Minimum Model-Based Definition (MBD) for Type Design Certification

Problem Statement, Desired State, and Requirements

Release 3.0

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AEROSPACE & DEFENSE PLM ACTION GROUP

Abstract

Minimum Model-Based Definition (MBD) for Type Design Certification is important to the Aerospace and Defense industry because multiple and ever-changing engineering and manufacturing software tools used to design and produce a product add time and cost by requiring data representation changes to maintain a current definition of the product.

This position paper captures the list of minimum data items required for standard MBD for Type Design Certification. The paper identifies the necessary Part Types and data items within each that are needed to develop, build, and certify the product. The paper first presents use cases As Is today without model-based definition support, including the business impact. The paper then lists To Be (desired state) use cases once minimum MBD requirements are met, including the business benefits. This latest release of the paper identifies specifics of the minimum required list of data items necessary for minimum MBD support. Terms in this paper are defined in a common *AD PAG Glossary* on the AD PAG web site (www.ad-pag.com).

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Revision Record

Release	Date	Description
1.0	August 2019	Initial Release
2.0	May 2020	Second Release with a revised Abstract and Executive Summary and new content, including Objectives and Desired State
3.0	November 2020	Third Release with a slightly revised Abstract and Executive Summary and new content, including Part Type Requirements (information), Compliance, a Request to Industry, and a Go Forward Plan

Minimum MBD for Type Design Certification

Executive Summary

The Aerospace and Defense Product Lifecycle Management Action Group (AD PAG) is an association of aerospace Original Equipment Manufacturers (OEMs) and aircraft engine providers within CIMdata's globally recognized PLM Community Program, which functions as a ***PLM advocacy group***. One of the key business issues identified by this industry group is that collaboration within a large, global, distributed supply chain of design and development partners is seriously hindered by relying on traditional, document-based development processes. As such, one of the key business challenges identified by this group is achieving OEM and supply chain collaboration through bi-directional exchange of technical data packages via digital tools and model-based processes.

In response, a project team of domain experts from the AD PAG member companies has been established to **evaluate current data interoperability standards, enabling a Model-Based Definition (MBD) set of concepts, processes, and tools that allow the creation of a semantically (computer interpretable) annotated 3D product definition that is linked to a Bill of Materials (BOM) system**. The MBD dataset includes all Engineering Intent requirements (e.g., Process Specifications, Geometric Dimensioning and Tolerancing (GD&T), Product and Manufacturing Information (PMI), and other required information). Combined with Product Lifecycle Management attributes, a parts list, and general notes, this product dataset constitutes an authoritative, single source of master product definition data that does not include or depend upon traditional 2D drawings. The MBD dataset also defines complete requirements for a product in its nominal condition, as well as permissible limits of variation and other acceptance criteria, providing all the data needed to plan, fabricate, and validate an article of product hardware.

The research activity on which this position paper is based was to assess the feasibility of exchanging digital data requirements and systems architecture models instead of documents within a collaborative product development activity. Phase 1, which has been completed with the publication of a position paper in December 2017, identified a gap in the capability of MBD and BOM authoring tools to support data exchange out-of-the-box.

The recommended Phase 2 short-term solution was to evaluate, validate, and employ the use of third-party MBD and BOM interoperability software tools that support data exchange and product interoperability for the life of the product. Release 1 of this position paper, published in August 2019, included a problem statement, use cases for the current As Is product interoperability environment, and use case business impacts. The Release 2 position paper, published in May 2020, had the AD PAG identifying the desired state with use cases aligned with that To Be environment. This Release 3 details the AD PAG minimum set of Part Types and data items within each required for 3D MBD certification support. The AD PAG strongly desires to see the data and model interoperability requirements be incorporated with a long-term data retention system.

Introduction

In March 2016, executives from the AD PAG member companies–Airbus, Boeing, Embraer, Gulfstream, and Rolls-Royce–met with the intent that informal discussions of Product Lifecycle Management (PLM)-related issues would lead to agreement on common objectives, requirements, and plans for remediation of their common PLM pain points.

This discussion resulted in agreement of the member executives to jointly sponsor and staff a select set of projects, each chartered to define objectives, requirements, and roadmaps for eliminating or significantly reducing a key inhibitor to the value potential of PLM. The topic addressed by this particular special project, which was initiated in 2017, is Minimum Model-Based Definition (MBD) for Type Design Certification. The scope of the team's activity has been to agree on the minimum content required in a full 3D MBD definition needed for certification and to agree on a set of recommended standards for representation of that information.

Since the initial agreement in 2016, AD PAG membership has increased from five to nine OEMs and suppliers, including the addition of GE Aviation, Mitsubishi Regional Jet, Pratt & Whitney Canada, and Safran, and this project team has added subject matter experts (SMEs) from many of them.[1]

Drawings Versus Model-Based Definition Content

Drawings have been the descriptive engineering foundation of component design, assembly, and installation since the beginning of the A&D industry. The drawings captured diverse information supported by several pictorial views of the item(s), such as a drawing or part number, dimensions, datums, tolerances, flag notes, general notes, etc. Drafting standards, including the ANSI/ASME Y14[2] family and the ISO 1101 family, have been supporting the industry's drawings definition for decades. The drawings were, and in some cases still are, then consumed or repurposed downstream to enable aircraft planning, manufacturing, and servicing.

The rise of 3D CAD (Computer-Aided Design) modelers in the late 1980s and 3D As Master in the early- to mid-1990s ushered in the beginning of MBD in the 1990s. To improve design cycle time and cost, MBD use led to the development of processes and tools that have helped the A&D industry move away from creating 2D drawings and toward 3D models as the data of record.

Industry leaders worked with PLM vendors to define what is known today as *Model-Based Definition* or *Model-Based Enterprise (MBE).* This new approach and its continuous innovation have advanced from the basic transfer of all detailed information from 2D drawings to 3D model Geometric Dimension and Tolerances (GD&T) with annotation—known as *Product and Manufacturing Information (PMI)*—to a recognizable, semantic, fully-dimensioned 3D model to minimum dimensioning with intelligent features, parameters, and more. These continuous advancements are not only improving the global strategy but are also expanding the gap between industry knowledge, existing standards, and available solutions proposed by PLM software providers.

[1] Bombardier, an AD PAG member at the start of this project, has since withdrawn, as has Dassault Aviation.
[2] https://www.asme.org/topics-resources/content/y14-standards-overview

Problem Statement

This section of the position paper first establishes the context within which product development occurs and then identifies, through four current state use cases, the common roadblocks that slow current product development processes that rely on the exchange of model data between stakeholders. Each use case is presented as a user story in table format. Business consequences and the root causes of the problem are noted for each.

Context

As noted earlier, with the advancement of technology and the maturity of CAD tools, the past decades have seen an increase in the transition from 2D drawing-based designs to 3D MBD designs within the A&D community. Today, A&D companies are seeing active CAD data as an asset that is continuously versioning. The available neutral formats, such as ISO STEP AP242, are attempting to keep up, but the scope is also expanding to more and more data types.

A common objective of the AD PAG is to evaluate the minimum digital thread of MBD data elements required to fulfill type design certification requirements set forth by the global regulatory bodies. The team evaluated the certification requirements, the collective part types currently certified by the A&D industry, and the various open data standards such as, but not limited to, ISO 10303-242 (STEP AP242), ISO14306 (JT), and ISO32000/14739 (PRC for 3D PDF) to support data exchange and interoperability requirements for existing MBD design processes.

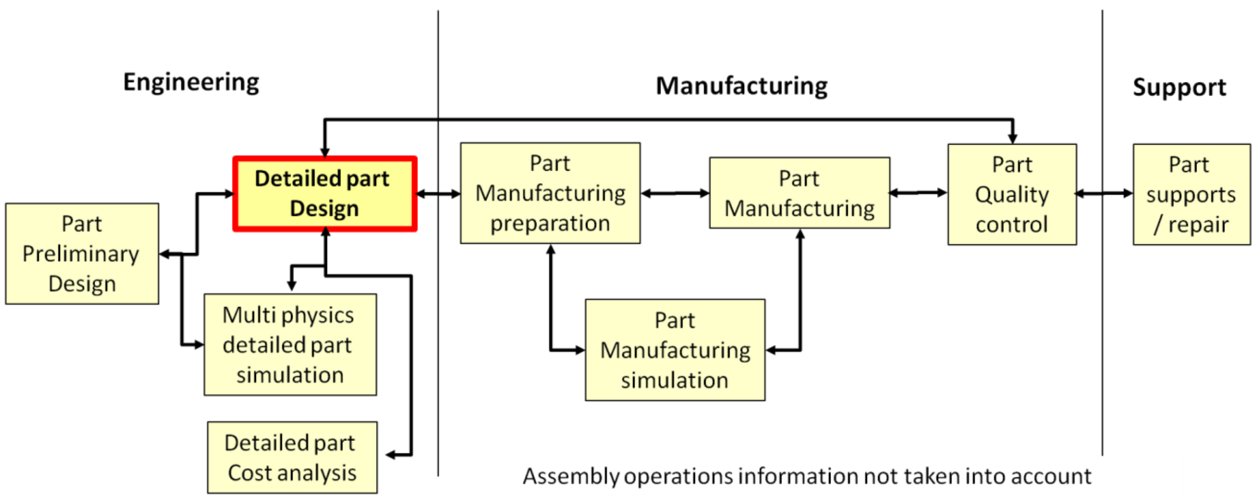


Figure 1 – Generic, High-Level Process Flow for 3D MBD Parts

The AD PAG's goal is to cover the minimum semantic of the different categories of parts used by the A&D industry. The AD PAG supports the following:

- Communication between the OEM and Engineering suppliers during the design phase of product development.
- Communication to downstream processes between Engineering and Manufacturing with computer-readable semantic data for
  - Preparation of 3D NC machining programming,
  - Preparation of 3D NC quality control, and

  - Input for simulation of manufacturing processes (specific to each category of part type).
- Communication between Design Engineering and upstream processes, including
  - FEM simulation of structural parts,
  - Electromagnetic Interference (EMI) simulation of electrical wiring harnesses, and
  - Pressure simulation for tubing systems (pumps, etc.).

As a result of this support, the group defined a minimum list of required 3D MBD data items organized by the category of parts. This list was first described in the AD PAG's published position paper, titled *Minimum Model-Based Definition (MBD) and Bill of Material (BOM) Definition with STEP AP242*, which is available at www.ad-pag.com under the link for Position Papers named *Model-Based Definition (MBD) and Bill of Material (BOM) Definition – Position Paper*. The file will download with filename ad-pag-mbd-bom-pp-4.0.pdf. Two additional part types—Deformable and AM - Additive Manufacturing and ALM - Additive Layer Manufacturing—have been added since that paper's publication. The group is actively researching the following 17 part types.

Table 1 – List of 17 Actively Researched Part Types by the AD PAG

PART TYPE
Composite - Detail - Core Stiffened Bond
Composite - Detail - Co-Cured/Co-Bonded
Casting
Forging
Sheet Metal
Machined
Wire Harness
Tube Assembly - Flexible
Tube Assembly - Rigid
Ducting - Metallic - Mechanically Fastened
Installation
Standard Part - Mechanical
Standard Part - Electrical (Connector, Back Shell, etc.)
Supplied Part - Mechanical Systems (Pump, Actuator, etc.)
Supplied Part - E/E Systems (Battery, LRU, etc.)
Deformable
AM - Additive Manufacturing and ALM - Additive Layer Manufacturing

Use Cases Introduced

The initial release of the MBD Type Design Certification project identified four current As Is use cases that include the generation of 3D MBD data. Each As Is use case starts on a separate page for easy reference and offers a description of the process, the issues that arise, and the business consequences of their impact.

- Use Case 1: Visual Interpretation and Visual Consumption
- Use Case 2: Feature-based Machining/Manufacturing
- Use Case 3: OEM Submission of Technical Data Package to Authority for Certification
- Use Case 4: Statistical Process Control

Use Case 1: Visual Interpretation and Visual Consumption

Manufacturing has historically relied on visual interpretation of the dimensions, tolerances, and other technical data, such as notes and specifications, to plan and program the fabrication of parts and facilitate inspection, quality, etc. This has been done with 2D drawings for many years. With MBD, the same information (dimensions, tolerances, etc.) is conveyed in 3D space with MBD views. This is done by applying PMI on the 3D geometry.

Visual consumption can be directly from the native CAD system or through a neutral format viewer, such as Adobe with 3D PDF. The ability to visualize the MBD product definition is the most basic and critical use case. Prior to the release of a product definition, many business functions (i.e., manufacturing, quality, assembly) must visualize and approve the design. These functions may not have access to native CAD data; hence, they must use a simplified neutral format with a simple visualization tool (e.g., Adobe 3D PDF).

