

In partnership with



AFNeT Standards Days

Interoperability of structural joints for assembly & installation based on AP242

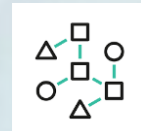
Pierre Duchier (AIRBUS)

- Motivation for the data interoperability of structural joints for assembly & installation
- Business values of a model based definition
 - Visual presentation / semantic representation
- Activities related to ISO 10303 standard for structural joints for assembly & installation
- LOTAR requirements for Assembly/Installation with fasteners
- Assembly/Installation with fasteners essential information
- STEP AP242 Managed model-based 3D engineering
 - Semantic representation of 3D GD&T
 - Machining features
 - Recommended practices for hole and fastener assembly installation
- LOTAR pilot for hole and fastener
- Future perspectives

Motivation for the data interoperability of structural joints for assembly & installation



Data volumetry



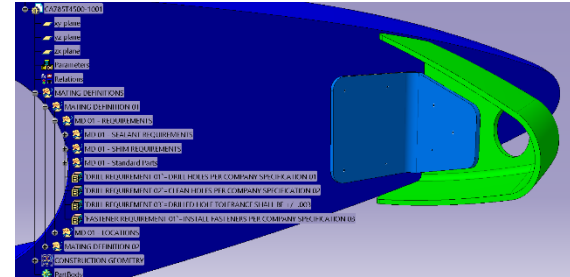
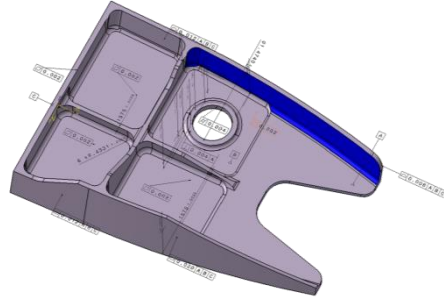
Semantic data

Business values of a model based definition

Before CAD system



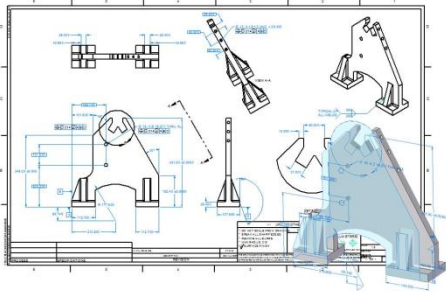
With CAD system



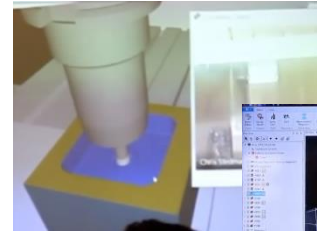
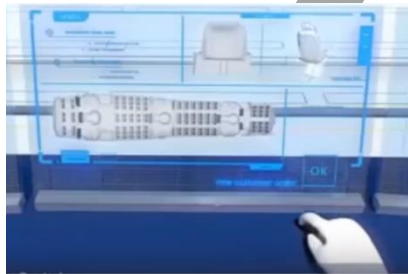
explicit 3D model with annotations

3D model based definition with PMI

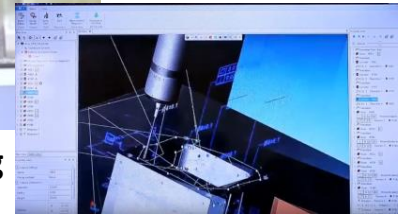
2D Drawing



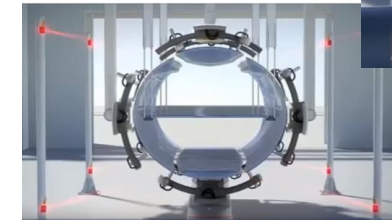
3D viewer



NC machining



NC metrology



Laser tracking

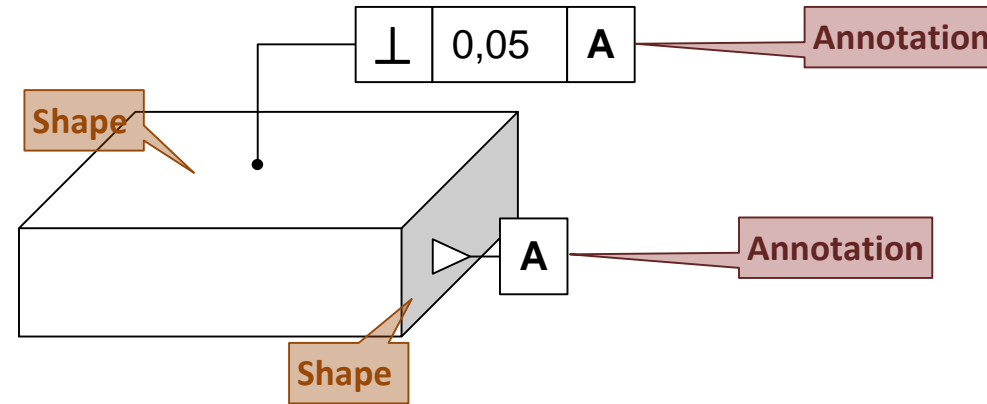


Robot

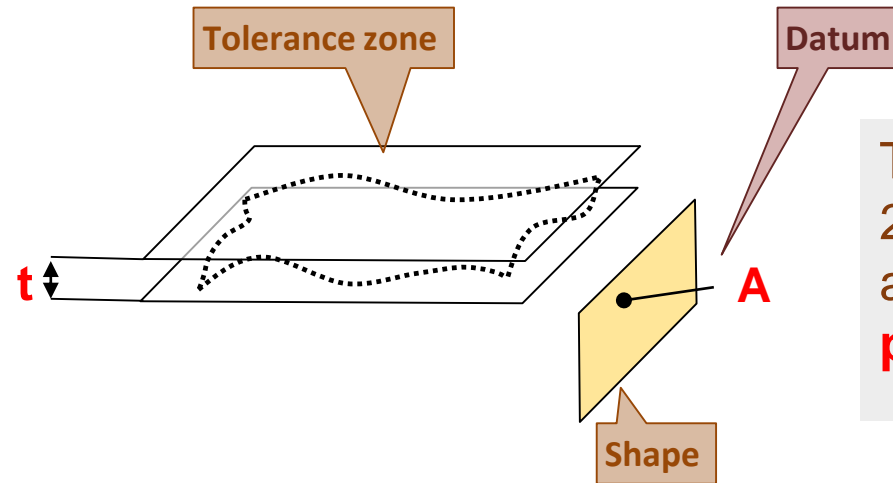
Human

automatic consumption by machines / computers / applications

Visual presentation of the geometric tolerance



Semantic representation of Geometrical tolerance



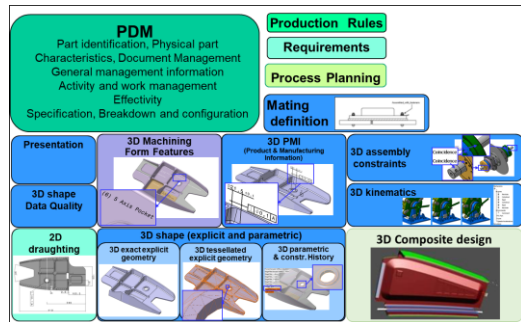
The **tolerance zone** is limited by 2 parallel planes a distance $t=0.05$ apart and **perpendicular** to the datum **A**



- LOTAR International objective: develop, test, publish and maintain standards for **long-term archiving** of digital data. EN / NAS 9300
- LOTAR Mechanical working group
 - released standards for LTA of **3D, Assembly structure**, Product and Manufacturing Information (**PMI**).
 - In development: LOTAR P132: Structural joints for assembly & installation



ISO 10303-242



CAX Interoperability Forum

CAX-IF: implementation and testing of the STEP AP242 standard based on **user group** requirement and use cases.

