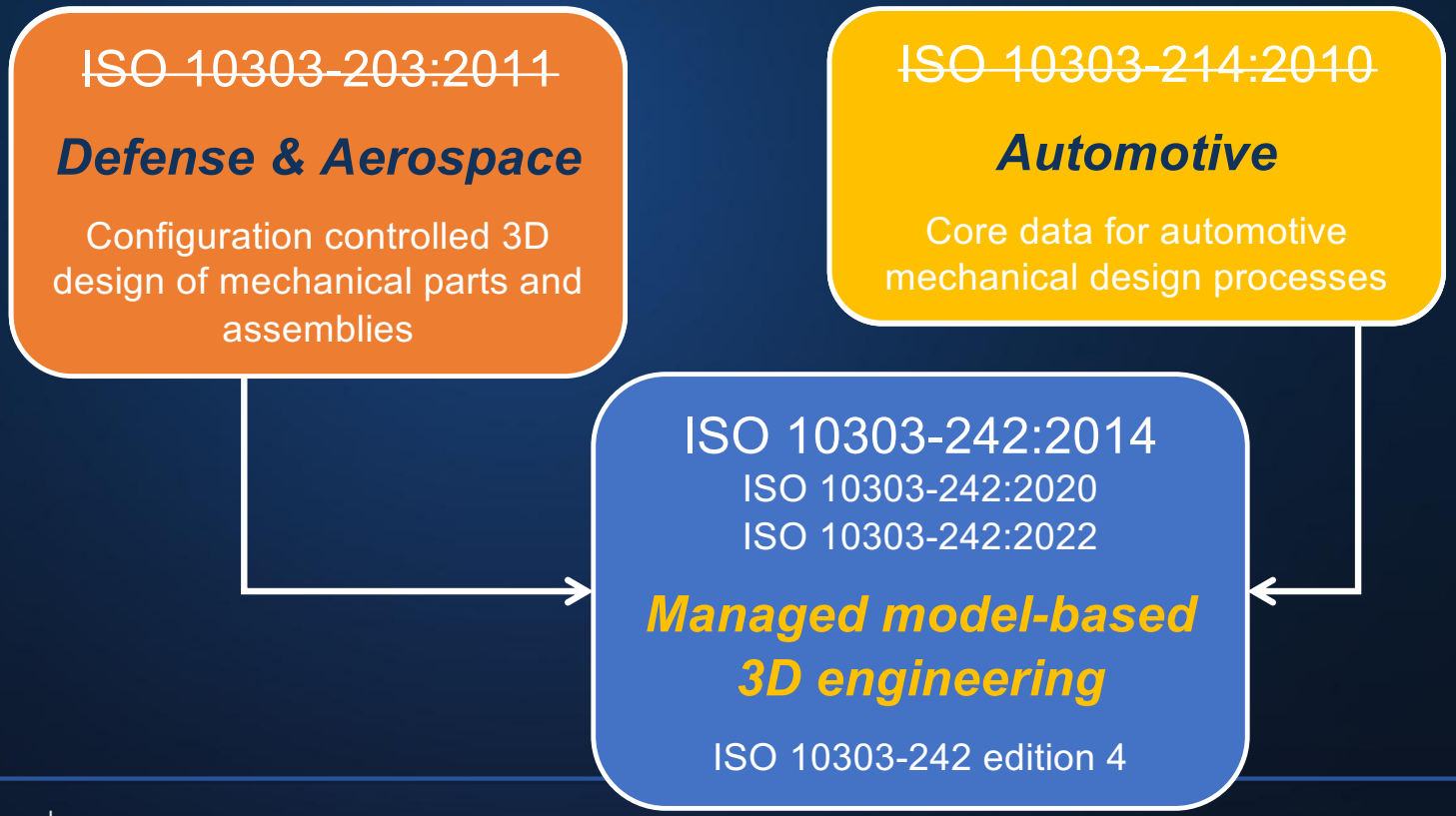
- ## Interpretation/Mapping

  The process of understanding application domain concepts and identifying and specializing the entities and patterns in the IRs that are semantically equivalent to the ARM concepts. A table that specifies the relationship between concepts in the ARM and constructs in the AIM.

- ## Application Interpreted Model (AIM)

  A model that specifies the STEP data structures that are semantically equivalent to the concepts documented in the ARM and AAM.

First Widely Adopted STEP APs



STEP Today

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STEP Architecture (Now)