Production Planners must be able to visualize the dimensions to plan the manufacturing sequences. Numerical Control (NC) and Coordinate Measuring Machine (CMM) Programmers must visualize dimensions and tolerances in conjunction with the 3D geometry to program the NC machine and inspection machine operations, respectively. Any loss of visual data can lead to manufacturing defects.

Regardless of the neutral format used—ISO STEP, ISO JT, or ISO 3D PDF—the visualization tools must quickly and reliably display the 3D model with PMI content.

Difficulties arise immediately whenever the native CAD solution or the neutral format in use does not yet support the MBD display of all necessary data items used in downstream functions.

Table 2 - Visual Interpretation and Visual Consumption Use Case

EPIC	Feature/Sub-Process	CFP	ID	Created by	User Story
As a Manufacturing Process Planner	**I want to** define the sequence of steps to manufacture the product	**So that I can** inform factory floor production staff,	**Given** a 3D model-based view of the product.	**When** manufacturing process planning is done,	**Then** manufacturing planning is complete, and production can start.

Tools/Apps	Predecessor
3D data model with PMI Display Viewer	2D drawings

Business Consequences of Use Case 1

When downstream NC Programmers or CMM Programmers cannot visualize a needed dimension or other part manufacturing data item, they are left either to interrupt the overall process by requesting clarification from the design organization or to make an assumption. If the programmer's assumption proves incorrect, time and money are lost in order to correct the problem. In severe cases, the overall product schedule may slip, and the company could miss market opportunities.

Causal Analysis of Use Case 1

The predominant cause of missing visual data can often be traced to the lack of capability, either in the CAD solution itself or in a lagging definition within a standard format. In addition, even if the capability is supported, the designer may not realize a particular dimension or tolerance is needed downstream and, as a result, may fail to add it to the 3D MBD view.

A current concern is that there are a limited number of different viewers that can accurately display standard data. Development of an application-independent format (or standard) would allow suppliers and manufacturers to develop solutions that could significantly reduce the cost of business.

Use Case 2: Feature-Based Machining/Manufacturing

Within MBD, features capture the engineering intent of a 3D model (Product Definition) and serve as significant support for Computer Integrated Manufacturing (CIM). Feature-based design systems typically act as interpretive processors between Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) environment actions. These systems can enable feature-based product definition systems, geometry-based process planning, automatic feature recognition, and design-by-feature systems.

Integrating such technologies is a major concern within current engineering practices and has been a high priority topic for research and development activities. In various engineering and manufacturing domains, the design-by-feature model is a main tenet in the CAD/CAM integration effort. The most preferred system architecture for a feature-based system is a blend of the aforementioned approaches. The approaches used for automatic feature-recognition systems are becoming more mature and are being used in Advanced Manufacturing practices.

The more the A&D industry can utilize Advanced Manufacturing and feature-based capabilities, the more able the industry will be to predict the quality of products coming off the machine tool. This will allow companies to provide to their regulatory agencies better, more accurate data in support of certification and compliance.

Certification of Feature-Based Machining/Manufacturing systems that produce data used for verification and validation, as well as for inspection purposes, must be accredited and approved for use in compliance with regulatory requirements.

Table 3 - Feature-Based Machining/Manufacturing Use Case

EPIC	Feature/Sub-Process	CFP	ID	Created by	User Story
As a Manufacturing Employee (Machinist)	**I want to** manufacture a machined part from model data	**So that I can** meet the OEM requirements/ schema,	**Given** that the data is in an easily readable format that contains the minimum necessary information and requirements to machine/manufacture the part.	**When** the part data has been consumed and the requirements have been met,	**Then** the OEM job is complete, and the part can be delivered.

Tools/Apps	Predecessor
Intellectual Property (IP)-protected CAD model w/PMI	2D drawing
Agnostic 3D visualization	STL model
ISO neutral formats STEP, JT, 3D PDF, etc.	IGES

Tools/Apps	Predecessor
LOng Term Archiving and Retrieval methods (LOTAR)	Paper, Velum, Mylar, Linen, Microfiche, etc.

Business Consequences of Use Case 2

Today, parts for manufacturing are contracted to suppliers in a variety of formats with varying degrees of requirements. With ever changing software tools, this puts a lot of pressure on suppliers to meet the requirements and keep up with the software.

For example, within programs that had to transition from CATIA V4 to CATIA V5, suppliers were required to read and interpret data from both Version 4 and Version 5 models.

Causal Analysis of Use Case 2

The cost of making changes to a company's infrastructure impacts its ability to compete. Even if the company is well established and has sufficient capital in reserves to pay for the changes, there is still an impact on the schedule and delivery of goods. This may lead to a search for additional suppliers to help meet the schedule, and there is an added cost of review, certification, and contracts associated with potential new suppliers.

Use Case 3: OEM Submission of Technical Data Package to Certification Authority

With the emergence of digital data-based processes, including MBD, requirements were identified that predicate the need for a long-term data retention solution(s) to meet the regulatory and business requirements. Traditional legacy retention and retrieval methods do not support complex digital product definition data.

Prior to MBD, the authorized type design process output was 2D drawings. Certification was performed by providing access to those drawings. In MBD, the design is an annotated 3D model, in which certification can be performed by giving access to the 3D data in a format compatible with the certification authorities. This is a requirement for LOTAR of product and technical data, as defined by the EN/NAS 9300-xxx LOTAR standards.

Those LOTAR standards include the following:

- EN/NAS 9300-001-009 – Basic Fundamentals & Concepts
- EN/NAS 9300-010-030 – Common Process for Data Preparation, Management, Archive and Storage
- EN/NAS 9300-1xx through 7xx – Domain Specific Type Preservation (Mechanical, PMI, Composites etc.):
  - EN/NAS 9300-1xx: *LT Archiving and Retrieval of Mechanical Information*
  - EN/NAS 9300-2xx: *LT Archiving and Retrieval of Product Management Data*
  - EN/NAS 9300-3xx: *LT Archiving and Retrieval of Advanced Manufacturing Data* (Composite, Additive Manufacturing, etc.)
  - EN/NAS 9300-4xx: *LT Archiving and Retrieval of Electrical Information*
  - EN/NAS 9300-5xx: *LT Archiving and Retrieval of Model-Based System Engineering*
  - EN/NAS 9300-6xx: *LT Archiving and Retrieval of Engineering Analysis and Simulation*
  - EN/NAS 9300-7xx: *LT Archiving and Retrieval of Electronics Information*

Currently with MBD, the certification authorities are given access to the 3D data, according to three types of solutions based on a:

- Lightweight format (3D PDF, ISO 14306 JT, etc.),
- CAD neutral data format (ISO 10303, AP242[3]), or
- Native CAD model.

This puts the burden of interpreting the native CAD model on to the certification authority that may be certifying multiple OEMs with different CAD systems. Additionally, a native CAD model often contains IP beyond the final design, and the OEM may not wish to expose that IP (e.g., construction methods, constraints, and relationships) to the certification authority. OEMs may want to strip out or mask that data before providing a minimum product definition package to the certification body or restrict access via thin client architectures.

[3] AP203 and AP214 have been merged in AP242.

Table 4 - OEM Submission of Technical Data Package to Authority for Certification Use Case

EPIC	Feature/Sub-Process	CFP	ID	Created by	User Story
As an OEM Supplier	**I want to** provide access to a graphic presentation of my product definition	**So that I can** show proof of complete product design and definition to the government/ regulatory body,	**Given** the data is in a readily consumable format containing the minimum necessary information and/or requirements to effectively satisfy the government/regulatory body.	**When** the government body is able to access and understand the content of the product definition,	**Then** the standard documentation of design is accepted as valid, compliant, and complete.

Tools/Apps	Predecessor
2D CAD model (drawing)	Hand Drawings
3D CAD model digital mockups	Physical Mockups
Enhanced 3D model with PMI	
Agnostic 3D visualization	STL model
ISO Neutral Formats (STEP, JT, 3D PDF, etc.)	IGES
LOTAR	Paper, Velum, Mylar, Linen Microfiche, etc.

Business Consequences of Use Case 3

Evolving software tools may render certain applications and data formats inaccessible. Inadequate access control and protocols—Intellectual Property Export Control (IPEC) and internal People and Organization (PNO) requirements—create the risk of unauthorized transfer, manipulation, and export of data.

The impact of technology readiness and differences on concurrent collaboration among partners and suppliers may affect the schedule and quality of the product. Failure to keep pace with the evolution of delivery and consumption media creates processes and tools that become isolated and ineligible for further migration. Misinterpretation of product definition may lead to quality issues and loss of design intent.

Causal Analysis of Use Case 3

Restricted information flow and misinterpretation of definition, quality issues, and loss of design intent will lead to the potential loss of type data and inability to recreate it, as well as to exposure to data manipulation. This presents a potential for compromised Unauthorized Data Export IP, which may lead to a loss of confidence from the regulatory authorities.

Use Case 4: Statistical Process Control

Statistical Process Control (SPC) is a data-driven methodology for analysis and an improvement methodology for measuring and controlling quality during the manufacturing process. Quality data in the form of product or process measurements is obtained in real-time during manufacturing.

This data is then plotted on a graph with pre-determined control limits. Control limits are determined by the capability of the process; whereas, specification limits are determined by the customer. Data that falls within the control limits indicates that everything is operating as expected. Data outside the control limits indicates that the cause is likely the source of process variation, and something within the process should be changed to resolve the issue before defects occur.

Table 5 - Statistical Process Control (SPC) Use Case

EPIC	Feature/Sub-Process	CFP	ID	Created by	User Story
As a Quality Assurance Employee	**I want to** collect and analyze SPC data points from manufactured product data	**So that I can** meet the OEM design requirements /schema,	**Given** the data is in an easily readable format that contains the minimum necessary information and requirements to machine/ manufacture the part.	**When** the part data has been consumed and the requirements have been met,	**Then** the job is complete, and the part can be delivered.

Tools/Apps	Predecessor
Data Mite, SPC sensors	2D drawings, Manual measurement

Business Consequences of Use Case 4

- This new process requires new software, integrated with internal software structures and machine tools, along with new processes to capture data. In addition, testing, training, restructuring, and maintenance of these new systems must be in place.
- Implementing an SPC process on machine tools and in quality management policies will impact current operating processes and affect scheduled delivery of the product.

Causal Analysis of Use Case 4

- Restricted information flow
- Difficulty absorbing (i.e., interpreting) information
- Loss of confidence by the regulatory authorities due to poor quality

Objectives

At the start of this MBD project in 2017, the AD PAG members defined and published the team's mission. The Mission Statement identified that the goal was to develop the common definition for A&D of MBD, including the following:

- The common definition of the content of 3D MBD
- The minimum content to enable certification

The vision of the team is to define the A&D industry minimum standard for 3D MBD and the regulatory Technical Data Package (TDP). The vision also includes providing the team's requirements to both PLM providers and standards bodies.

The MBD team outlined their task as follows:

- Produce a definition of 3D MBD
- Identify the minimum content of 3D MBD to
  - Satisfy certification requirements
  - Enable manufacturing and support
  - Design integration
- Issue industry requirements to PLM providers and standards bodies
- Identify and test current standards to verify if the standards enable the minimum content
- Test and assess the capability of existing toolsets
- Define the content of the TDP that the OEM proposes to its certification authority
- Provide recommendations to close gaps in standards and toolsets
- Develop guidance and considerations for deployment within the member companies, updating the standards and processes as needed

Desired State (To Be)

This section describes the To Be state of each of the four previously identified use cases. In each, the To Be state has all the data items included in the list of minimum 3D MBD data items necessary for certification supported in the standards and in the PLM solution providers' tools.

Context

As indicated in the context of the Problem Statement section, the AD PAG's goal is to cover the minimum semantic of the different categories of parts used by the A&D industry. A minimum list of required 3D MBD data items organized by the category of parts has been defined through AD PAG support of communication between the OEM and Engineering suppliers during the design phase of product development, communication to downstream processes between Engineering and Manufacturing with computer-readable semantic data, and communication between Design Engineering and upstream processes. The group identified and actively researched 17 part types, which are listed in Table 1 – List of 17 Actively Researched Part Types by the AD PAG.

Use Case 1: Visual Interpretation and Visual Consumption

In the To Be environment envisioned by the AD PAG, the flow of Use Case 1 is the same, however, now **all necessary MBD data is supported by the standards and by the solution providers**.

Business Benefits of Use Case 1

The benefit of MBD and MBE contained within the TDP is that the design is an annotated 3D model from which all downstream functions can leverage to complete their work. For the specific downstream function of manufacturing process planning, the manufacturing engineer has access to the 3D product model and all necessary PMI information. The work can proceed according to schedule with quality assured.

Use Case 2: Feature-Based Machining/Manufacturing

In the To Be environment envisioned by the AD PAG, the flow of Use Case 2 is the same, however, now **all necessary MBD data is supported by the standards and by the solution providers**.