Capability #1 Assembly and installation with fasteners and holes



AEROSPACE & DEFENSE PLM ACTION GROUP

A&D PLM Action group / MBD working group / Minimum Model-Based Definition (MBD) for Type Design Certification

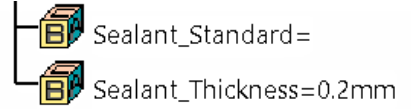
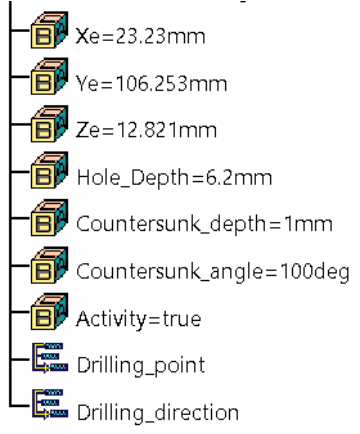
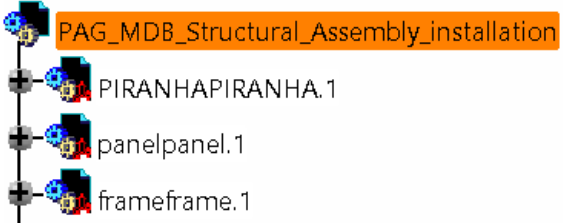
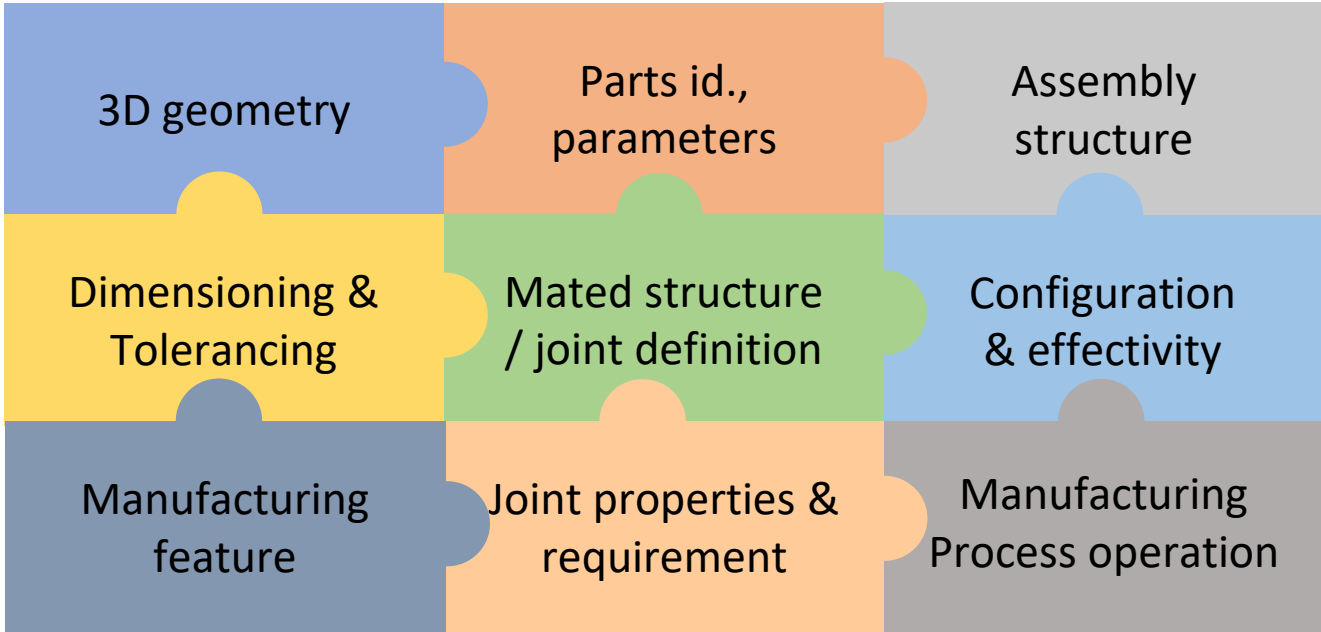
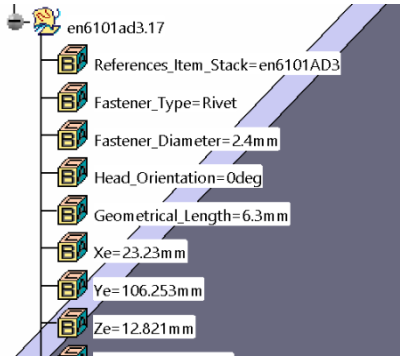
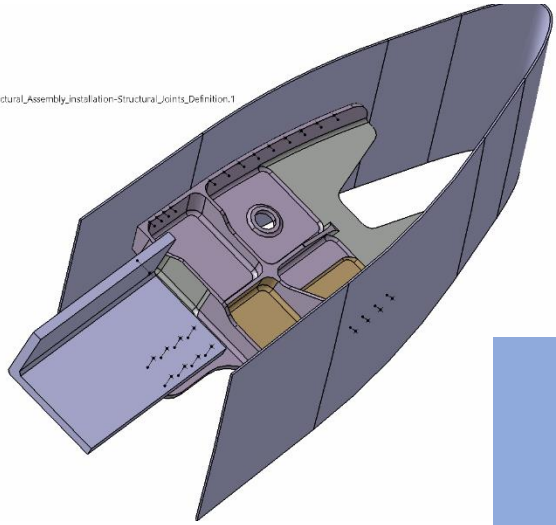


Mating Requirements – Fastener Stack up	List of fastener hardware, represented as attributes/parameters in the model tree
Mating Requirements – Joining Parts	List of components being joined, along with material type and thickness ordered from the head side of the fastener; represented as attributes/parameters in the model tree

- Need to part numbers (**identifiers**) of fastener parts, e.g. fastener, washers, nutplates, nuts, etc.
- Need to represent fastener **location and orientation**.
- Need to identify the ordered sequence of how the fasteners are installed, e.g., the **stackup** of the fastener and the parts being joined either explicitly via geometry or implicitly.
- Fastener parts may be explicitly modeled or implicit by reference (need to define **parameters** for fasteners, e.g. library reference to a standard part)
- Hole features may be **explicitly modeled or implicit**.
- Need to associate **requirements and/or specifications** with a fastener instance (specific occurrence or location). Requirements may be applicable to the fastener or the hole.
- Requirement could be a text string, e.g., “Torque to XX N-m”,
- A reference to a specification, e.g., “Seal per Company Specification XXX”. Reference could be represented as a test string and/or a document reference such as URL.
- Where fastener instances share common requirements and/or specifications, need to group the instances together into a collection or group.
- Need to identify collector object to consume into MBOM

Assembly/Installation with fasteners: essential information

Structural_Assembly_installation-Structural_Joints_Definition.1



STEP AP242 Managed model-based 3D engineering

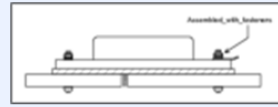
PDM – Configuration Management E

Part Identification, Physical Part Characteristics, Document Management
 General Management Information
 Activity & Work Management, Delta Change Approval And Certification
 Effectivity, Specification, Breakdown, Configuration Project Management, Contract Management.