Description Methods

New from 2021:
SysML XMI to XSD transformation

SysML XMI to EXPRESS transformation

EXPRESS to SysML CXMI transformation

SysML XMI to Web services transformation

Data Specifications

Application Protocols
Parts 200+

Application Modules
Parts 400+ and 1000+

Core and Domain Models
Parts 4000+1999

Integrated Resources
Parts 100-199

Integrated Resources
Parts 41-99

Implementation Methods

Part 21 Physical File, Parts 22-29 Data access methods

Interoperability Testing

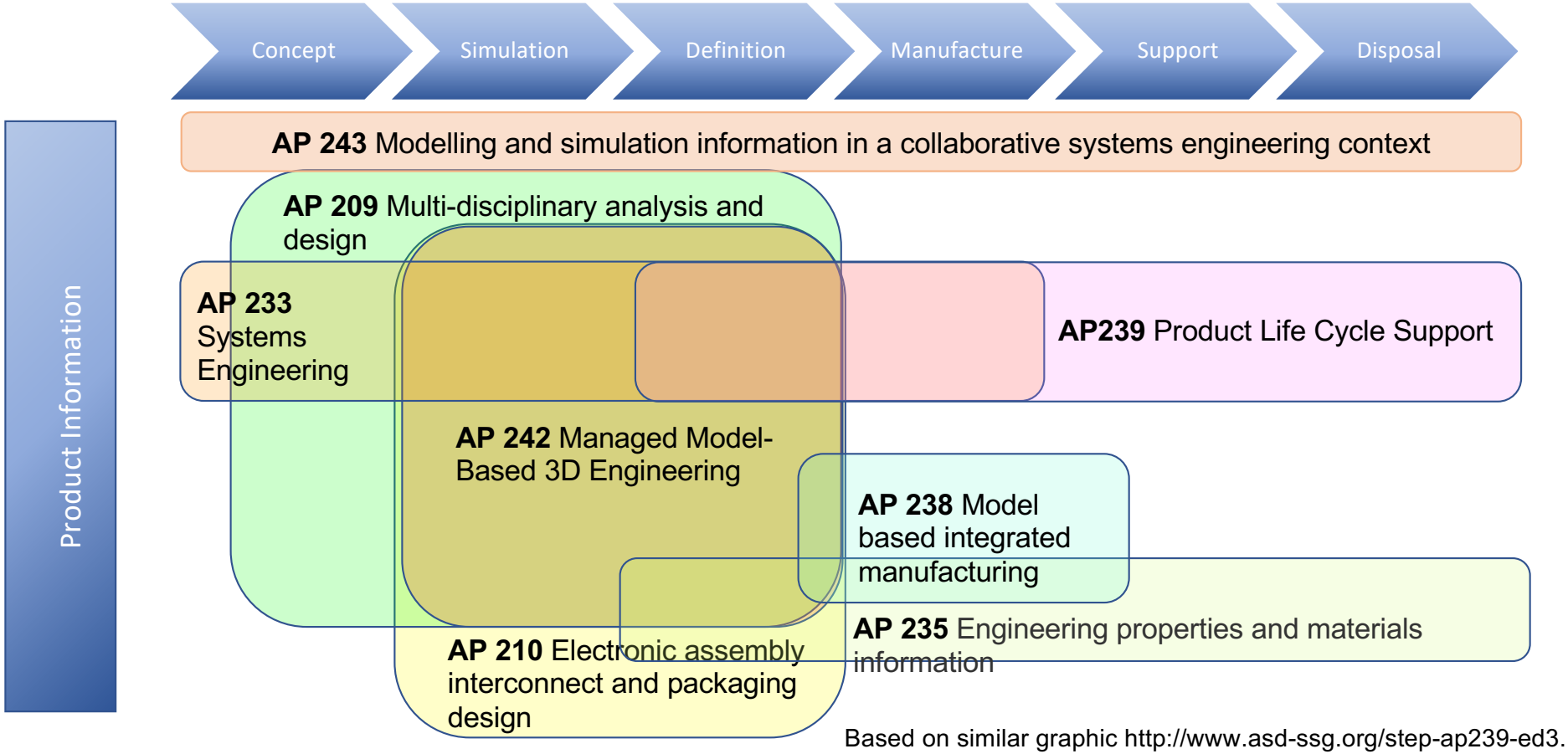
MBX-IF Umbrella Org.
- CAx – Shape, PMI
- EWIS – Wire Harness
- CAE – FEA