Business Benefits of Use Case 2

The more often the A&D industry can use advanced manufacturing, predictive should-costing, quality control, and feature-based capabilities, the more often the industry will be able to predict the quality of products coming from the machine tool. This enables the association of model part features with manufacturing process steps. It also allows companies to provide to their regulatory agencies more complete and accurate data in support of certification and compliance. Feature-Based Machining/Manufacturing systems that produce data used for verification and validation, as well as for inspection purposes, must be accredited and approved for use in compliance with regulatory requirements.

Use Case 3: OEM Submission of Technical Data Package to Certification Authority

In the To Be environment envisioned by the AD PAG, the flow of Use Case 3 is the same, however, now **all necessary MBD data is supported by the standards and by the solution providers**.

Business Benefits of Use Case 3

The benefit of MBD contained within the TDP is that the design is an annotated 3D model in which certification can be performed by giving access to the 3D data in a format compatible with the certification authorities' needs. The government/regulatory body will be able to access and understand the content of the product definition data throughout the life of the product. This is a requirement for the LOng-Term Archival and Retrieval (LOTAR) of product and technical data, as defined by the EN/NAS 9300-xxx LOTAR standards.

By using MBD within the TDP, the certification authorities can be given access to the 3D data according to three types of solutions based on an:

- Open Data Format: Lightweight format for Visualization (3D PDF, ISO 14306 JT, HTML, ISO 10303-242, etc.)
- Open Data Format: Exact Representation Manufacturing/Inspection (ISO 10303-242, 14306 JT, etc.[1])

This allows the certification body to certify multiple OEMs with different CAD systems. With the data being CAD agnostic, interpretation will be more accurate as it will not depend on a specific CAD tool to view and interpret the data. The OEMs have the capability to strip out or mask that data before providing a minimum product definition package to the certification body.

Use Case 4: Statistical Process Control

In the To Be environment envisioned by the AD PAG, the flow of Use Case 4 is the same, however, now **all necessary MBD data is supported by the standards and by the solution providers**.

Business Benefits of Use Case 4

Statistical process control—in short, the collection and application of statistical methods used to control manufacturing processes—has been around for many years. However, the majority of companies rarely do anything with the data they so painstakingly collect.

With the onset of MBD, it has become critical to use the data collected during the manufacturing process in order to make real-time improvements on the shop floor. This is demonstrated in the Digital Thread/Digital Twin concept where speeds, feeds, and tool changes are made based on the data received in real-time from the machine tools. SPC demonstrates in real-time what is actually happening during the manufacturing process. When equal access to the same data is made available to everyone, more educated decisions can be made during the machining and measurement processes. In addition, manufacturing and quality intelligence through SPC will ensure a more valid and accurate certification process.

Requirements

The requirements in the tables on the following pages define the data exchange content that must be met to achieve the above objectives. The A&D PLM Action Group evaluated the certification requirements, the collective part types currently certified by the A&D industry, and the various open data standards such as, but not limited to, ISO 10303-242 (STEP AP242), ISO14306 (JT), and ISO32000/14739 (PRC for 3D PDF), to support data exchange and interoperability requirements for existing MBD design processes. The stated goal is to have each of the industry standards support the following requirements equally, and that any solution provider that provides a tool to data exchange their native formats into the specified standard formats do so equally.

List of Requirements

As stated in the Problem Statement – Context section, the A&D PLM Action Group investigated 17 specific part types for required data items, as well as a list of data items common to all part types. During the investigation, a number of part types were merged. For example, Composite – Detail – Core Stiffened Bond and Composite – Detail – Co-Cured/Co-Bonded were merged under a single heading, Composites. A number of other part types, such as Additive Manufacturing, were put on hold in order to document the requirements in a timely manner. Those part types not yet detailed will be investigated at a later date.

Part Type Information

The information captured in each MBD varies by part type. A part type is usually, as in this context, defined by the manufacturing method. A part produced by additive manufacturing will have different information requirements than a part produced by hydroforming sheet metal.

The AD PAG team focused on Model Based Definition analyzed the information requirements of the following part types:

- General Part
- Machined
- Casting/Forging/Molded
- Sheet Metal
- Composite
- Electrical Wire Harness
- Mechanical System – Tubing Transport Elements
- Structural Assembly/Installation

The team documented a set of specific information requirements that need to be semantically represented in the model, according to the use cases defined in this paper. Semantic representation requires the information identified in the following tables to be system/machine/software interpretable consistent and clear to the consuming systems.

In the future, the team will continue to add part types as time permits.

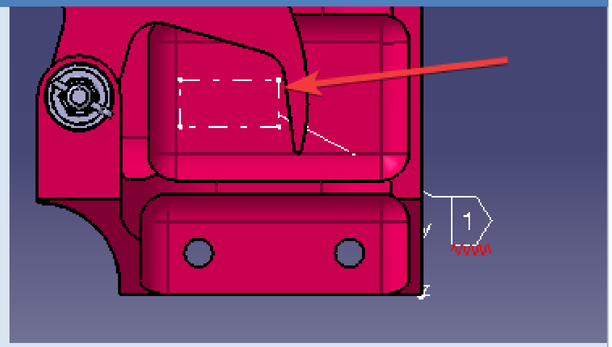
The AD PAG team has built a number of CAD models that can be used for testing solution provider conversion applications. All of the CAD models are hosted on the A&D web site under the *MBD Models* heading.

General Part

This section describes a set of common information (i.e., data elements) that applies to all part types.

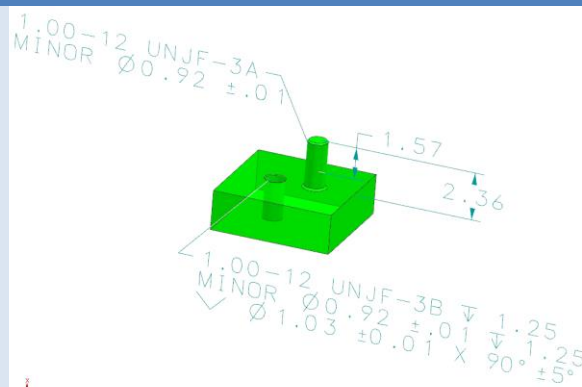
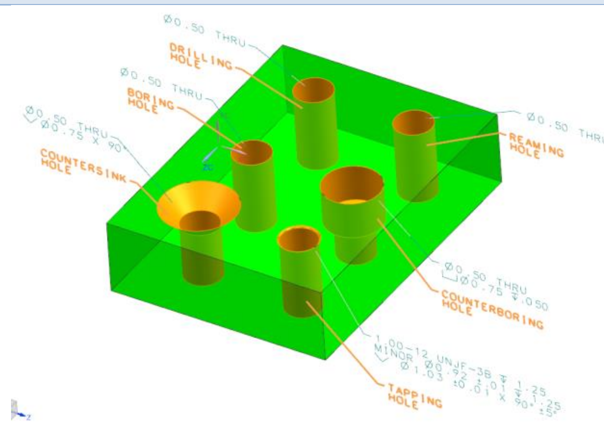
Minimum Data Element	Description	Example
Part Number & Revision ID	Unique identifier and version of the part	Part numbers and versions are usually stored as properties of the document
Physical Shape	3D solid, surfaces, or wireframe defining the finished shape of the part	
Material	Material ID	Material is, at a minimum, stored as property and/or a parameter; when instantiating from a material catalog it will contain more properties of the material type
Management Data (Part Marking)	Export control, approval status, or company proprietary markings to control usage and access	Stored as an attribute, property, or parameter in the model
Notes – Standard	Non-engineering notes used to convey business information (e.g., company address, per ASME/ISO)	Stored as an attribute, property, or parameter in the model
Notes – Part	Engineering requirements that apply to the entire part (e.g., general tolerance)	Stored as an attribute, property, or parameter in the model
Axis/ Coordinate System	Coordinate system	
Dimension Tolerances (PMI)	GD&T – definition of the physical dimensions of a component and the allowable variation on those dimensions, includes semantic and non-semantic annotation	
3D Annotations	Non-Semantic 3D notes and symbology	

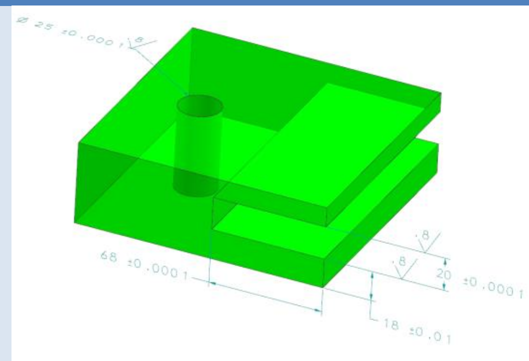
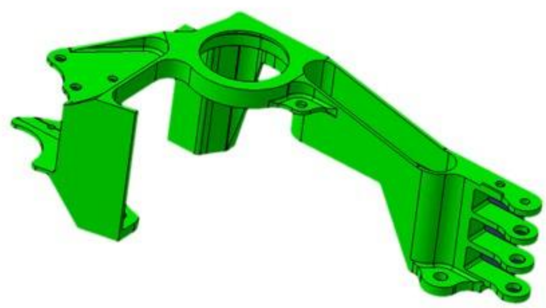
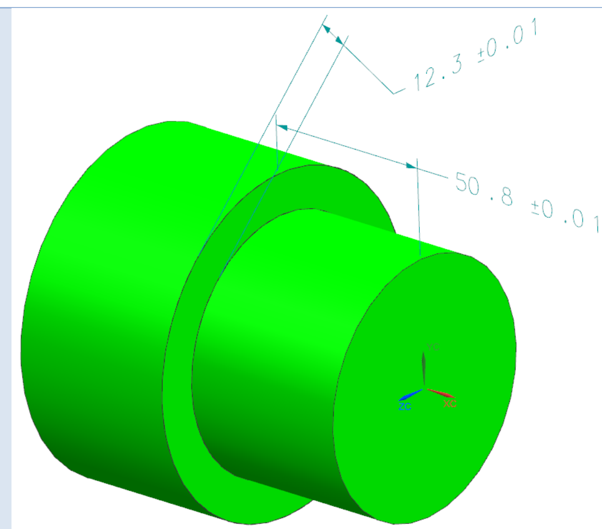
Minimum Data Element	Description	Example
Saved 3D Views	Saved views of a design model that facilitate presentation of the model and its annotation. A saved view shall have an identifier; be retrievable on demand; may contain a model coordinate system that denotes the direction of the view relative to the model; and contain one or more of the annotation plane(s), a selected set of annotations, or a selected set of geometry	
Key Characteristics	An attribute or feature whose variation has a significant effect on product fit, form, function, performance, service life, or producibility that requires specific actions for the purpose of controlling variation	
Limited Length Area Indicator	An organized group of surfaces that can contain a profile that is smaller than the total area of the underlying geometries or a boundary area not tied to limits of the total surface	

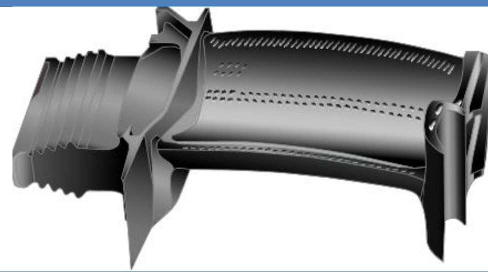
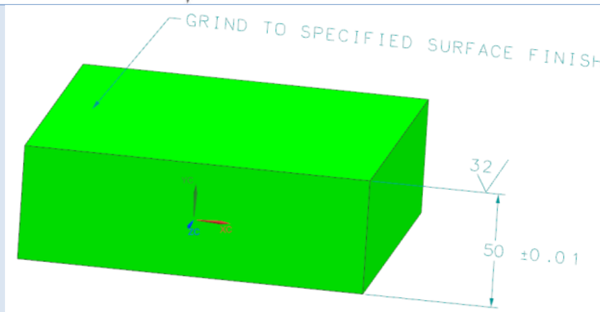
Minimum Data Element	Description	Example
Engineering/ Supplemental Definition	Geometry used to add additional context to the view; geometry is usually wireframe but can be any type, such as surfaces or solids	 

Machined Part

A machined part is a metallic part created by cutting (i.e., material removal) raw material to fit specific measurements.