Requirements, Validation & Verification E

Message N

Mating definition N

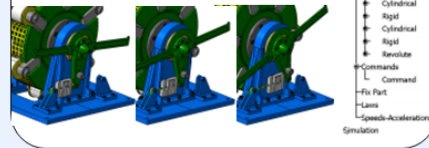


Production Rules

Process Planning

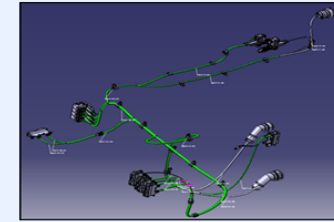
Analysis Management N

3D Kinematics E



Interface Management N

Electrical Wiring Harness N

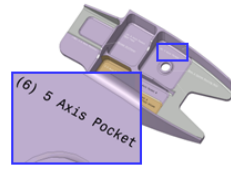


Equivalence Validation N

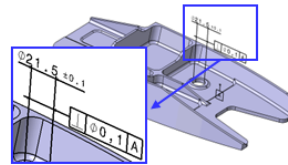
3D Shape Data Quality

Presentation (Colours, layers, etc)

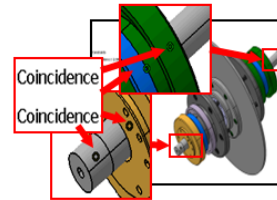
3D Machining Form Features N



3D PMI (Product & Manufacturing Information) E



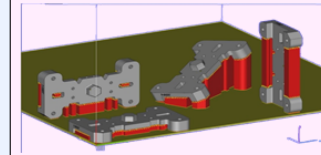
3D assembly Constraints E



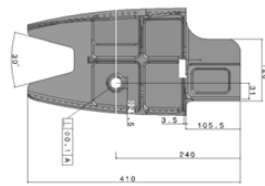
3D Composite Design E



Additive Manufacturing N

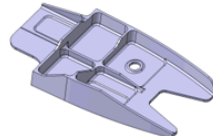


2D Draughting

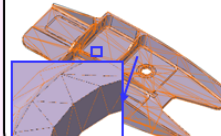


3D shape (explicit and parametric) N

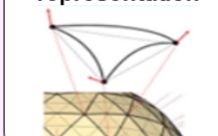
3D Exact Explicit Geometry N



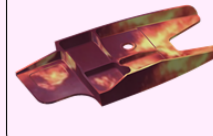
3D Tessellated Explicit Geometry N



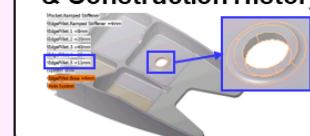
3D curved triangle representation N



Surface Texture N



3D Parametric & Construction History N



3D scan N



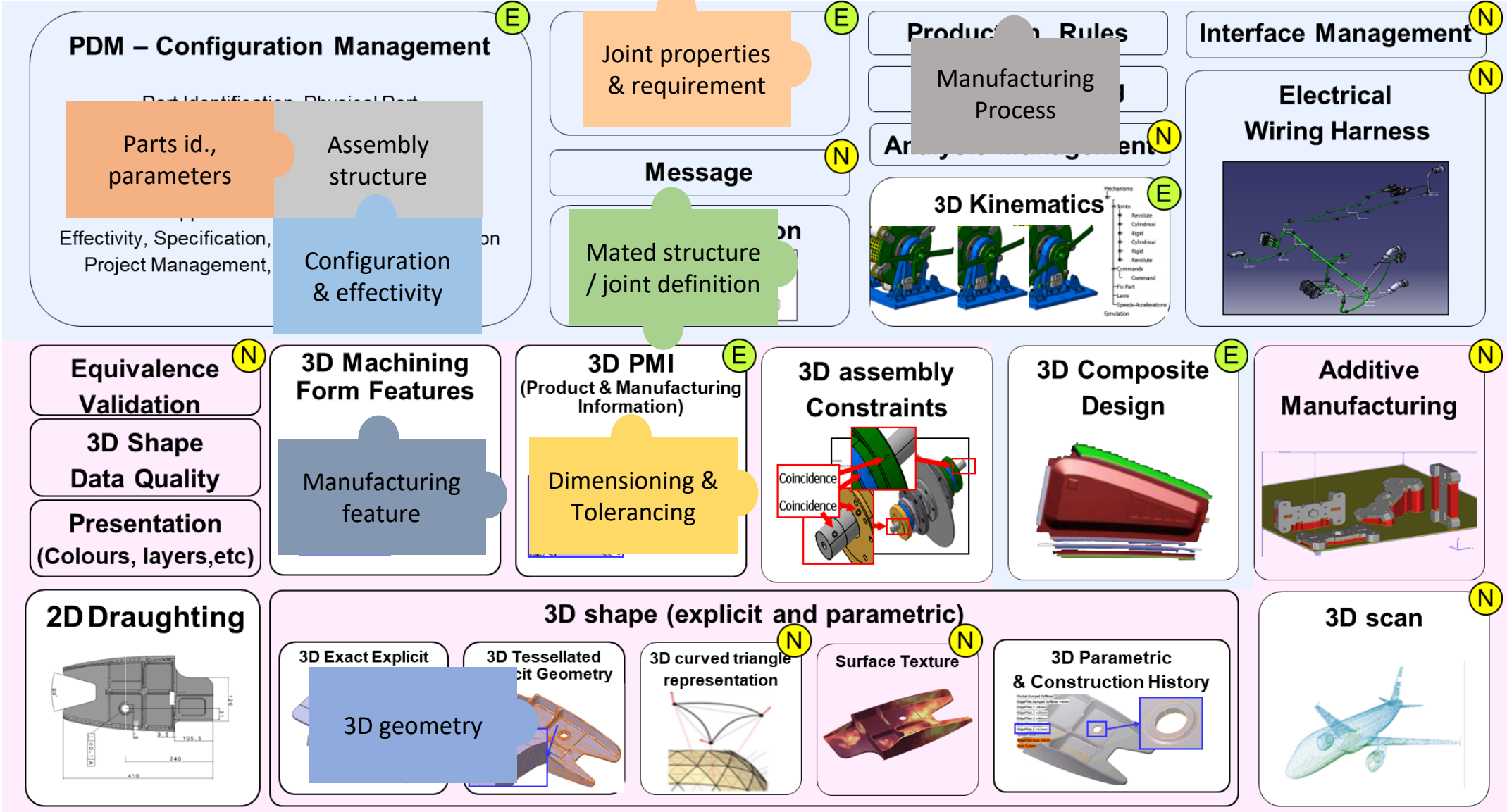
Enhancement E

New (Extension) N

Domain model + AP module

AP Module only

STEP AP242 Managed model-based 3D engineering



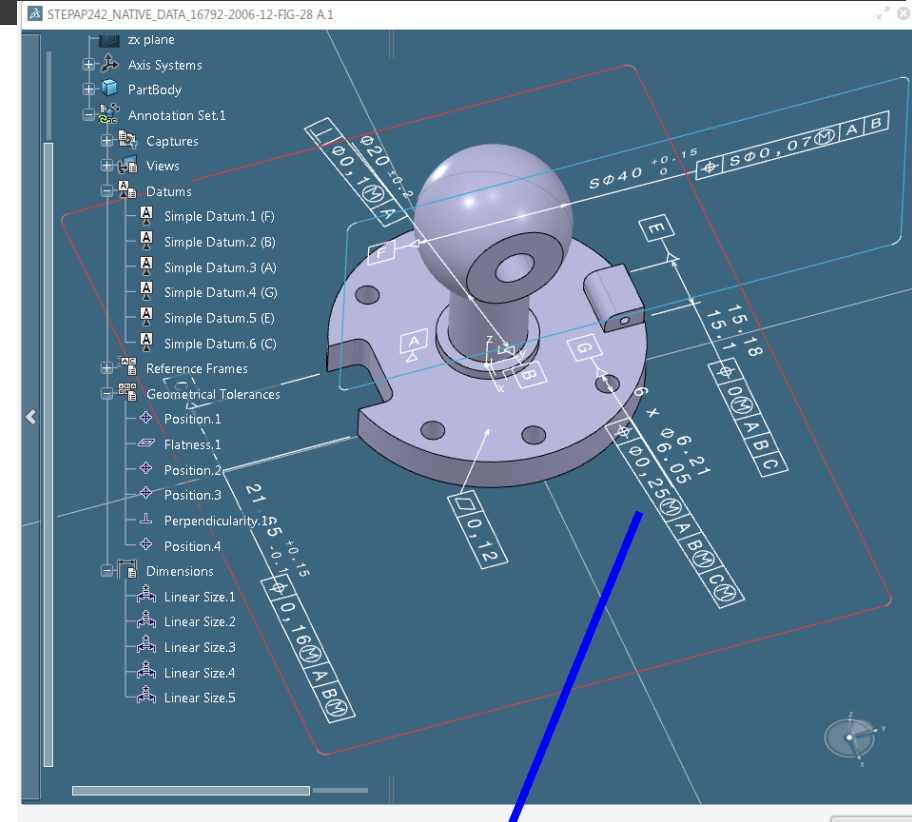