Each IF has User Group
- Requirement id and prioritization

Implementer Group
- Support test rounds

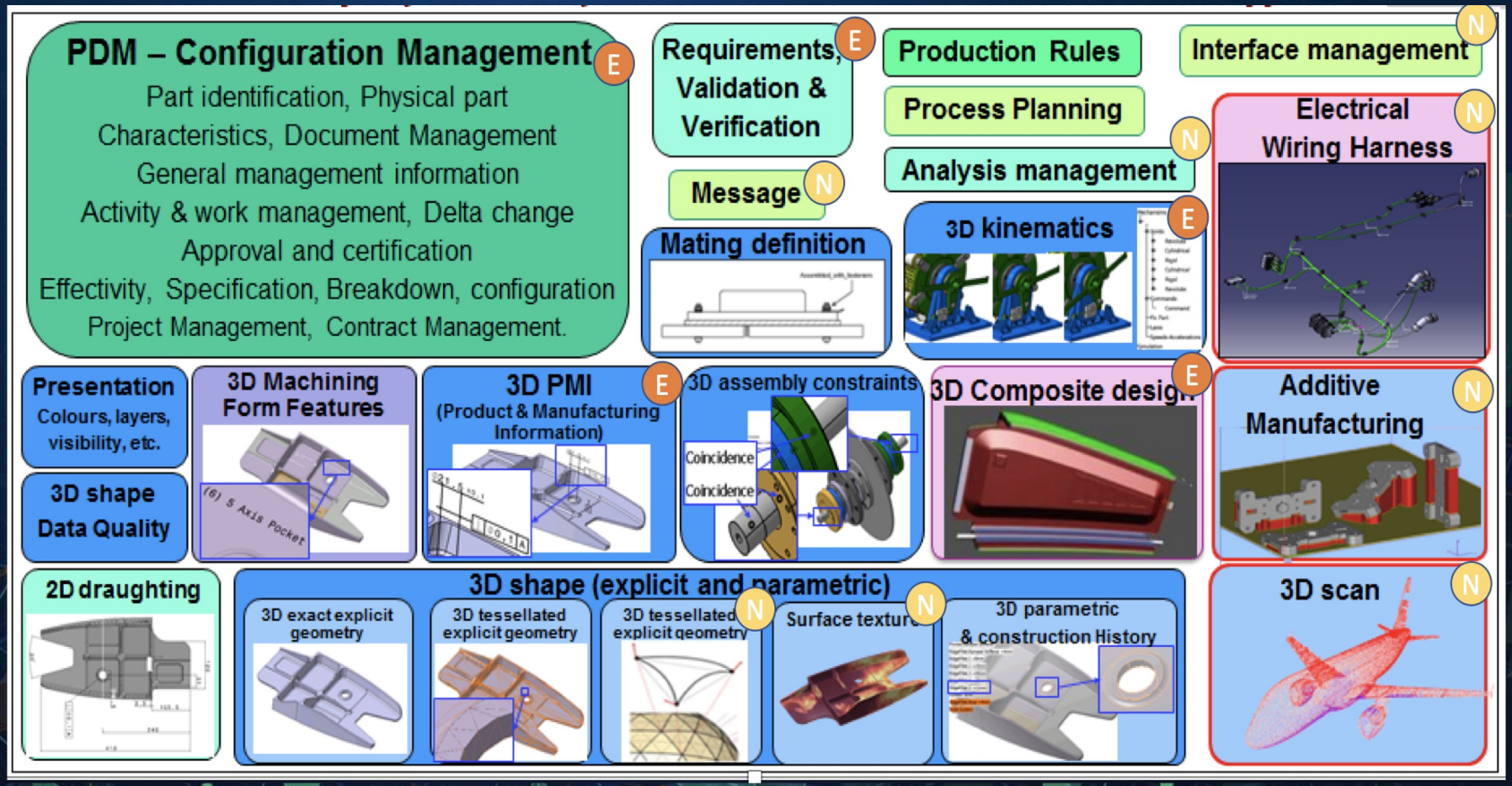
Produces Recommended Practices

ISO 10303 – Product Lifecycle Coverage



Based on similar graphic http://www.asd-ssg.org/step-ap239-ed3.

ISO 10303-242:2022 Current Capabilities



Source: www.AP242.org

ISO TC 184/SC 4 Product Data Standards

ISO 10303 Application Protocols

10303-209:2014	Multidisciplinary analysis and design, e2
10303-210:2021	Electronic assembly interconnect and packaging design, e4
10303-233:2012	Systems Engineering
10303-235:2019	Engineering properties and materials information, e2
10303-238:2022	Model based integrated manufacturing, e3*
10303-239:2012	Product life cycle support, e2*
10303-242:2022	Managed model based 3D engineering, e3*
10303-243:2021	For modelling and simulation information in a collaborative systems engineering context (MoSSEC)

Related SC 4 standards

ISO 23952:2020	Quality Information Framework – An integrated model for manufacturing quality information

ISO 23247 Digital twin framework for manufacturing

ISO 23247-1:2021	Overview and general principles
ISO 23247-2:2021	Reference architecture
ISO 23247-3:2021	Digital representation of manufacturing elements
ISO 23247-4:2021	Information exchange

* Denotes standards currently under revision

STEP Strengths

- Accurate data exchange
  - STEP has a long history of being able to accurately capture product definition and provide data interoperability between native systems
- Product data repurposing and reuse
  - CAM / CMM solution providers can use AP242 PMI representation data for the automation of manufacturing and inspection planning
- Consistent long term archival
  - LOTAR Int'l concluded STEP is stable for long term archival (>70 years) and recommends STEP for complying with NAS/EN 9300: *Long Term Archiving and Retrieval of digital technical product documentation such as 3D, CAD and PDM data*
- Widely implemented
  - STEP file exchanges number in the hundreds of millions annually
  - Savings through improved interoperability in $ billions annually

STEP Gaps and Challenges

- STEP currently lacks the geometric modeling formalism to perform reconciliation of CAx data across domains
  - This is an impediment to achieving *digital twins*
- STEP lacks persistent IDs for traceability to the authority CAD model through all process steps
- Implementations lag behind standards development – By a LOT! We lack robust implementation of manufacturing features in AP242.
- The STEP publication process depends on a brittle, bespoke toolchain.
- We need better and free tools that make our standards more attractive to entrepreneurs seeking to innovate in our ecostystem.
- We need people developing and championing the standard. Come join the fun!

Your tax dollars (and more!) at work

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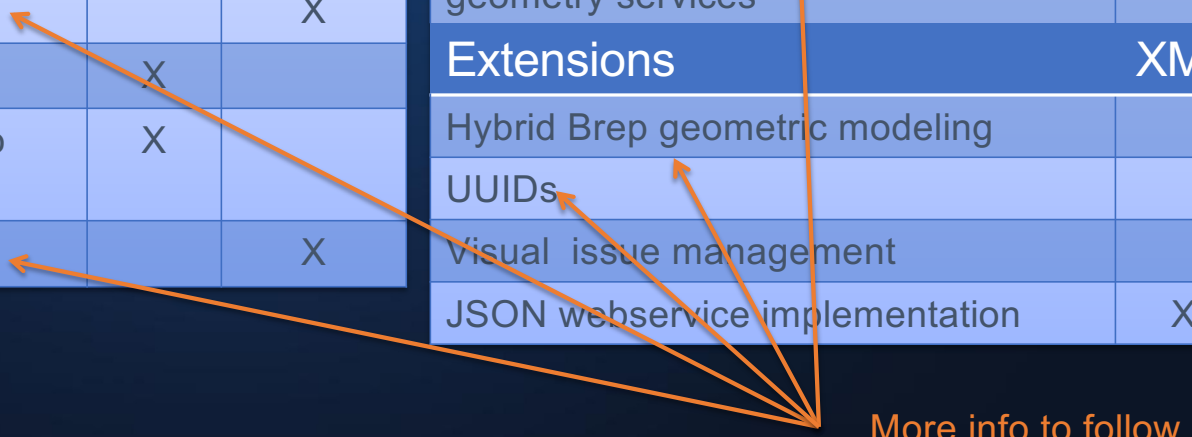
ISO 10303-242 edition 4