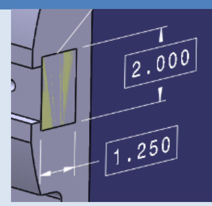
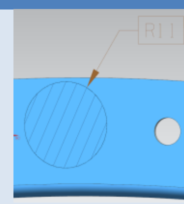
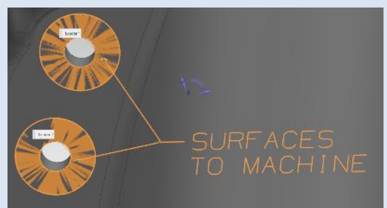
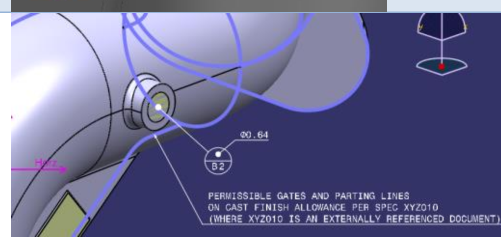
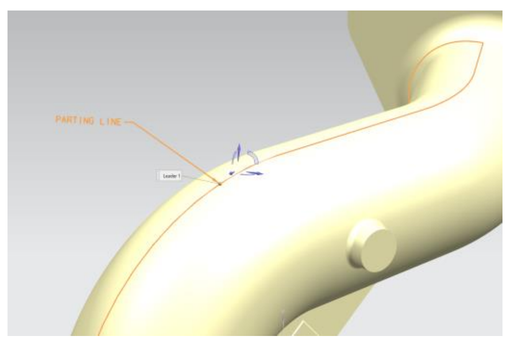
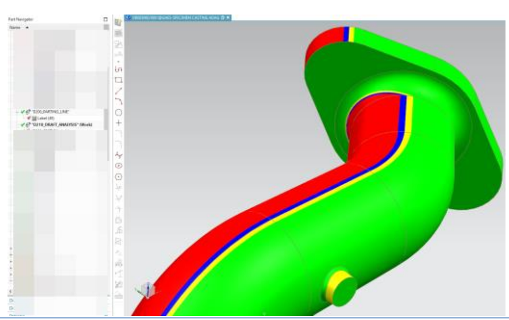
Minimum Data Element	Description	Example
Symbolic Feature Representation - Threaded Features	A depiction of internal or external threads created in a CAD model that represent actual cut/formed thread definition. CAD systems depict the threads in varying methods, typically as concentric circles representing the major or minor thread diameters May require specifying cutting feed, speed, direction, and depth in the form of attributes	
Drilling Features	A feature (e.g., hole) created in a CAD model using a simulated cutting process (drilling) that uses a bit to cut a circular cross-section in material. May require specifying cutting feed, speed, direction, and depth in the form of attributes. These features include: counterbore, countersink, counterdrill, spotface, conical, etc.	

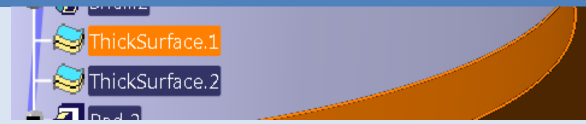
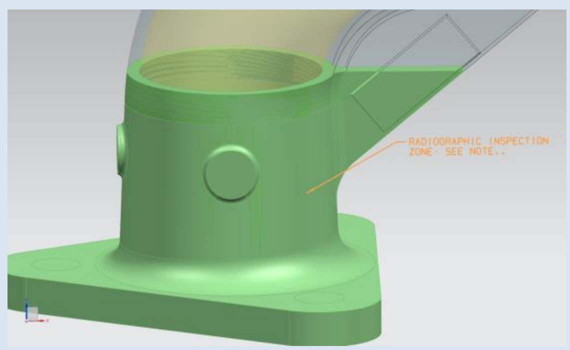
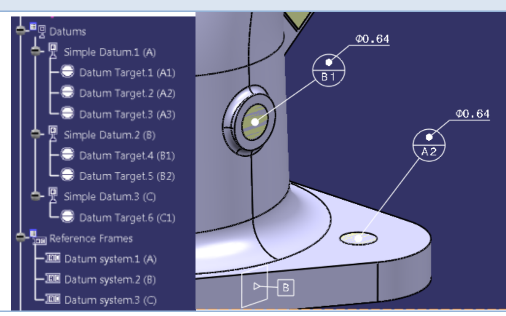
Minimum Data Element	Description	Example
Broached Features	Broaching removes layer of material of desired width and depth by a rod type cutter - Close tolerances - Good surface finish	
Milling Features	A feature involving material removal using a simulated cutting process (milling) that uses a cutting tool to remove material from the surface of a CAD model May require specifying cutting feed, speed, direction, and depth in the form of attributes	
Turning (Lathe) Features	A feature created in a CAD model using turning operations (e.g., lathe) used principally by holding and rotating the part while a tool bit is advanced into the part, causing the material removal May require specifying cutting feed, speed, direction, and depth in the form of attributes	

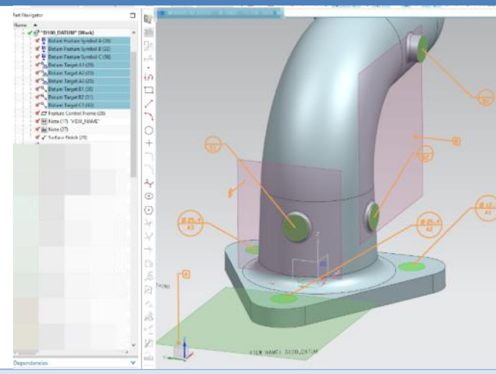
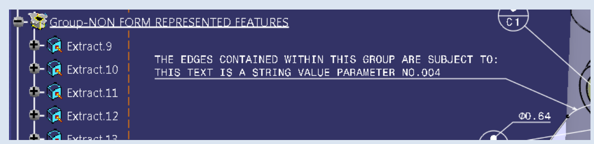
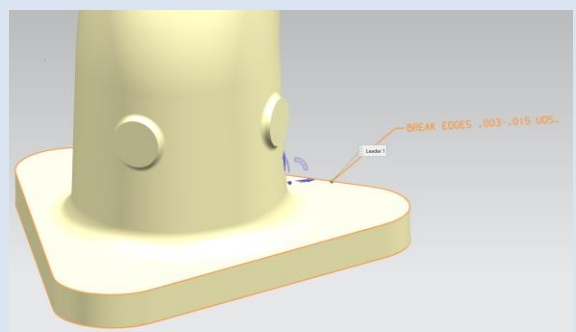
Minimum Data Element	Description	Example
EDM Features (via Die Sinker, Wire, or Hole Drilling Type)	Manufacturing process whereby a desired shape is obtained by using electrical discharges to erode material	
Grinding Features (via Creep-Feed, Cylindrical, Surface, Centerless)	Widely used to produce a smooth finish on flat surfaces. Abrasive machining process in which a spinning wheel covered in rough particles is used	
Machined Features (including Boss, Chamfer, Counterbore, Countersink, Fillet, Keyway, Spotface, Clevis, etc.)	Used on machined parts to provide edge breaks to reduce stress and facilitate assembly of other machined parts or mechanical designs	

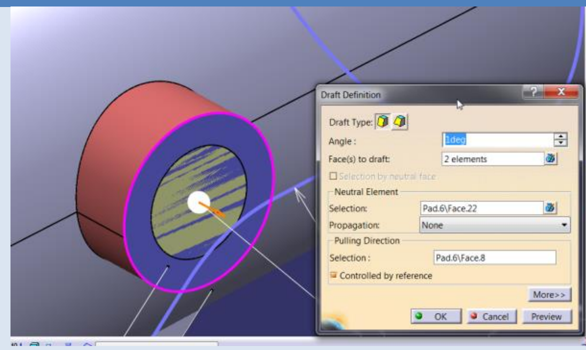
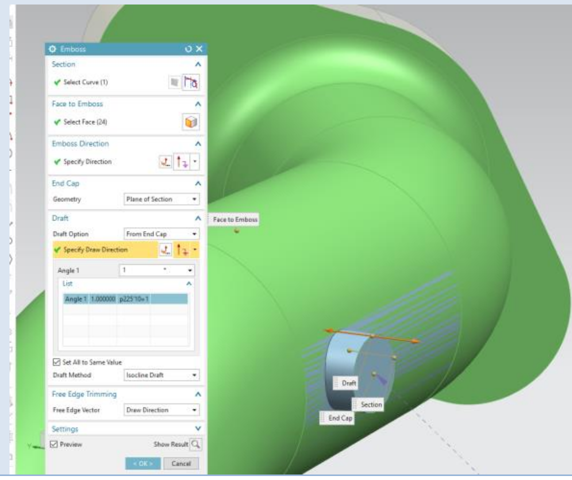
Casting/Forging/Molded

ASME Y14.8 collects casting, forging, and molded parts into a singular set due to common information requirements. A casting is a part obtained by solidification of material in a die or mold. A forged part is one created by plastically deforming metal. And a molded part is when the form is made by pouring or injecting material to produce a part.

Minimum Data Element	Description	Example
Limited Area Application Indicator	Organized group of surfaces that can contain a profile smaller than the total area of the underlying geometries or a boundary area not tied to limits of the total surface	  
Parting Surface	A surface group or wireframe boundary with a unique identification as a surface/zone/offset to allow remnants of the parting line (i.e., a differential surface profile zone due to manufacture process. Can carry associated specification reference link)	  

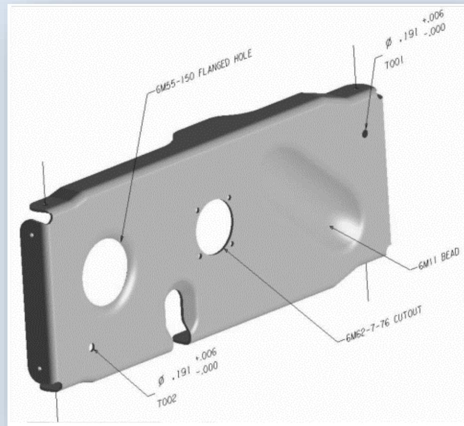
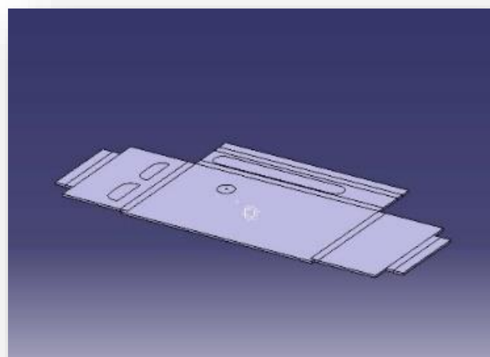
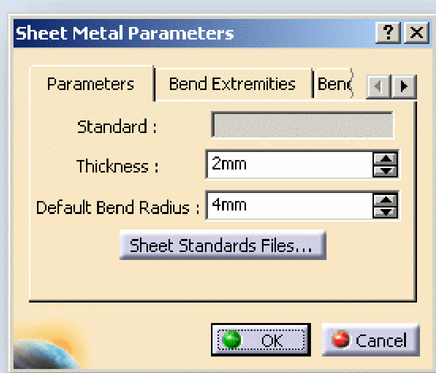
Minimum Data Element	Description	Example
Prolongation Area	An area of additional material beyond the normal envelope of shape definition (i.e., material that is to be machine finished in subsequent operation)	
Test Specimen	An additional area of geometry that is separable from the main object, typically for the purpose of properties testing, either destructive or stored "proofs" for future use	See general use of "supplemental geometry" if presented within solid model
Non-Destructive and Mechanical Property Inspection Notes	Specific instruction or conditions, relating to the inspection process captured as general or linked notation	Hyperlink to separate location/doc, attachment described in specifications. Inspection areas and volumes can be modelled as a supplement geometry and defined with PMI annotations 
Datum Target Bossing	A grouping of pad features that are used to establish the principle datum planes Of particular importance when no obvious area can be used as a datum feature	

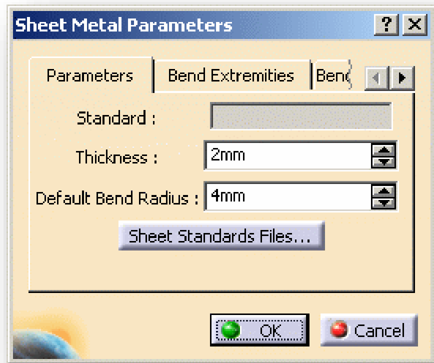
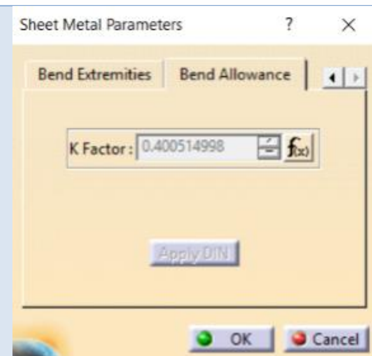
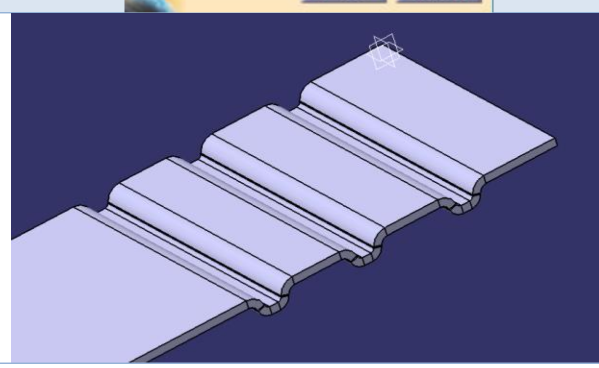
Minimum Data Element	Description	Example
		