Enhancement (E) New (Extension) (N) Domain model + AP module AP Module only

semantic representation of 3D GD&T in STEP AP242

3D geometry

Dimensioning & Tolerancing

PMI symbol	Design Standard	STEP AP242 ed 1	
		status	STEP AIM entity
Geometric tolerance			
—	ISO 1101	YES	straightness_tolerance
▧	ISO 1101	YES	flatness_tolerance
○	ISO 1101	YES	roundness_tolerance
⊘	ISO 1101	YES	cylindricity_tolerance
⌒	ISO 1101	YES	line_profile_tolerance
⌒	ISO 1101	YES	surface_profile_tolerance
//	ISO 1101	YES	parallelism_tolerance
⊥	ISO 1101	YES	perpendicularity_tolerance
∠	ISO 1101	YES	angularity_tolerance
⌒	ISO 1101	YES	line_profile_tolerance
⌒	ISO 1101	YES	surface_profile_tolerance
⊕	ISO 1101	YES	position_tolerance
◎	ISO 1101	YES	concentricity_tolerance
◎	ISO 1101	YES	coaxiality_tolerance
≡	ISO 1101	YES	symmetry_tolerance
⌒	ISO 1101	YES	line_profile_tolerance
⌒	ISO 1101	YES	surface_profile_tolerance
↗	ISO 1101	YES	circular_runout_tolerance
↗↗	ISO 1101	YES	total_runout_tolerance



Extract of STEP AP242 file:

```
#2708=(GEOMETRIC_TOLERANCE('Position.2',#2706,#2619)GEOMETRIC_TOLERANCE_WITH_DATUM_REFERENCE((#2497)GEOMETRIC_TOLERANCE_WITH_MODIFIERS((.MAXIMUM_MATERIAL_REQUIREMENT.,.COMMON_ZONE.))POSITION_TOLERANCE());
#2706=(LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()MEASURE_WITH_UNIT(LENGTH_MEASURE(0.25),#2705)QUALIFIED_REPRESENTATION_ITEM((#2707)REPRESENTATION_ITEM("));
```