Updates	XML	Part 21
Assembly PMI	X	X
PMI		X
Product Data Quality ed3, PMI data quality and triangulated shape DQ		X
Composites harmonization		X
EWIS corrections	X	
Domain model mappings to ISO 4000	X	
Deprecate geometry AICs		X

Enhancements	XML	Part 21
Process planning harmonization with AP238/AP239	X	X
Integrate CAx-IF recommended practices in documentation	-	-
Bounding boxes and LOD for STEP geometry services	X	

Extensions	XML	Part 21
Hybrid Brep geometric modeling		X
UUIDs		X
Visual issue management		X
JSON webservice implementation	X	

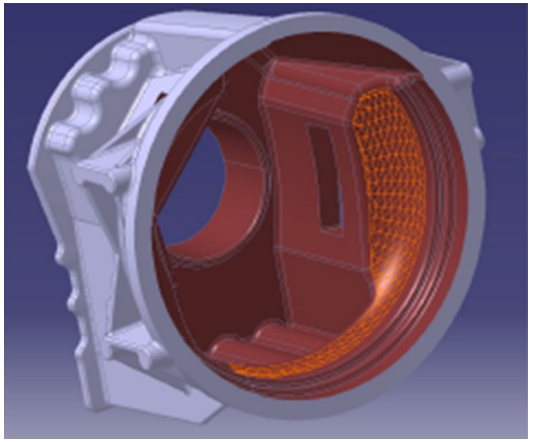


Hybrid Brep Geometric Modeling

Hybrid b-rep modeling offers formal integration of multiple sources and types of geometry into a single b-rep geometric model.

e.g., include facet geometry with precise geometry in a 3D model and edit seamlessly, without conversion.

STEP hybrid b-rep data structures support mappings to Polyhedral B-reps™ (Dassault Systèmes), Convergent B-reps™ (Siemens), Mixed Modeling (PTC onshape), etc.



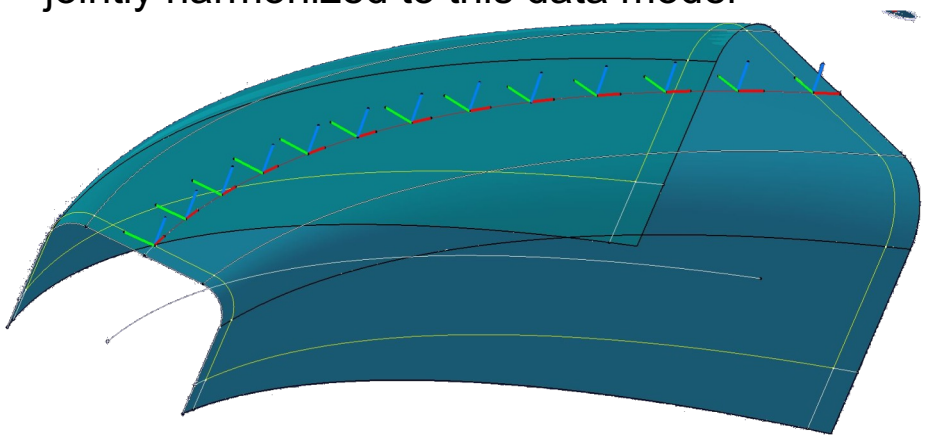
Torque converter
(courtesy of prostep ivip, used with permission)

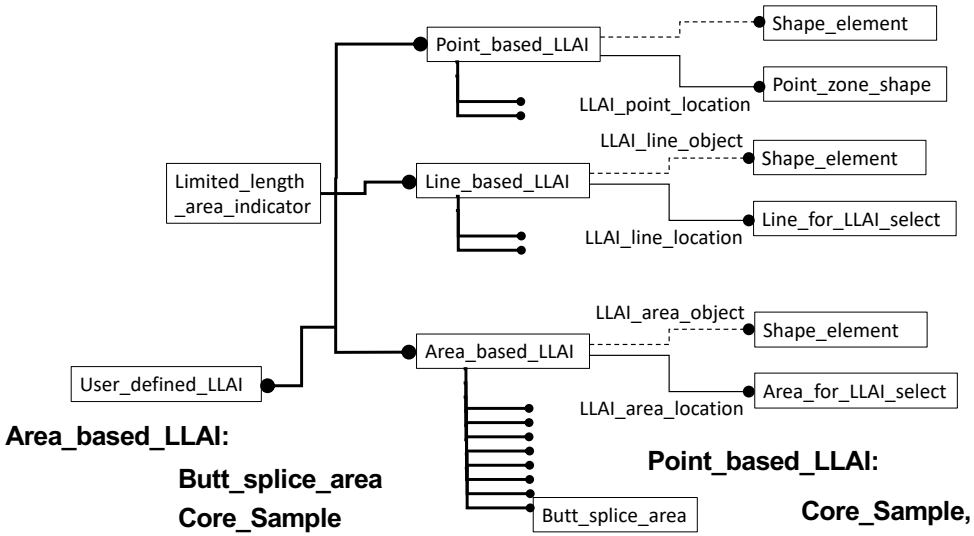
The new hybrid b-rep model:

- is consistent with geometric models and geometric model elements in ISO 10303-42 *Geometric and topological modeling;*
- is aligned with ISO 23952 *Quality information framework* hybrid geometric model;
- supports modeling requirements for Isogeometric Analysis (IGA).