Break-Edge	The directed implication of either an outside fillet or chamfer against a hard edge within solid definition, which has not been implicitly modelled	Engineering requirement against all sharp OUTSIDE edges "BREAK EDGES .003-.015 UOS." If non-semantic or feature-grouped and tagged for semantic representation  
Corner Round & Unspecified Radiuses	The directed implication of an inside fillet radius even when the solid model has hard edge intersect geometry	Engineering requirement against all sharp INSIDE corners "CORNERS MUST HAVE FILLETS R.005-.020 UOS." If non-semantic or feature-grouped and tagged for semantic representation (See Break-Edge)

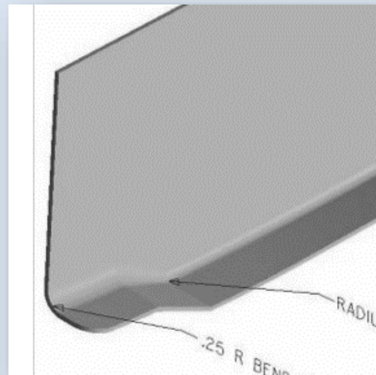
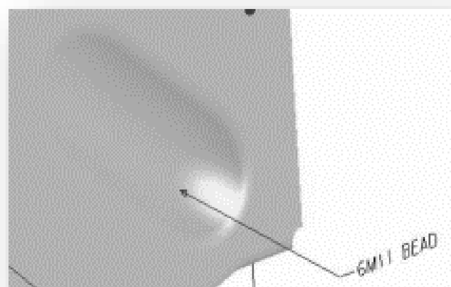
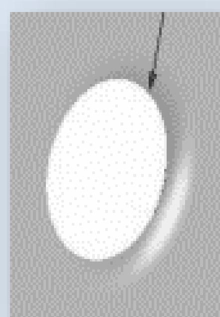
Minimum Data Element	Description	Example
Draft	Additional material geometry added with a shallow angle, typically parallel to mold extraction orientation	 

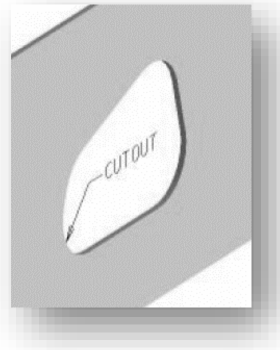
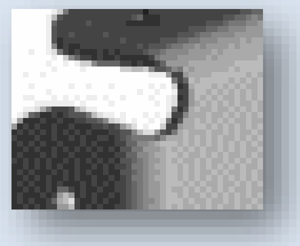
Sheet Metal

A sheet metal part is formed by taking thin sheets of metal and performing metal works, such as bending, rolling, or hammering.

Minimum Data Element	Description	Example
As-Formed Condition Shape	Folded shape definition of the part	
Flattened Condition Shape	Flattened view for manufacturing; flattened view can be in separate CAD file (2D or 3D)	
Inside Bend Radius	Radius of the bends	

Minimum Data Element	Description	Example
Material Thickness	Thickness of the metal	
K-Factor	Ratio between the material thickness and neutral fiber axis	
Crimps	Small fold or rig	

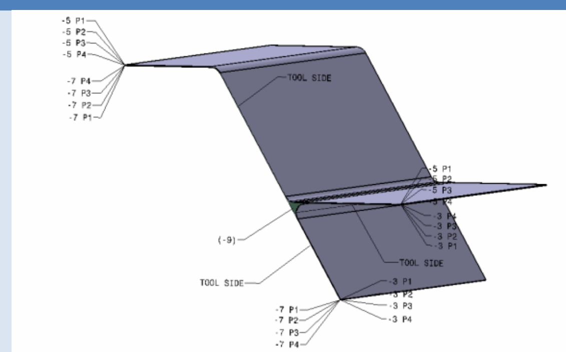
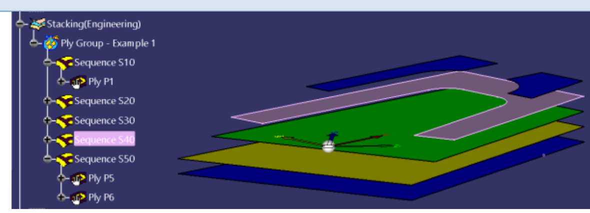
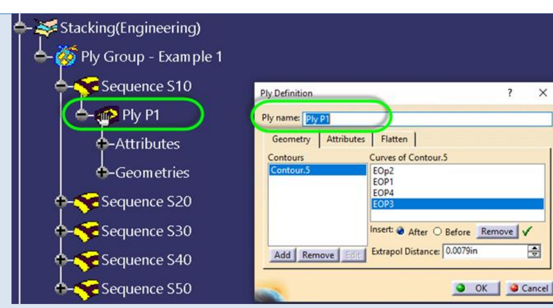
Minimum Data Element	Description	Example
Joggles	Small offset near the edge of a piece of sheet metal; it allows one sheet of metal to overlap another sheet while maintaining a flush surface	
Beads	Long, drawn-out impression, which is impressed to increase stiffness in metal sheets or plates	
Flanged Holes	Hole with a flange	

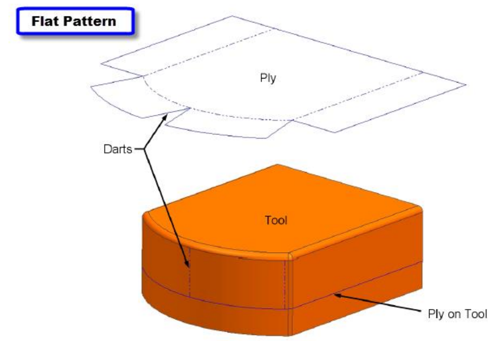
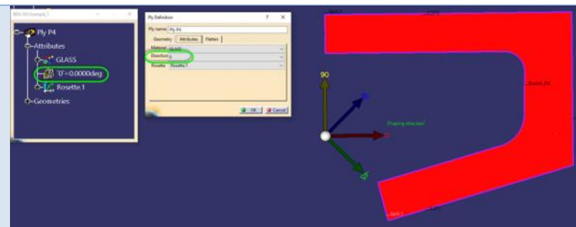
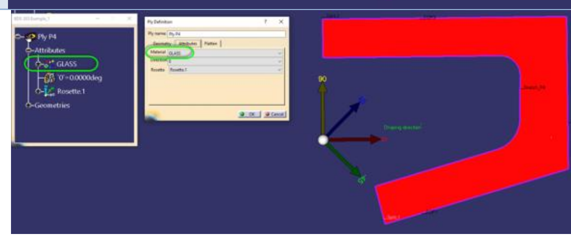
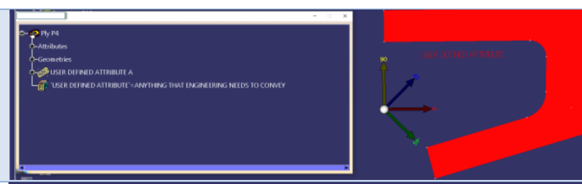
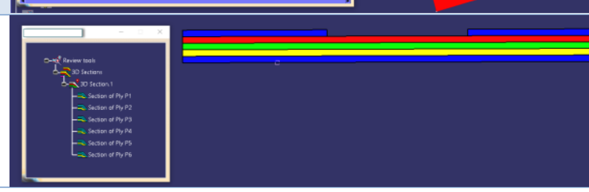
Minimum Data Element	Description	Example
Cutouts	Shape cutout form the metal	
Flange Relief	A relief is two small incisions cut out into a piece of sheet metal to free the metal in between; it separates the material to be folded from the rest of the part	

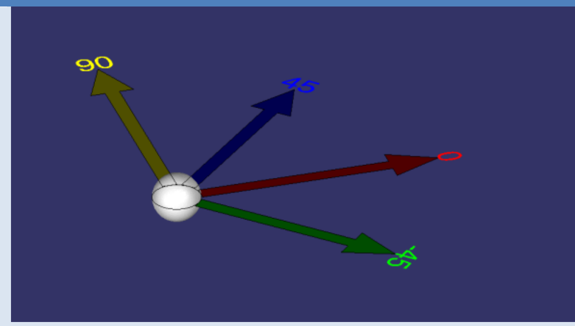
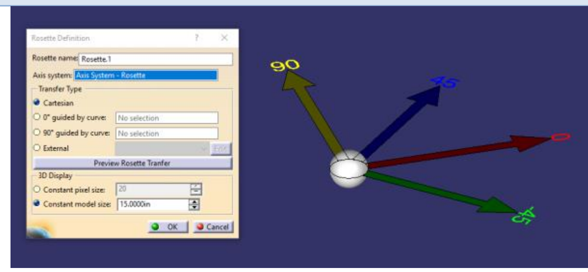
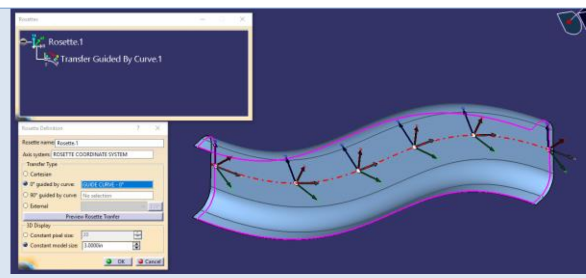
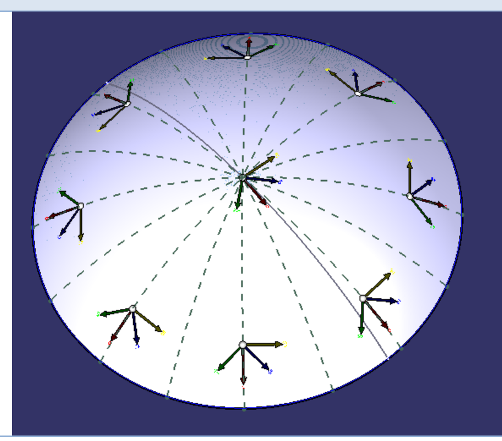
Composites

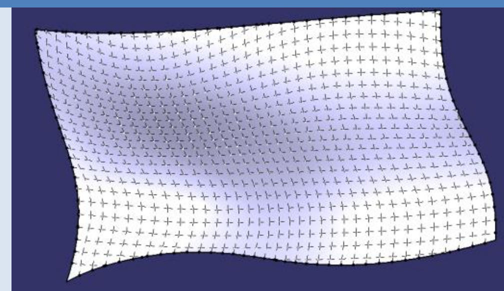
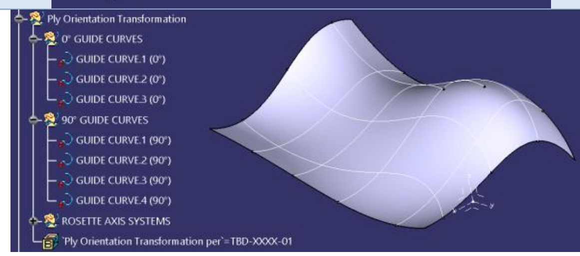
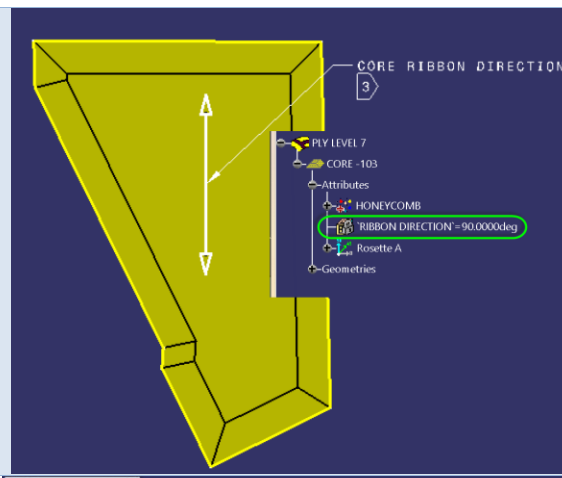
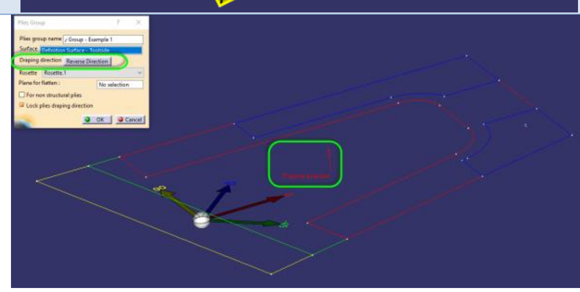
ASME Y14.37 "Production Definition of Composites Parts" specifies the content, representation, and presentation requirements for composite parts. Attributes are assigned to the ply representation for material, fiber direction. Specified fiber direction is related to a local frame of reference (i.e., coordinate system) and usually specified as an angle measure (e.g., +45°).