Dedicated objects in STEP AP242 for the semantic of GD&T

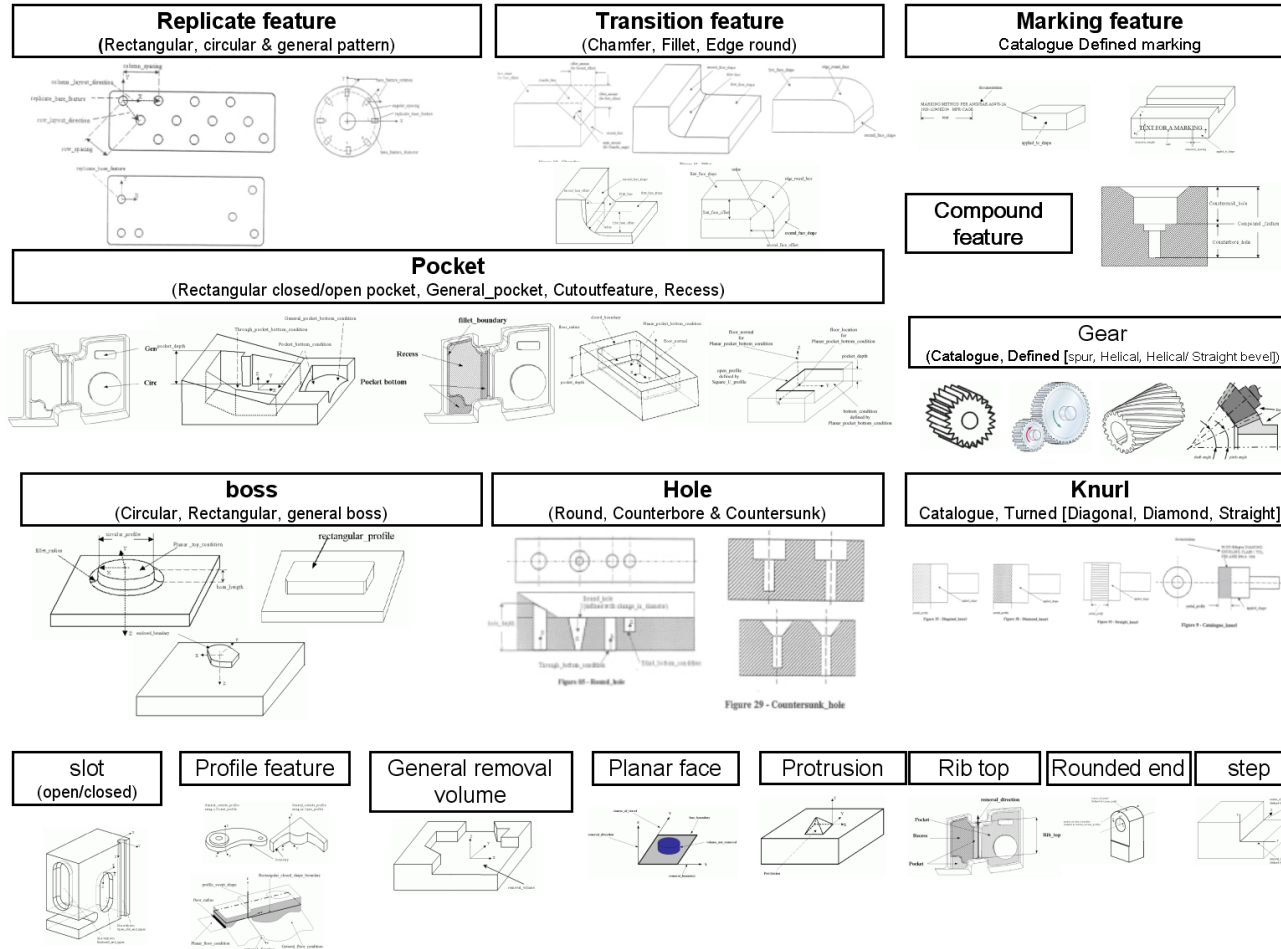
3D geometry

Dimensioning & Tolerancing

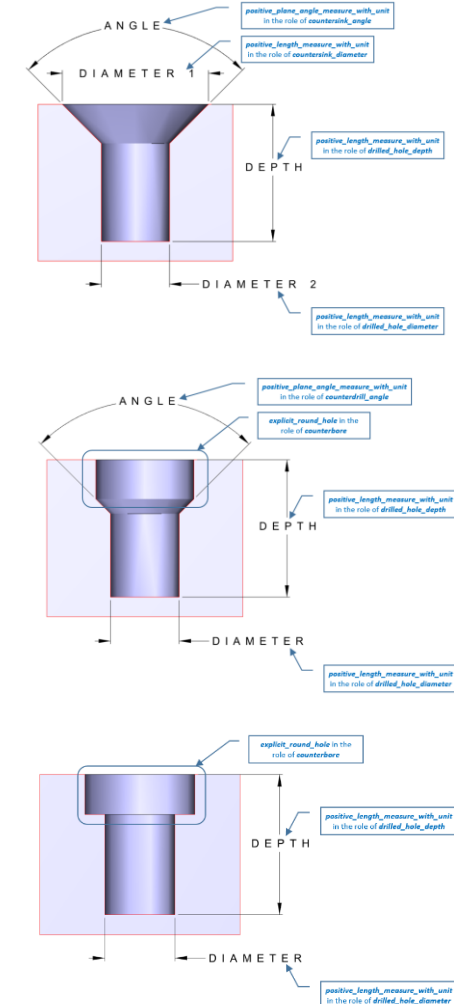
Manufacturing feature

New hole feature entity subtype introduce in AP242 edition 2

STEP Machining feature (former AIC 522)



STEP Hole feature in part 113

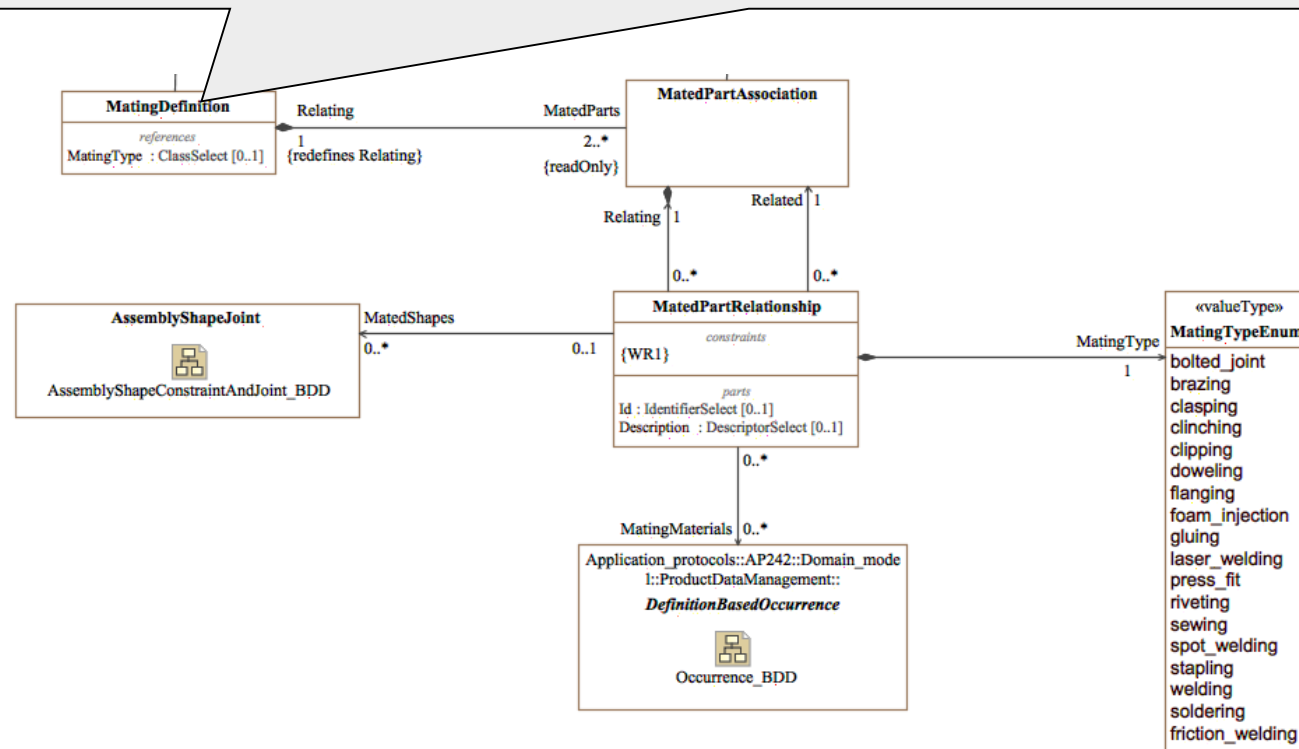


Mating capability in AP242

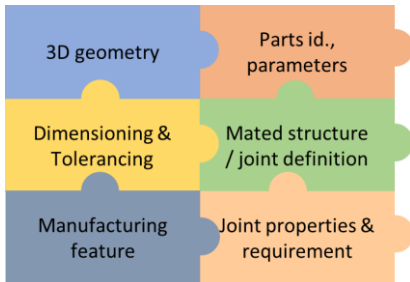
Mated structure / joint definition

MatingType: the kind of mating, that is, how the items shall be mated together. Where applicable, the following values shall be used:

- **'bolted joint': Attachment of two or more items that are screwed together using screws, bolt nuts, and washers;**
- 'brazing': Attachment of two or more items established by soldering or brazing;
- ...
- 'laser-welding': Attachment of two or more items that are welded together using a laser technique;
- 'press fit': Attachment of two or more items obtained by forces resulting from the selected size tolerances;
- **'riveting': Attachment of two or more items that are riveted together at a certain spot using a rivet;**
- 'sewing': Attachment of two or more items that are sewn together;
- 'spot welding': Attachment of two or more items that are welded together at a certain welding spot;
- 'stapling': Attachment of two or more items at a certain spot using a nail or a wire stitch to establish the connection;
- 'welding': Attachment of two or more items by welding together with one weld bead.



A recommended practices is in work for hole in part, hole in assembly and mating definition with fasteners



Recommended Practices for Representation of Hole and Fastener Information (AP242)

Status: *In progress*
Version 0.6
Friday, May 15, 2020

Contacts

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Boeing		
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CAX-IF Recommended Practices
Representation of Hole and Fastener Information
Version 0.6, Friday, May 15, 2020

5.3.3 Stacking

In the case of fastener composed of several items, it may be needed to have to ordered list of items from the head of the fastner, for example (bolt head, part1, part2, washer, nut).

This section describes how to use AP242 edition 2 assembly shape joint concept.

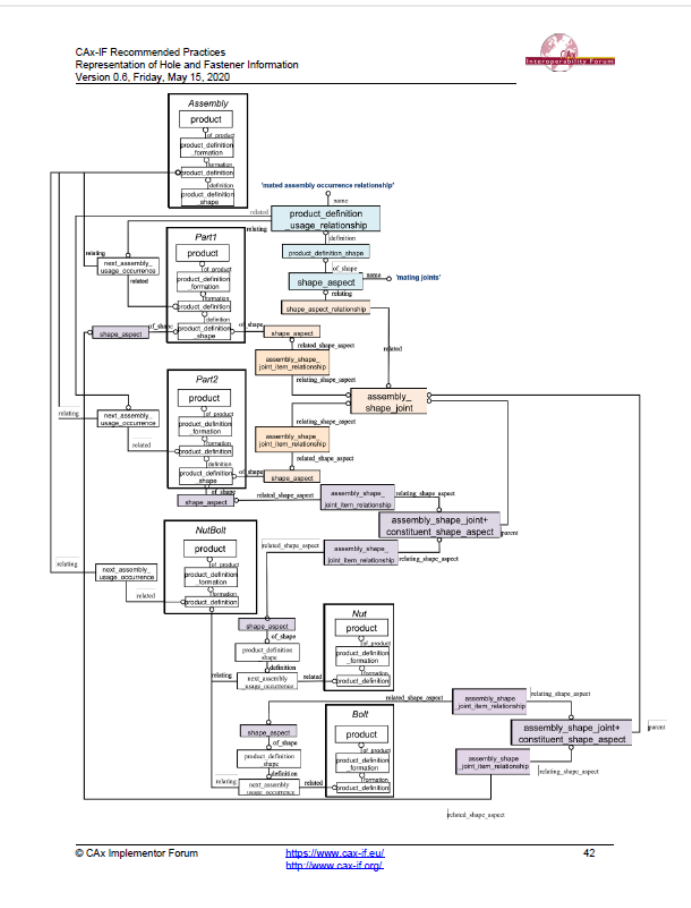
The assembly_shape_joint define the joint between the shape features. The assembly with fastener is composed by the main assembly joint of the mated assembly. Auxiliary joints can describe the different joints between each parts and fasteners.

The advantage to model the assembly joint to represent the stack is to get the connection between between all parts that will allow analytics and allows to attached different requirements, properties, ...

The example below illustrates an assembly of 2 parts with 2 Nuts bolts. In addition to the main assembly joint, a auxiliary joints are defined between the head of the bolts and the bracket and the nuts and the plates. So the stack for the fastener 1: bolt.1 < ASJ.1 -> bracket.1 < main joint -> Plate < ASJ.2 -> Nut.1

The complex entity assembly_shape_joint+constituent_shape_aspect is uses to define the auxiliary shape joint The following figure illustrates the usage of these AIM entities.

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<http://www.cax-if.org/> 41



The working group is investigating the P21 and XML implementation

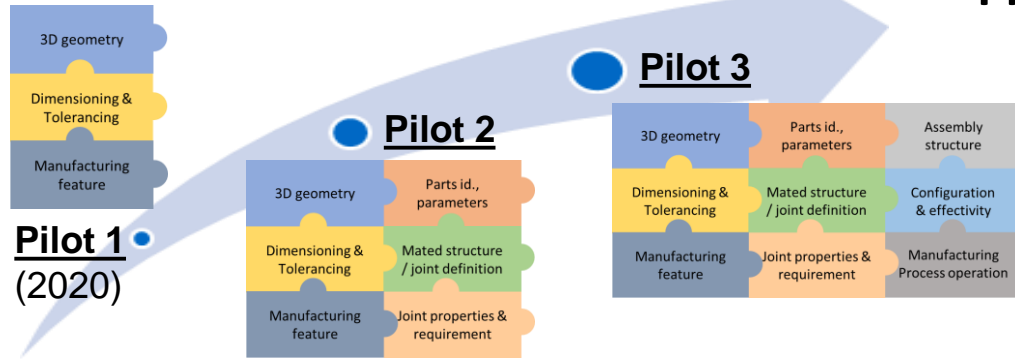
AP242 Domain model XML

```
<PartView uid="_8" xsi:type="n0:MatingDefinition">
...
<ShapeElement uid="_10" xsi:type="n0:AssemblyShapeJoint">
  <ShapeElementRelationship uid="_12" xsi:type="n0:AssemblyShapeJointItemRelationship">
    <Related uidRef="_13"></Related>
  </ShapeElementRelationship>
  <ShapeElementRelationship uid="_14" xsi:type="n0:AssemblyShapeJointItemRelationship">
    <Related uidRef="_15"></Related>
  </ShapeElementRelationship>
</ShapeElement>
<ViewOccurrenceRelationship uid="_16" xsi:type="n0:MatedPartAssociation">
  <Related uidRef="_28"/>
...
<Placement>...</Placement>
</ViewOccurrenceRelationship>
<ViewOccurrenceRelationship uid="_17" xsi:type="n0:MatedPartAssociation">
  <Related uidRef="_39"/>
  <RelationType> ...</RelationType>
  <Placement>...</Placement>
  <MatedPartRelationship uid="_100">
    <MatedShapes>
      <AssemblyShapeJoint uidRef="_10"></AssemblyShapeJoint>
    </MatedShapes>
    <MatingType>bolted_joint</MatingType>
    <Related uidRef="_16"></Related>
  </MatedPartRelationship>
</ViewOccurrenceRelationship>
<AssemblyType>...</AssemblyType>
<MatingType>
  <ClassString>bolted_joint</ClassString>
</MatingType>
</PartView>
```