Composite Structures Harmonization

- New STEP capability for intelligent notes with associated specifications for laminate tables
- 10303-1854 Limited length or area indicator assignment (LLAI) – published
  - An LLAI may be associated with point, line, or area aspects of a laminate table or components of a laminate table
- 10303-1854 and ASME Y14.37 have been jointly harmonized to this data model





Area_based_LLAI:

Butt_splice_area
Core_Sample
Darting_area
Fiber_orientation_angle_tolerance_deviation_area
Manufacturing_edge_of_part
Manufacturing_edge_of_ply
No_splice_area
Overlap_splice_area
Ply_drop_off_stay_out_area
Ply_wrinkle_allowance_area
Potting_area
Stitching_area
Strategy_Point

Point_based_LLAI:

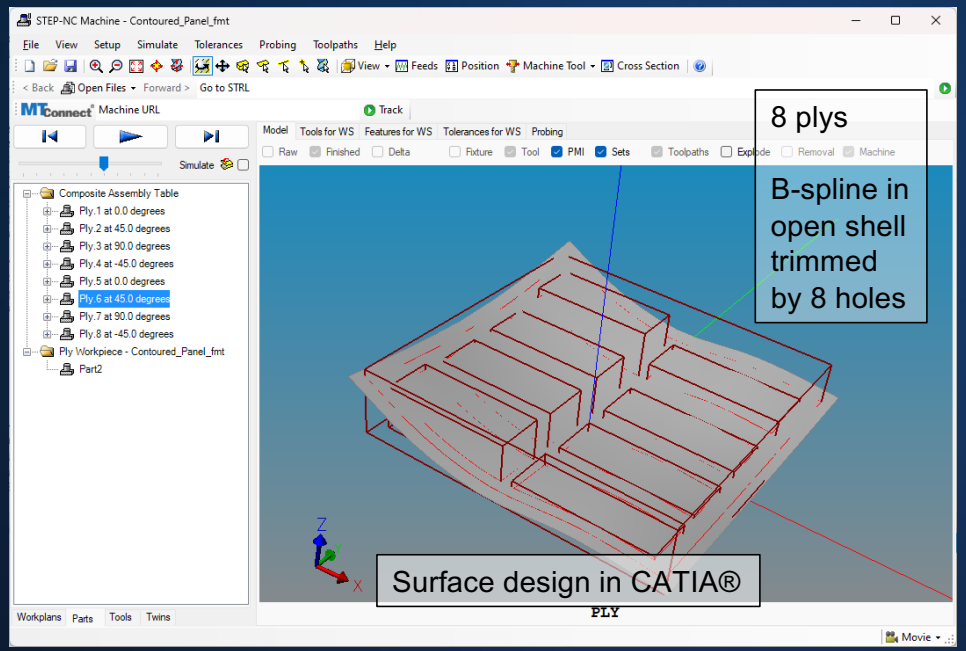
Core_Sample,
Strategy_point

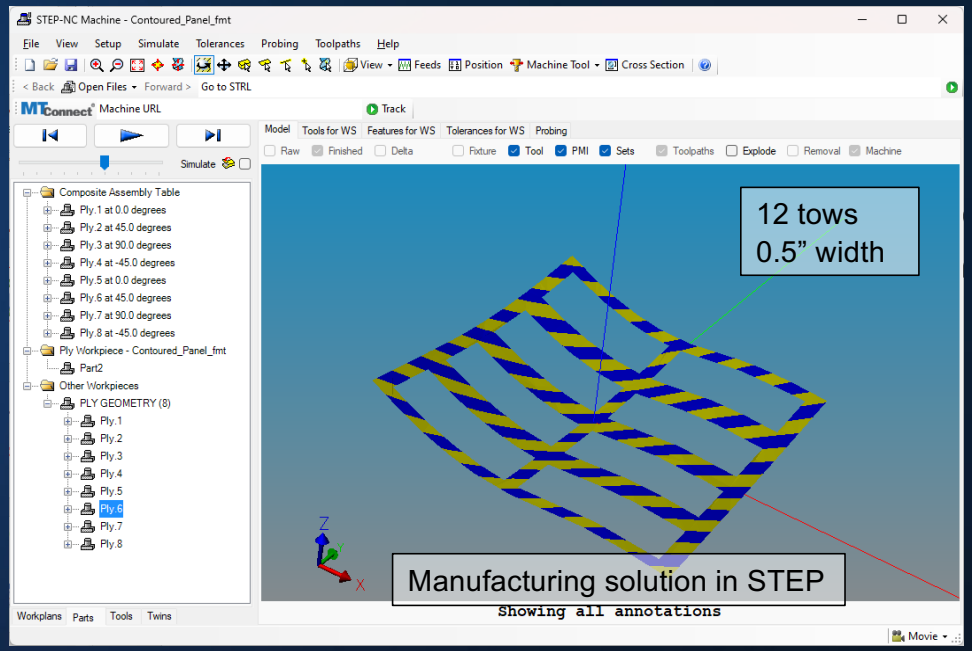
Line_based_LLAI

Edge_Sealing
Guide_Curve

User_defined_LLAI

Composites Manufacturing in AP238 E4





Phase 1 (CD) – Plan manufacturing solution for AP242 model

Phase 2 (DIS) – Test manufacturing solution on tape layup machine

Phase 3 (IS) – Build digital twin of laid solution and analyze for gaps

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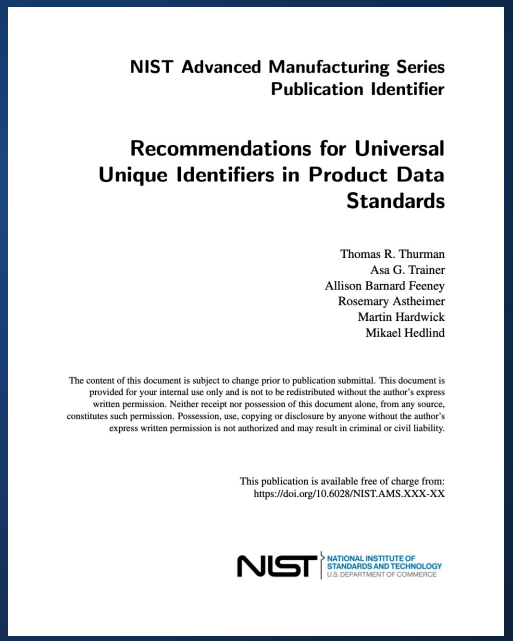
UUIDs in Product Data Standards

Associating UUIDs, combined with human-readable identifiers, to key manufacturing requirements, enables the enterprise to track all information related to that requirement over the life of the product.