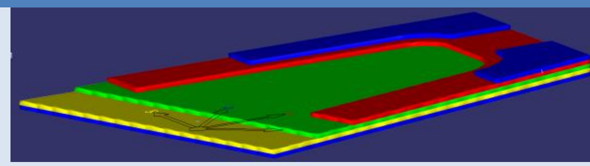
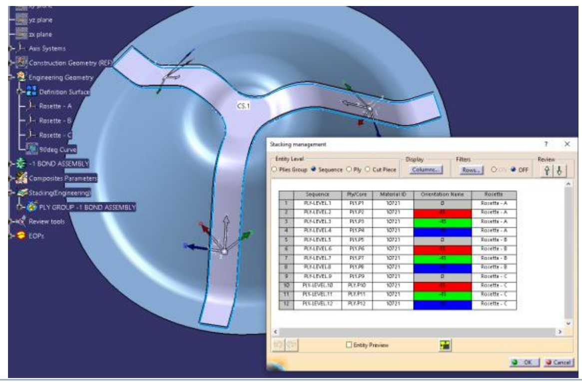
Other product definitions can be specified by way of the use of supplemental geometry, PMI, and attributes sometimes grouped via a collector referred to as a *Limited Length Area Indicator* (LLAI). Alternate shape representations of the plies geometry may also be present, such as surfaces, tessellated surfaces, and closed tessellated shells. Flat Pattern data may be associated to the ply representation as planar supplemental wireframe geometry. Cross-Sectional presentation may be included to help clarify ply layup sequencing in local areas, included in the product definition as supplemental geometry.

Minimum Data Element	Description	Example
Product Structure for Bonded Parts	Representation and presentation of co-cured or co-bonded (i.e., multi-stage bonded assemblies)	 ASMEY14.37-2019_Figure 12-4.vsdx
Ply Level	See *ASME Y14.37*-2019 paragraph "3.32 Ply Level" Commonly referred to as a *sequence* in industry and CAD/CAM	
Ply/Item Identification	See *ASME Y14.37*-2019 paragraph "3.31 Ply Identification" and "7.1.2 Ply/Item Identification"	

Minimum Data Element	Description	Example
Ply Flat Pattern Representation	See *ASME Y14.37*-2019 paragraph "7.1.3 Ply Representation (Geometry, Size, and Location)(c)"	
Ply Orientation	See *ASME Y14.37*-2019 paragraph "3.33 Ply Orientation"	
Ply/Item Material	See *ASME Y14.37*-2019 paragraph "7.2.5 Ply Material" Additionally, embedded non-composite items may have their materials defined in the corresponding item definition or within the composite bond part representation as reference	
User-Defined Ply Definition Attribute	Additional attributes associated with the representation of the ply (or ply level or sequence)	
Ply Stackup Schematic	See *ASME Y14.37*-2019 paragraph "3.35 Ply Stackup Schematic"	

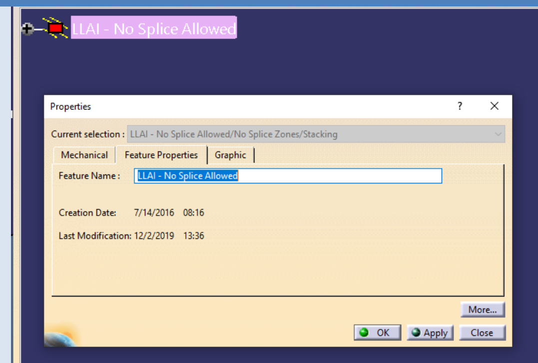
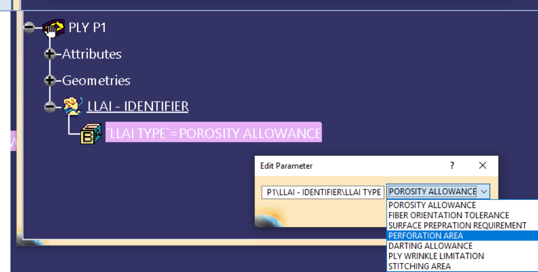
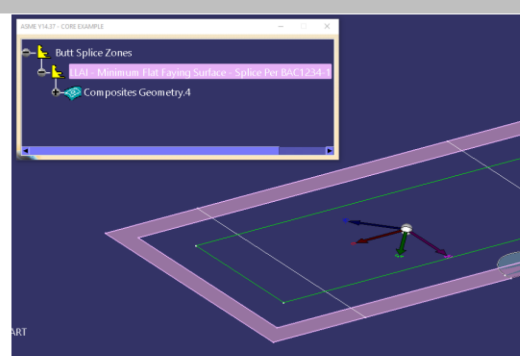
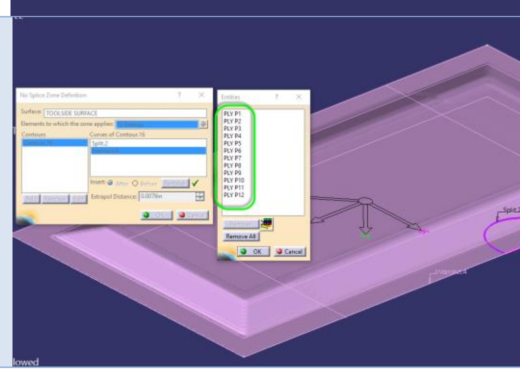
Minimum Data Element	Description	Example
Ply Orientation Symbol	Also known as a *rosette* See *ASME Y14.37*-2019 paragraphs “3.40 Rosette,” “3.34 Ply Orientation Symbol,” and “6.1.1 Ply Orientation Symbol”	
Ply Orientation Transformation Type 1	See *ASME Y14.37*-2019 paragraphs “6.1.2 Ply Orientation Query at Local Seed Point,” and “6.1.2.1 Ply Orientation Transformation Type 1: Standard (Cartesian) Orientation”	
Ply Orientation Transformation Type 2	See *ASME Y14.37*-2019 paragraphs; “6.1.2 Ply Orientation Query at Local Seed Point,” and “6.1.2.2 Ply Orientation Transformation Type 2: Orientation Guided by Curve”	
Ply Orientation Transformation Type 3	See *ASME Y14.37*-2019 paragraphs; “6.1.2 Ply Orientation Query at Local Seed Point” and “6.1.2.3 Ply Orientation Transformation Type 3: Polar (Radial)”	

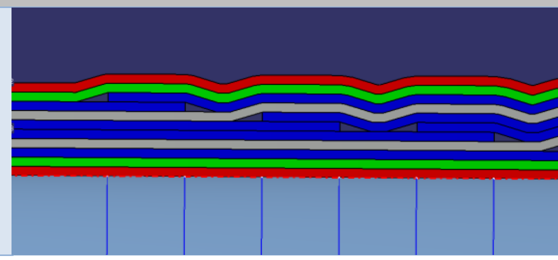
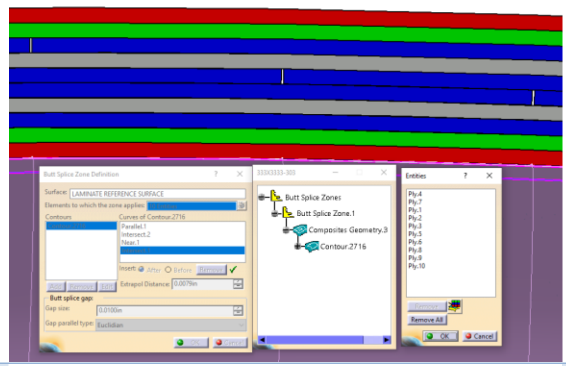
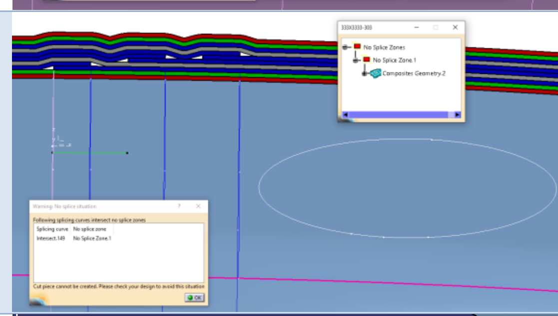
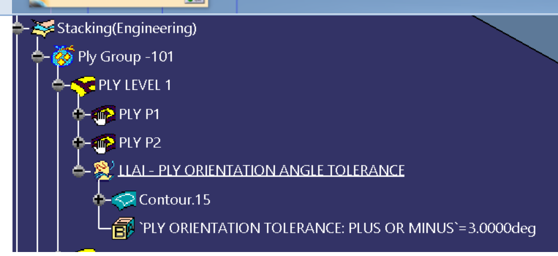
Minimum Data Element	Description	Example
Ply Orientation Transformation Type 4	See *ASME Y14.37*-2019 paragraphs; "6.1.2 Ply Orientation Query at Local Seed Point" and "6.1.2.4 Ply Orientation Transformation Type 4: Fiber Orientation Array"	
Ply Orientation Transformation Type 5	See *ASME Y14.37*-2019 paragraphs "6.1.2 Ply Orientation Query at Local Seed Point" and "6.1.2.5 Ply Orientation Transformation Type 5: User Defined"	
Core Ribbon Direction		
Laminate Layup Direction	See *ASME Y14.37*-2019 paragraphs "3.25 Laminate Layup Direction," "6.2(e)," and "6.2(f)" **Note:** The laminate layup direction is typically the surface normal direction of the laminate reference surface but may be the inverse direction	

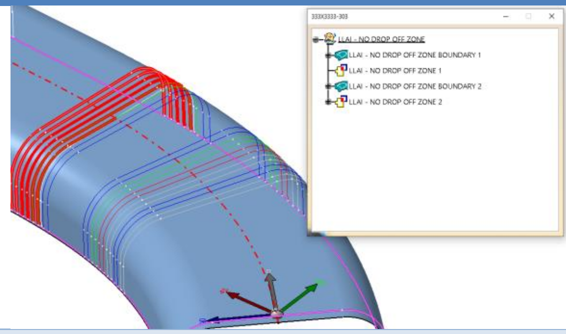
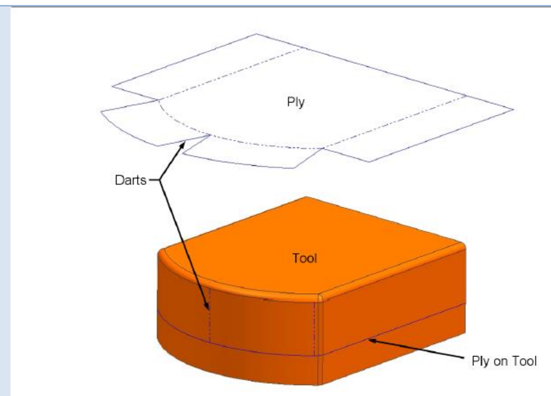
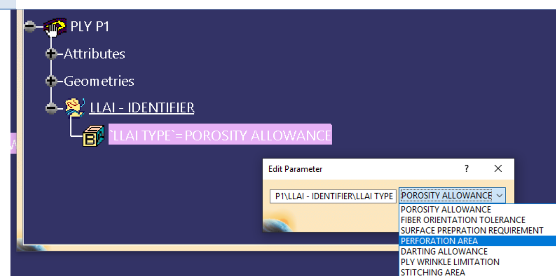
Minimum Data Element	Description	Example
Exploded Ply Representations	Volumetric "explicit" 3D representation or presentation of the ply geometry; scale may not be 1:1	
Rosette Association	Multiple rosettes associated with different plies within the same laminate table	See Figures 7-2 and 9-2 in *ASME Y14.37-2019* 