AP242 AIM P21

```
#28=PRODUCT_DEFINITION_USAGE_RELATIONSHIP($,'mated assembly occurrence relationship',$,#29,#30);
#29=MULTI_LEVEL_REFERENCE_DESIGNATOR($,$,$,$,$,#23);
#30=MULTI_LEVEL_REFERENCE_DESIGNATOR($,$,$,$,$,#22);
#31=PROPERTY_DEFINITION('mating types',$,#28);
#33=PROPERTY_DEFINITION_REPRESENTATION(#31,#34);
#34=REPRESENTATION('mating types',(#35),$);
#35=REPRESENTATION_ITEM('bolted joint');
#36=PRODUCT_DEFINITION_SHAPE('',$,#28);
#85=SHAPE_ASPECT('mating joints',$,#36,$);
#87=SHAPE_ASPECT_RELATIONSHIP($,$,#85,#37);
#37=ASSEMBLY_SHAPE_JOINT('', 'Main joint',#88,$);
#54=ASSEMBLY_SHAPE_JOINT_ITEM_RELATIONSHIP($,$,#37,#55);
#55=SHAPE_ASPECT($,$,#56,$);
#83=ASSEMBLY_SHAPE_JOINT_ITEM_RELATIONSHIP($,$,#37,#53);
#53=SHAPE_ASPECT($,$,#52,$);
```

Units of fonctionnalités	STEP AP242 AIM P21	STEP AP242 Domain model XML
Geometry	Implemented in CAD COTS	NOT In edition 2
GD&T	Implemented in CAD COTS	NOT In edition 2, Edition 3 ?
machining feature (hole)	in the standard (AIC 522 + P113)	NOT In edition 2
Part identification & parameters	in the standard	in the standard
Assembly structure	Implemented in CAD COTS	Implemented in PDM tools
Mated structure / joint definition	in the standard	in the standard
Properties definition / requirement	in the standard	in the standard
Configuration & effectivity	in the standard	in the standard
Manufacturing Process / Plan / Operation	in the standard	

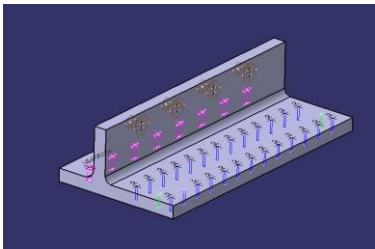


Phases planned:

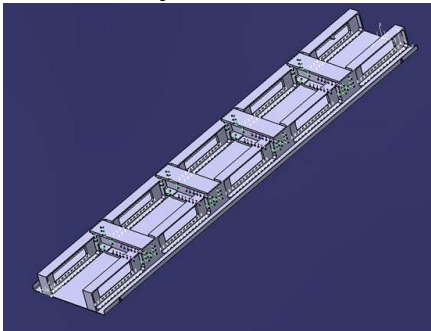
- 1) Hole definition in a part: STEP AP242 Edition 2 (on going)
- 2) Simple assembly with fastener: hole and requirement, STEP AP242 Edition 2 or +
- 3) Complex assembly structure