The lack of standards and commercial engineering software support of UUIDs is a major roadblock to realizing the promises of the digital thread and model-based enterprise.



NIST Advanced Manufacturing Series
Publication Identifier

Recommendations for Universal Unique Identifiers in Product Data Standards

Thomas R. Thurman
Asa G. Trainer
Allison Barnard Feeney
Rosemary Astheimer
Martin Hardwick
Mikael Hedlind

This publication is available free of charge from:
https://doi.org/10.6028/NIST.AMS.XXX-XX

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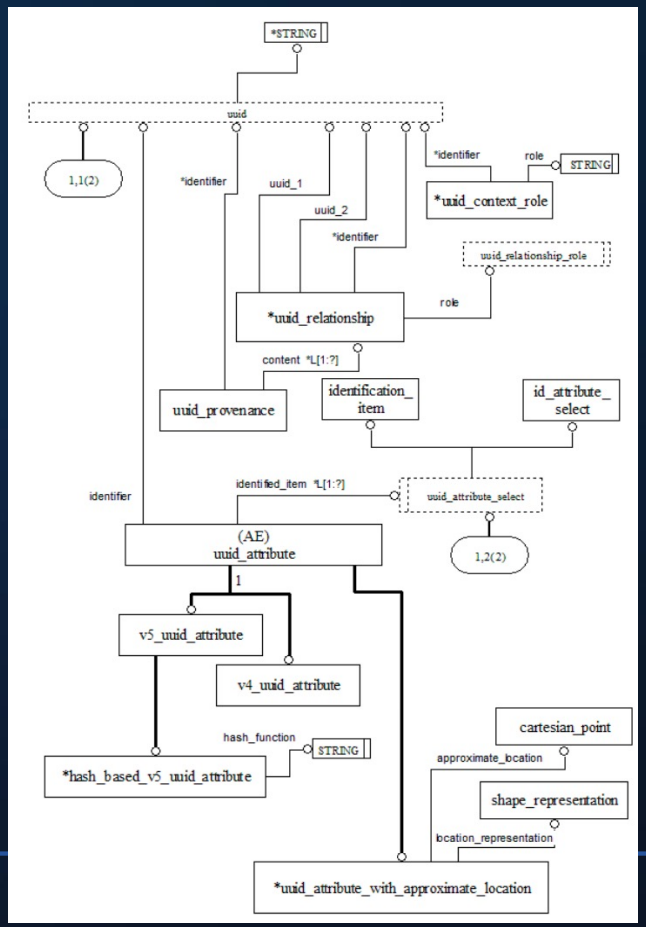
```
ENTITY uuid_attribute;
  ABSTRACT SUPERTYPE OF(ONEOF(
    v5_uuid_attribute,
    v4_uuid_attribute)
    ANDOR uuid_attribute_with_approximate_location);
  identifier             : uuid;
  identified_item : LIST [1:?] OF UNIQUE LIST [1:?] OF
  UNIQUE uuid_attribute_select;
 UNIQUE
  UR1 : identifier;
END_ENTITY;
```



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EasyEXPRESS – Editing Support for EXPRESS

EXPRESS language server

Integrates EXPRESS model validation with authoring environment.

Reduces cognitive load on modelers

Common code editing conventions provide integrated and real-time feedback:

- red squiggly lines identify errors
- syntax highlighting for visual navigation
- traditional development features such as IntelliSense, Code Navigation, or Symbol renaming.

Available through the Visual Studio Code Marketplace @

https://bit.ly/49DfBfA

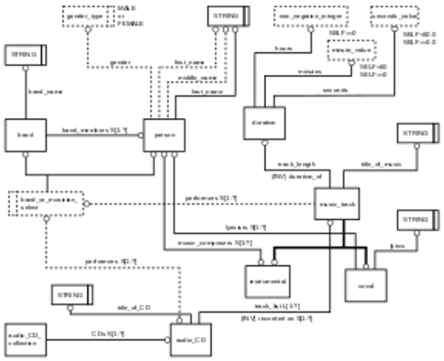
```
1  SCHEMA Nist;
2
3  USE FROM Help (Date, getAge);
4
5  ENTITY Person;
6  firstName: STRING;
7  lastName: STRING;
8  dateOfBirth: Date;
9  END_ENTITY;
10
11 ENTITY Employee SUBTYPE OF (Persson);
12 WHERE:
13 WR1: getAge(SELF.dateOfBirth) > 16;
14 END_ENTITY;
15
16 END_SCHEMA;
```

Same EXPRESS model with easyEXPRESS visual feedback

ISO/TC 184/SC 4/TF 1

SMRL architecture innovation

- ISO/TC 184/SC 4/WG 12 manages a tool chain for a computer generated version of ISO 10303 that fully integrates all the parts of the standard, performs integrated quality checks and publishes to ISO.
- Project will deploy a GIT source code control server and associated defect management system within the ISO IT infrastructure enabling the concurrent development of ISO 10303 and its parts, including models, schemas, validation and modeling tools.
- The SMRL will be refactored into a STEP Reference Library (SRL) resulting in significant reduction in publications and improvement in quality.
- Prototype for other TC's to follow for standards where code management techniques are a better fit than document management.