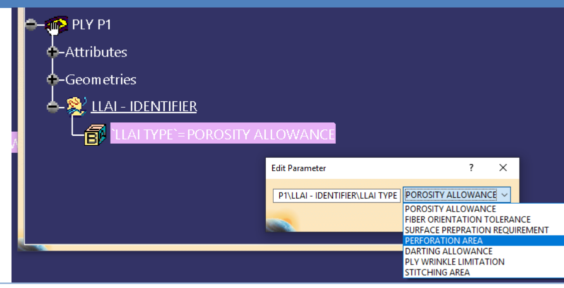
Composite LLAI

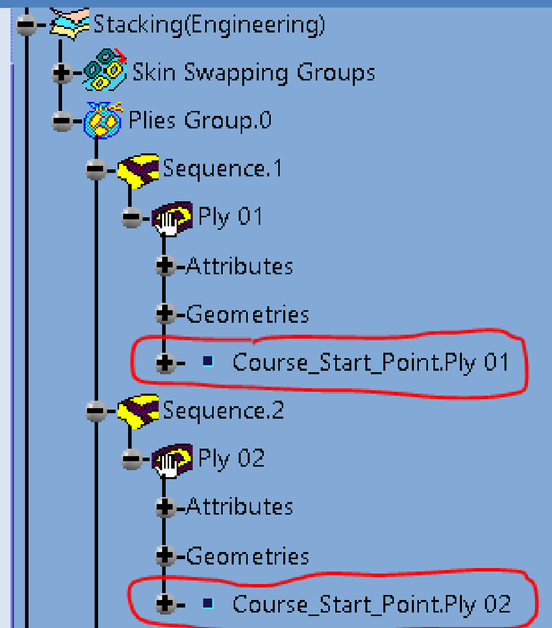
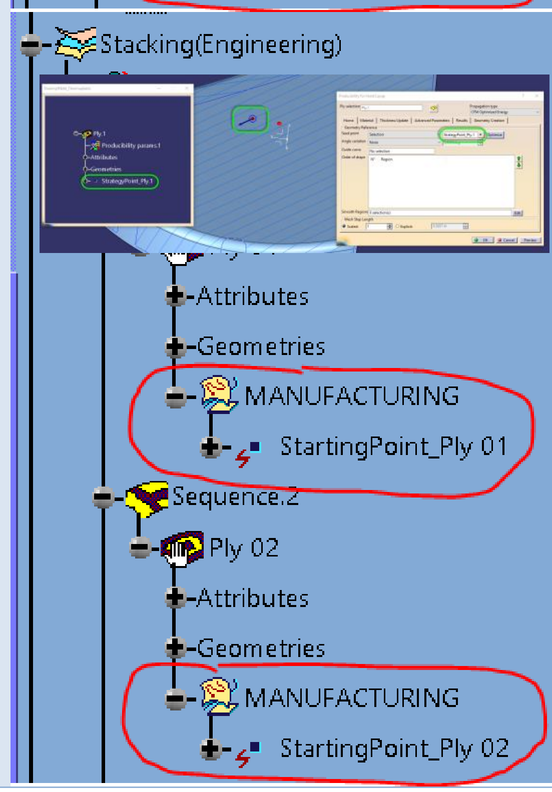
Composite LLAI is the breakdown of Limited Length Area Indicators (LLAIs) as used within composite part types.

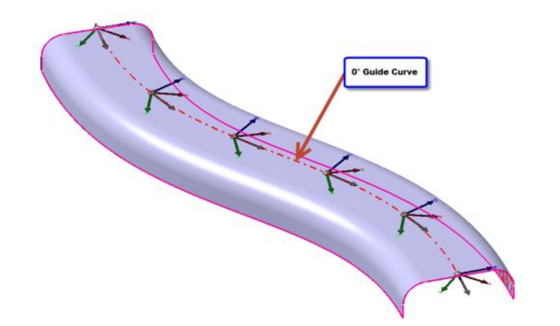
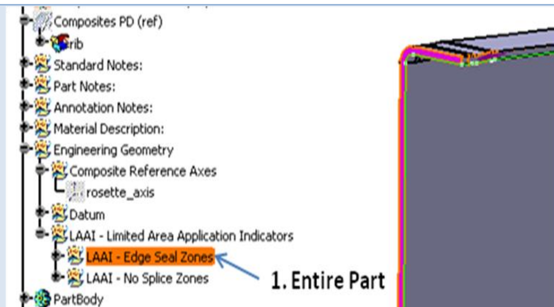
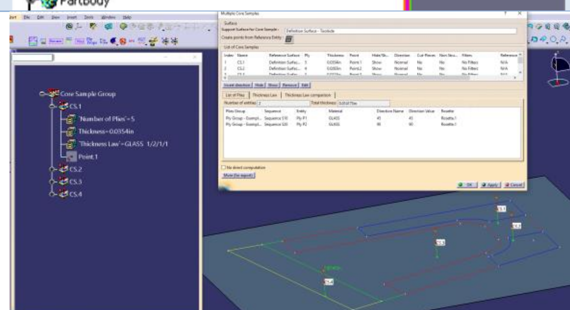
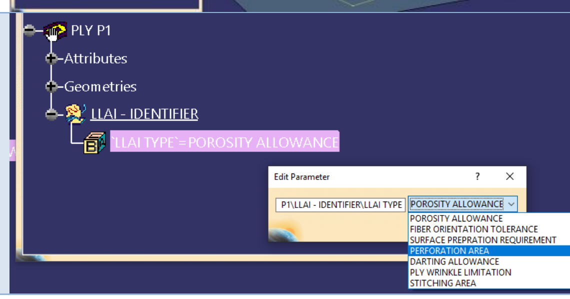
Minimum Data Element	Description	Example
Identifier	LLAI identifier per *ASME Y14.37*-2019 paragraph “6.4(a)”	
Type	LLAI type per *ASME Y14.37*-2019 pararaph “6.4(b)”	
Attributes		
Related Geometry	Wireframe or Surface representing the limited area. LLAI geometric representation per *ASME Y14.37*-2019 paragraph “6.4(c)”	
Associated Composite Entities	LLAI associated composite entities (plies, cores, etc.) per *ASME Y14.37*-2019 paragraph “6.4(e)”	

Minimum Data Element	Description	Example
LLAI Types		
TYPE: Overlap Splice Area	Overlap Splice Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(a)"	
TYPE: Butt Splice	Butt Splice Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(b)"	
TYPE: No Splice Area	No Splice Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(c)"	
TYPE: Fiber Orientation Angle Tolerance Deviation Area	Orientation Angle Tolerance LLAI per *ASME Y14*.37-2019 paragraph "6.4.1(d)"	 **Note:** Could also be accomplished with GD&T and PMI
TYPE: Surface Porosity Allowance Area	Surface Porosity LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(e)"	

Minimum Data Element	Description	Example
TYPE: Ply Drop-Off Stay Out Area	Ply Drop-Off Stay Out Area LLAI per *ASME Y14.37-*2019 paragraph "6.4.1(f)"	
TYPE: Surface Preparation Area	Surface Prep Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(g)"	
TYPE: Potting Area	Potting Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(h)"	
TYPE: Darting Area	Darting Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(i)"	
TYPE: Perforation Area	Perforation Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(j)"	
TYPE: Ply Wrinkle Allowance Area	Ply Wrinkle Allowance Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(k)"	

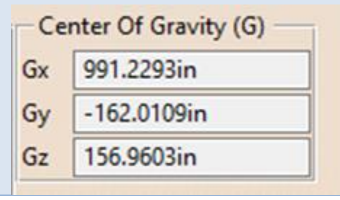
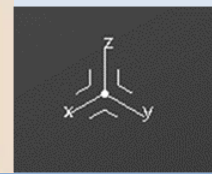
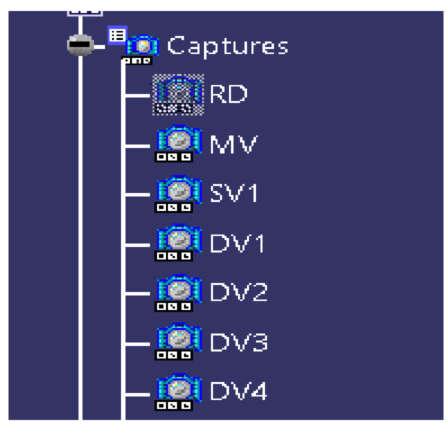
Minimum Data Element	Description	Example
TYPE: Stitching Area	Stitching Area LLAI per *ASME Y14.37*-2019 paragraph “6.4.1(l)”	

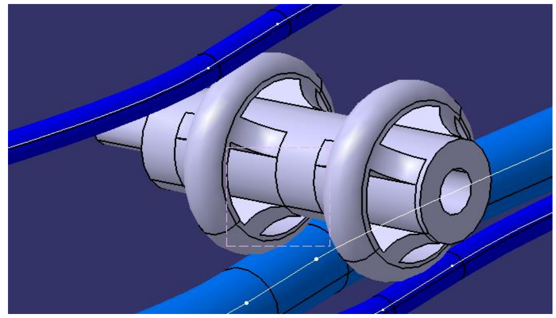
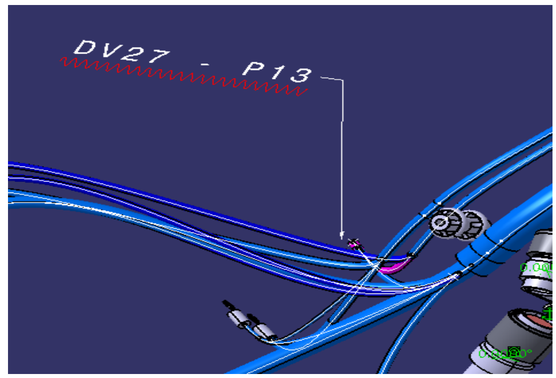
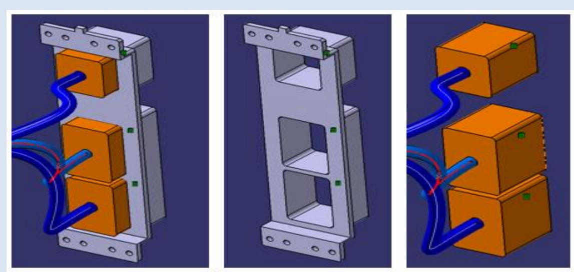
Minimum Data Element	Description	Example
TYPE: Strategy Area	Layup Strategy Point (curve, surface) LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(m)" This would contain a definition and parameters such as those included in DS V5 "producibility" features; also used for AFP/ATL Start Points	

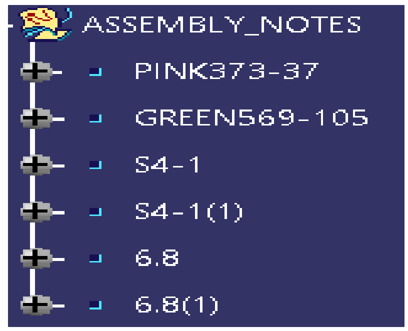
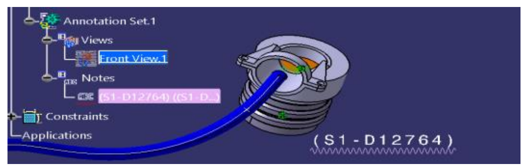
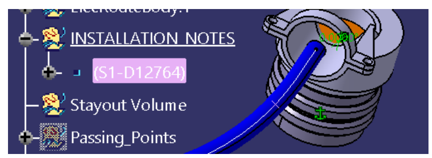
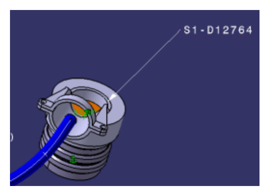
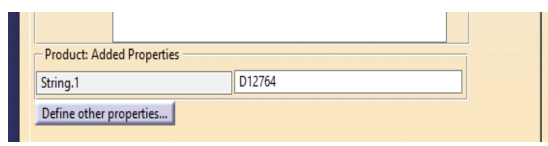
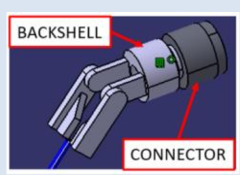
Minimum Data Element	Description	Example
TYPE: Guide Curve	Guide Curve LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(n)" For specifying a non-linear path for a primary rosette direction to follow	
TYPE: Edge Sealing	Edge Sealing Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(o)" A specific type of surface prep LLAI	
TYPE: Core Sample	Core Sample LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(p)"	
TYPE: User Defined	User Defined Area LLAI per *ASME Y14.37*-2019 paragraph "6.4.1(q)"	

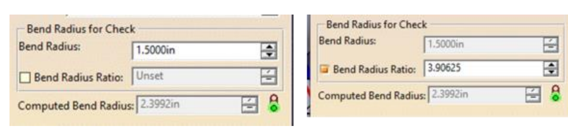
Systems – Electrical Wire Harness

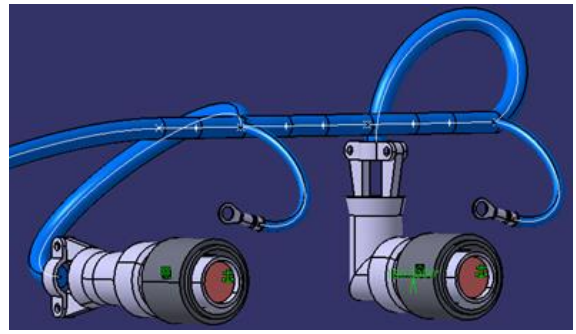
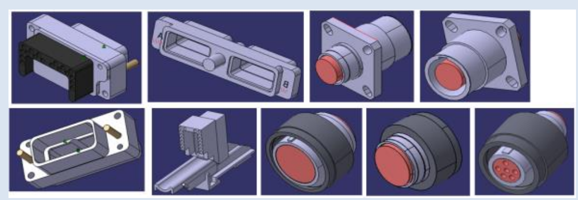
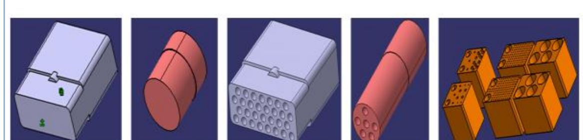
The table in this section describes a set of information for the minimum requirements and features of a 3D MBD wire harness.