Test model examples

Part simplified representation of the hole



Assembly installation with fasteners

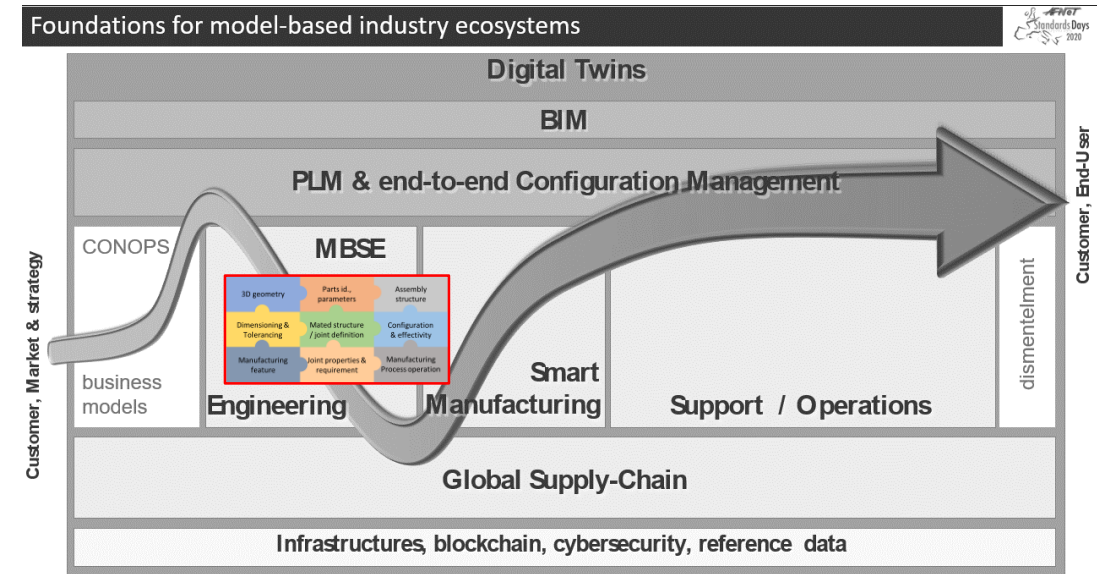


File examples

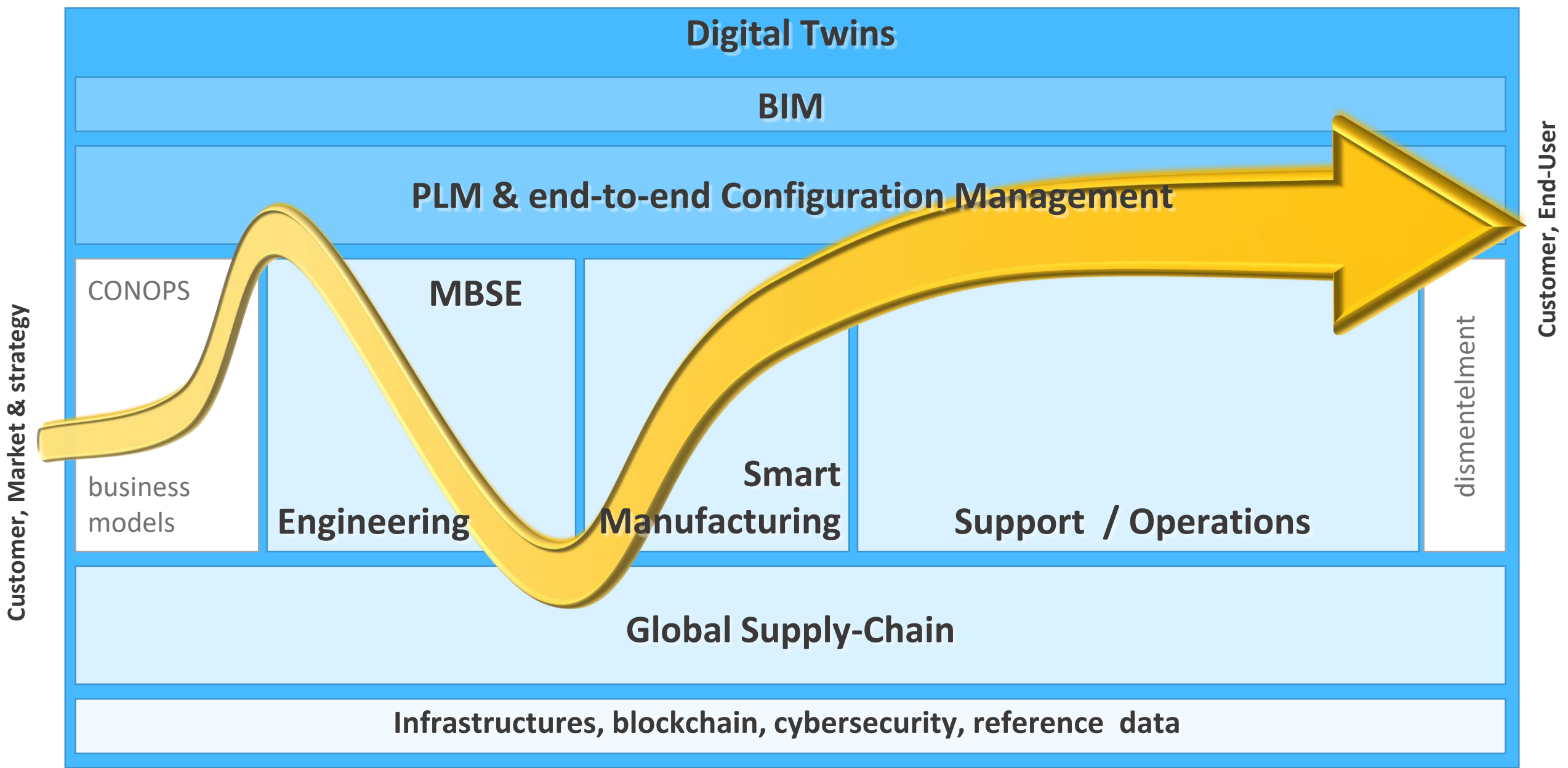
```
#8790=SIMPLIFIED_COUNTERSINK_HOLE_DEFINITION('Final_9.5mm.39',$,#8795,#8793,$,#8794,
    $,#8792,$,#8791,$,.F.);
#8791=POSITIVE_LENGTH_MEASURE_WITH_UNIT(POSITIVE_LENGTH_MEASURE(9.5),#8432);
#8792=POSITIVE_LENGTH_MEASURE_WITH_UNIT(POSITIVE_LENGTH_MEASURE(10.0),#8432);
#8793=POSITIVE_PLANE_ANGLE_MEASURE_WITH_UNIT(POSITIVE_PLANE_ANGLE_MEASURE(1.7453292519943295),
    #8433);
#8794=POSITIVE_LENGTH_MEASURE_WITH_UNIT(POSITIVE_LENGTH_MEASURE(11.88350718518842),
    #8432);
#8795=SHAPE_REPRESENTATION('Final_9.5mm.39 origin',(#8796),#16);
#8796=AXIS2_PLACEMENT_3D(' ',#8797,#8798,#8799);
#8797=CARTESIAN_POINT(' ',(0.0,0.0,0.0));
#8798=DIRECTION(' ',(0.0,0.0,1.0));
#8799=DIRECTION(' ',(1.0,0.0,0.0));
#8800=PROPERTY_DEFINITION('Hole_Family',$,#8790);
#8801=GENERAL_PROPERTY_ASSOCIATION('',$,#8445,#8800);
#8802=DESCRIPTIVE_REPRESENTATION_ITEM('','Final');
#8803=REPRESENTATION('',(8802),#16);
#8804=PROPERTY_DEFINITION_REPRESENTATION(#8800,#8803);
#8805=COUNTERSINK_HOLE_OCCURRENCE('Final_9.5mm.39',$,#11,.T.,#8790);
#8806=ID_ATTRIBUTE('Final_9.5mm.39',#8805);
#8807=ITEM_IDENTIFIED_REPRESENTATION_USAGE('Final_9.5mm.39 placement and geometry',
    $,#8805,#19,SET_REPRESENTATION_ITEM((#8808,#5670,#5691,#5711,#5731,#5751,#5771,
    #5791,#5811,#5831,#5851)));
#8808=MAPPED_ITEM(' ',#8809,#8810);
#8809=REPRESENTATION_MAP(#8796,#8795);
#8810=AXIS2_PLACEMENT_3D(' ',#8811,#8812,$);
#8811=CARTESIAN_POINT(' ',(40.0,0.0,40.0));
#8812=DIRECTION(' ',(0.0,1000.0,0.0));
#8813=DRAUGHTING_MODEL_ITEM_ASSOCIATION('Final_9.5mm.39',$,#8805,#6886,#8249);
#8814=COUNTERSINK_HOLE_OCCURRENCE('Final_9.5mm.40',$,#11,.T.,#8790);
#8815=ID_ATTRIBUTE('Final_9.5mm.40',#8814);
#8816=ITEM_IDENTIFIED_REPRESENTATION_USAGE('Final_9.5mm.40 placement and geometry',
    $,#8814,#19,SET_REPRESENTATION_ITEM((#8817,#5883,#5903,#5923,#5943,#5963,#5983,
    #6003,#6023,#6043,#6063)));
#8817=MAPPED_ITEM(' ',#8818,#8819);
#8818=REPRESENTATION_MAP(#8796,#8795);
#8819=AXIS2_PLACEMENT_3D(' ',#8820,#8821,$);
#8820=CARTESIAN_POINT(' ',(80.0,0.0,40.0));
#8821=DIRECTION(' ',(0.0,1000.0,0.0));
```

- Opportunity in STEP AP242 edition 3 to:
 - ensure external element reference to other files is applicable for this use cases
 - extend the domain model XML (GD&T, Machining, ...)
 - liaise with other standards

- Other lifecycle phases
 - Digital twins use cases:
 - Example fastener length based on measured parts
 - Link with Simulation



- COTS native function may ease the development of interoperability solution:
 - Currently many aerospace companies have developed specific function for hole and fasteners,
 - STEP AP242 mating capability covers more than structural joint with fasteners, it can be welding or other.



Questions
&
Answers



6th and 7th October

<http://standardsdays.afnet.fr>