Express Modeling Language

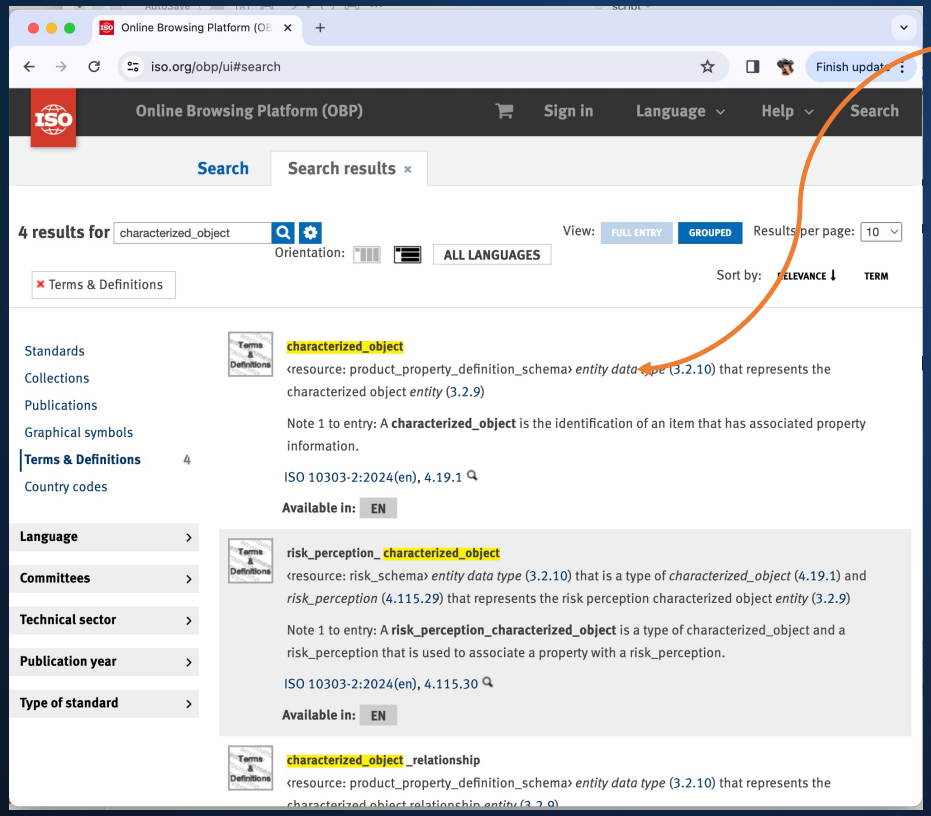
GitLab

GitHub

OMG SYSTEMS MODELING LANGUAGE™ SysML®

JIRA

ISO 10303-2:2024 Part 2: Vocabulary



‹resource: product_property_definition_schema› *entity data type* (

Hot off the presses!

STEP Part 2 contains all of the vocabularies in each part of the standard.

e.g., for an AP –

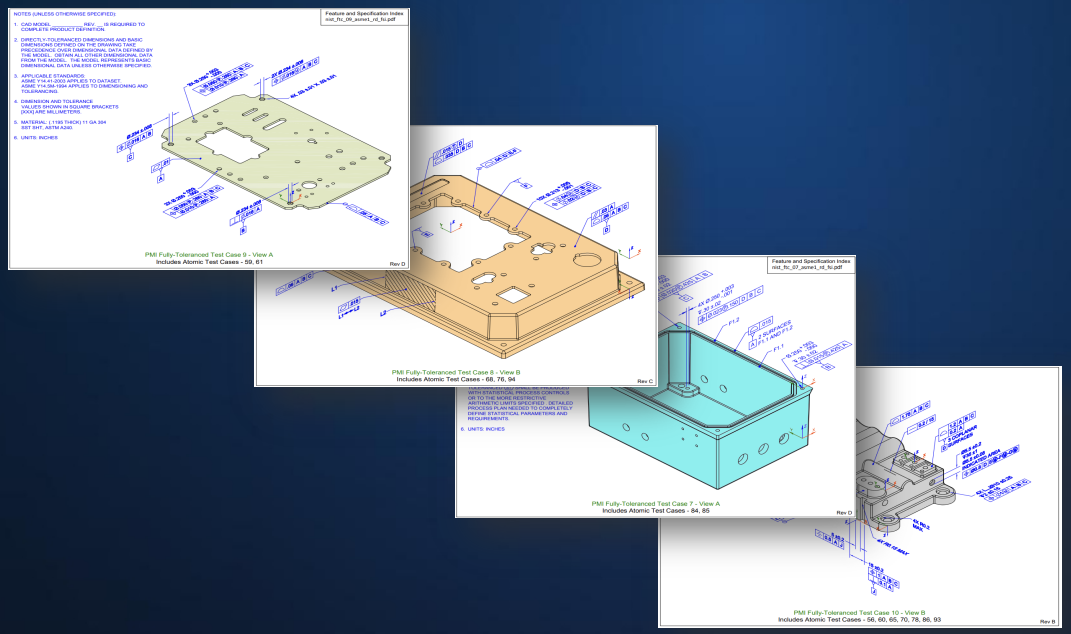
- Clause 3 Terms and definitions
- Clause 4 Application objects
- Clause 5 Interpreted model entities and types

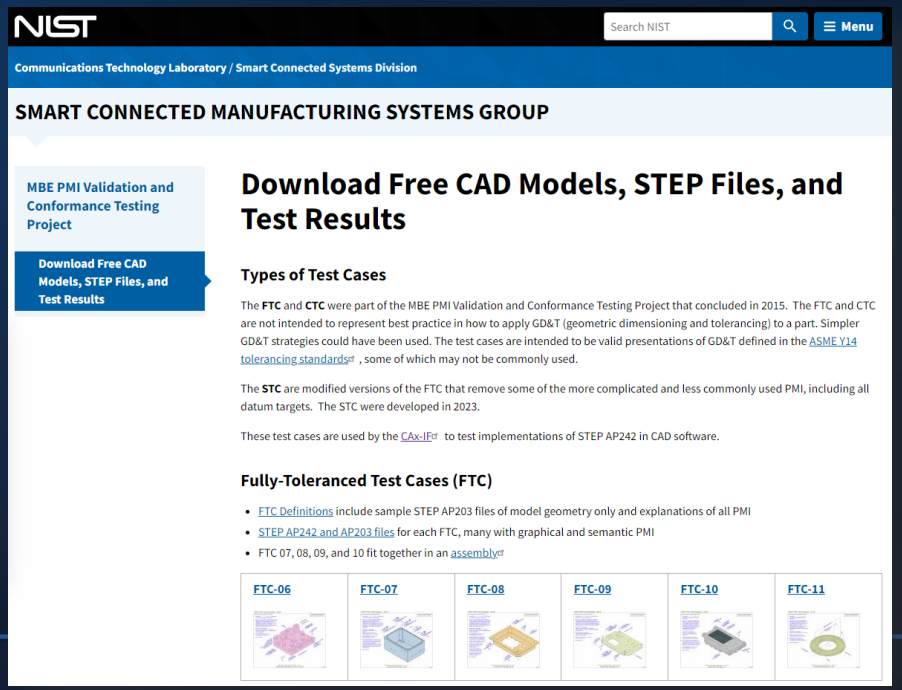
Every STEP definition is readable for free, via ISO's online-browsing platform.

https://www.iso.org/obp/ui

NIST Test Models

- Translated by and exchanged between vendors



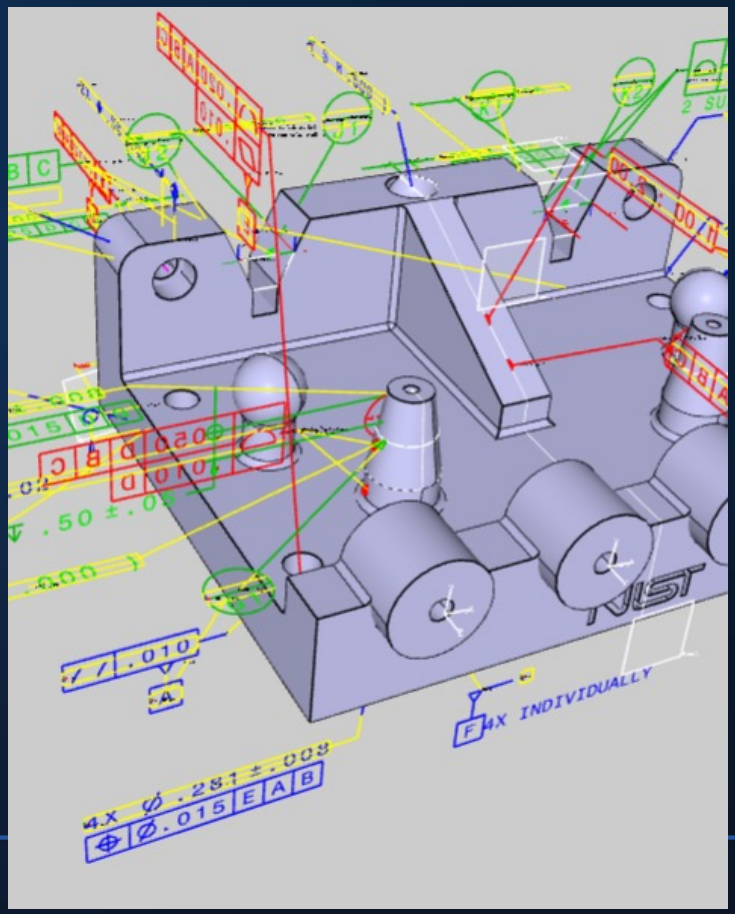


https://go.usa.gov/mGVm

NIST STEP File Analyzer and Viewer

- Generates spreadsheet of all entities and attributes
- Analyzes STEP files for conformance to CAx-IF Recommended Practices
  - Semantic PMI, Graphic PMI, Validation Properties
- Checks for basic STEP file format errors
- Viewer displays in a web browser
  - Geometry: b-rep, tessellated, supplemental, sketch
  - Graphical PMI, annotation placeholder, datum targets
  - Saved view viewpoints, section view clipping planes
  - AP209 finite element analysis model
  - Cloud of points validation property, point clouds
- Bill of Materials of assemblies and components

https://go.usa.gov/xuh9V



ISO 10303 - Resources

NIST Publication Portal https://www.nist.gov/publications
- Rich history of STEP involvement and publications
- Keywords: STEP, ISO 10303, Product Data Standards, etc.
- Authors: J. Lubell, A. Barnard Feeney, D. Libes, S.N. Clark, T. Hedberg, etc.

ISO TC 184-SC 4 committee website.
- User-oriented information about the subcommittees work. https://committee.iso.org/home/tc184sc4

MBx Interoperability Forum.
- Hosts user groups, vendor test rounds and produces recommended practices for implementation. https://www.mbx-if.org/index.php
- Recommended practices https://www.mbx-if.org/cax/cax_recommPractice.php

AP242 project website.
- Background on development of AP242 and its first two editions. www.ap242.org

STEP AP242 Day 2022 (and other years) webpages.
- Presentations include use cases, interoperability testing plans, vendor status reports. https://www.afnet.fr/en/feedback-afnet-prostep-ivip-step-ap242-day/

Questions?

Reach out:

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