Minimum Data Element	Description	Example
3 Point Location of Harness Equipment **Axis/Coordinate System**	Contextual location of equipment that is part of the harness definition, in X, Y, and Z coordinates (e.g., connectors, lugs, backshells)	X, Y, and Z coordinates for harness equipment in a vehicle; X, Y, Z Coordinate System of an assembly or part; Vehicle or Part Coordinate System (X,Y, Z) (Orthogonal axis)  
3D views	Views depicting height, width, and depth; captures showing the installed state of fasteners, stackups (i.e., arrangement) of supports, and the routing path of a harness through the vehicle to provide instructions to manufacturing for an installation	View captures created in the CAD system with annotations and engineering intent. The data can be exported to different file formats for 2D and 3D installation plans, such as in a CAD system, manufacturing planning systems, viewed in 2D drawings, or through the use of tablets, and virtual or augmented reality  

Minimum Data Element	Description	Example
		 
ARINC (Aeronautical Radio, Incorporated)	A corporation formed to define, coordinate, control, and publish system and interface design standards for the commercial airplane industry; ARINC developed the standards for trays and boxes used to hold standard line-replaceable units (LRU) in aircraft	Parts modelled with inserts or the inserts modelled separately and instantiated into the shell, includes part number and version, reference designators for shell and inserts; the cavities within the inserts may be identified on the part 

Minimum Data Element	Description	Example
Assembly / Installation Notes	Engineering information defining requirements for assembly or installation	Can be represented as annotations, metadata, a point re-identified with nomenclature for note identification, or using a point re-identified with the note information     
Backshell	Provides strain relief for wire terminations and connector contacts	Parts modelled in the CAD system, part number and version, reference designator  

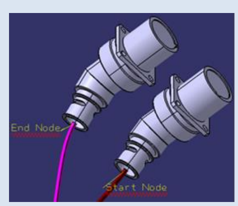
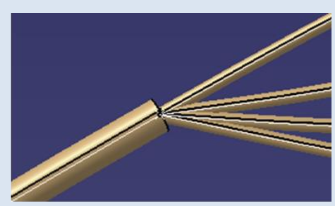
Minimum Data Element	Description	Example
	Connector accessory that performs one or both of the following functions: • Routes wire(s) exiting a connector in a specific direction and may be controlled by a swing arm backshell (e.g., 45 degrees, 90 degrees) • Facilitates environmental sealing of wires at a connector and protects crimping area.	
Conductive Backshell:	Backshell that provides an electrical path from cable shields to the attaching connector; the conductive backshell is made from or plated with conductive material	
Bend Radius	Term used to mathematically define the minimum inside curvature/radius of a bent wire, cable, or wire harness Minimum Allowable Bend Radius – The minimum bend radius allowed for a wire type, cable or fiber optic cable	Can be represented as a wire type object in the model or can be a value entered into the CAD system controlling bend radius of a harness segment 
Coil & Stow	If the stow of the unrouted length of the wire harness is specified, the unrouted length is put in a coil configuration	Can be represented as a coil in the model, an annotation indicating coil and stow, or a point re-identified as an engineering note in the CAD system

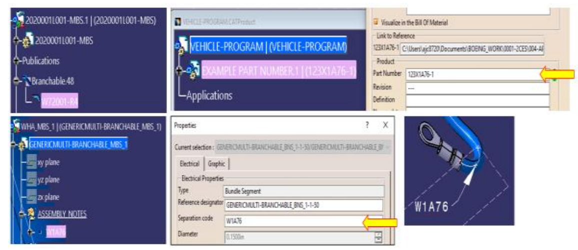
Minimum Data Element	Description	Example
Connectivity	Ability to deliver a signal or power between two or more terminations	Harness segments modelled between two or more harness equipment and linked in the CAD system 
Connectors and Receptacles	Used to join harnesses together or to connect a harness to non-bundle equipment to ensure electrical continuity Various types of connectors exist (by shape, material, installation type); specific types of rectangular connectors may also have an EMI grounding spring and shield ground block	Parts modelled with inserts or the inserts modelled separately and instanced into the shell, includes part number and version, reference designator; cavities within an insert or a ground block may be identified on the part 
Connector Insert	Portion of the electrical connector within the shell that carries and supports the contacts; it is composed of an insulating material, fits contacts of a specific size, and has a specific contact insert arrangement	Parts modelled with inserts or the inserts modelled separately and instanced into the shell, includes part number and version, reference designator; cavities within the inserts may be identified on the part 

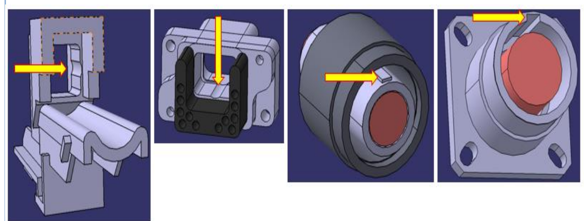
Minimum Data Element	Description	Example
Pin Contact	Electrical contact that is inserted into a socket contact	Can be represented in the model as points re-identified with engineering intent, annotations, metadata, parts modelled in the CAD system as a part number and version, reference designator, or not shown in the model and only contained within the logical database
Socket Contact	Electrical contact into which a pin contact is inserted	Can be represented in the model as points re-identified with engineering intent, annotations, metadata, parts modelled in the CAD system as a part number and version, reference designator or not shown in the model and only contained within the logical database
Data – Logical	Information regarding a harness that contains all the logical content required to support the fabrication of a harness; some of the logical data may not be shown on the physical harness model in the CAD system	Data resides in a logical database and can be exported in a format that can be used to create a CAD model and/or consumed by manufacturing for fabrication of the harness Can be represented as points re-identified with engineering intent, annotations, metadata, as parts, or not shown in the model and only contained within the logical database
Data – Physical	A 2D or 3D model of a harness in a CAD system that is the physical representation of the harness data stored in the logical database	Harness shape, harness parts, notes, length, breakouts, bend radius, harness diameter A 2D or 3D model of a harness in a CAD system that represents the physical harness for form and fit in a vehicle Can be represented as points re-identified with engineering intent, annotations, metadata, as parts, or not shown in the model and only contained within the logical database

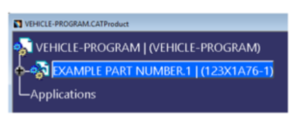
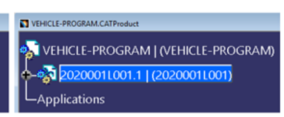
Minimum Data Element	Description	Example
Electrical Device	Refers to parts identified as electrical equipment in the CAD system (e.g., connectors, lugs, backshells, splices, resistors, etc...); the CAD system can be used to add electrical features to parts, which enables harness design functionality	Parts modelled in the CAD system, part number and version, and reference designator Can be represented as points re-identified with engineering intent, annotations, metadata, as parts, or not shown in the model and only contained within the logical database
Electrical Termination	Electrical connection to harness equipment; electrical and physical connection of a cable end to a piece of equipment or another cable. Harness equipment to LRU connection; harness equipment to harness equipment connection	Can be represented as points re-identified with engineering intent, annotations, metadata, as parts, or not shown in the model and only contained within the logical database
Electromagnetic Compatibility (EMC) and Interference (EMI)	EMI/Radio Frequency Interference is an unwanted disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source EMC is the ability of the system to operate within the presence of radiation; harnesses may contain connections of different, but compatible, separation and EMI values	A harness with multiple separations or EMI values is grouped as if all of its segments are the equivalent of its most restrictive separation and EMI values; values can be a metadata, point re-identified with engineering intent, or reside in a logical database

Minimum Data Element	Description	Example
Environmental Zones	Areas within a vehicle that contain different environments induced by operating conditions. Harness that passes through these "zones" must comply with the requirements to protect the harness from environmental conditions	Pressurized and unpressurized, swamp area, threat zones, ignition (fire), altitude, temperature, weather, heat, vacuum, bomb blast, tire burst, engine failure, condensation Environmental zones can be volumetric representation, annotations, point re-identified with engineering intent, metadata, logical information in the logical database
EWIS (Electrical Wiring Interconnect Systems) **Regulatory Requirements, Design Requirements**	Regulatory requirements for a wiring system and its components	EWIS [§ 25.1701(a)] Any wire, wiring device, or combination of these, including termination devices, installed in any area of the airplane for the purpose of transmitting electrical energy between two or more intended termination points Requirements and deviations can be indicated in the model with annotations, points re-identified with engineering intent, or data only contained within a requirements database and that are executed in the architecture of the electrical system in a vehicle **Note:** EWIS is not the following: • Electrical equipment or avionics qualified to acceptable environmental conditions and testing procedures • Portable electrical devices not part of airplane's type design • Fiber optics
Export Markings	Export Control, Approval Status, or Company Proprietary markings to control usage and access	Information indicating: International Traffic in Arms Regulations (ITAR), Military (MIL), Export Administration Regulations (EAR), Commerce Control List (CCL), and commercial products; in the form of annotations, metadata, data associated with the model in the physical and logical PDM

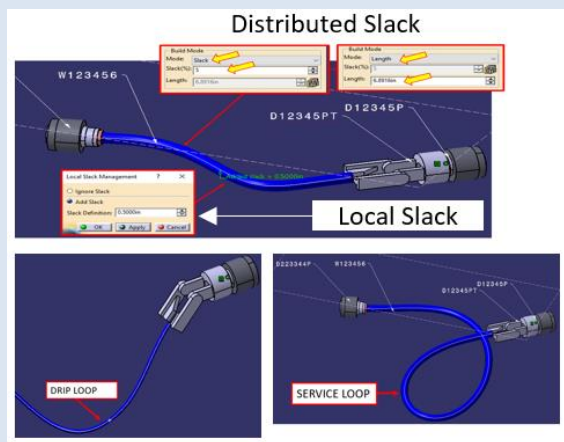
Minimum Data Element	Description	Example
Fiber Optic	Flexible, transparent fiber made of glass (silica) or plastic that is used as a means to transmit a signal between equipment using light	Represented as parts showing fiber optic harness segments in their installed shape; model can be flattened and arranged on a 2D or 3D formboard for fabrication of a harness
Flag Marker Identification	Flag markers are an aid to manufacturing; they ensure that each harness is installed in the vehicle as intended by Engineering	Can be represented as points re-identified with engineering intent, annotations, metadata, or part number and version
Harness Diameter	Each wire type will have a specification that identifies the gauge and its diameter When determining the route definition of wire harness segments, the total composite harness diameter must be taken into account for the main trunk of the harness and the diameter of the breakouts from the main trunk of the harness	Diameter values modelled in the harness segments
Harness Equipment	Equipment installed on the harness during the manufacturing process	Parts modelled in the CAD system, part number and version, reference designator
Harness Node	Electrical extremity node connection to an electrical device or standard equipment, allowing connection of the harness to equipment, other harnesses; harness node is also a point or connection between two or more branches	Modelled in the harness segments in the CAD system. Segment to segment, segment to bundle equipment, bundle equipment to bundle equipment or LRU 

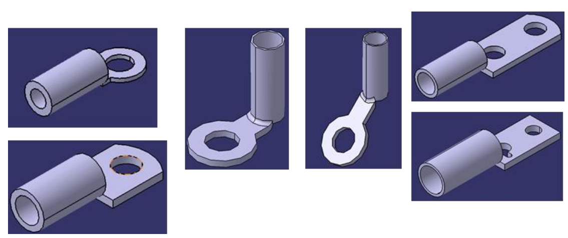
Minimum Data Element	Description	Example
Harness Number	Identification of the harness number in the physical model and logical database	Harness numbers can be represented by part number and version, re-identification of segments, added to the properties dialog of a segment in the CAD system, indicated by annotations, or re-identified points with harness numbers 
Harness Segment	Entity of a harness with the same cables content for a dedicated configuration connecting extremities or junctions	Physical transport element path that is modelled in a CAD system and consists of length, bend radius, segment diameter, and shape; multiple harness segments are used to define a harness
Harness Shape	Contour of the wire routing between equipment	Modelled in the CAD system, length, bend radius, segment diameter, and shape
Harness Support	Is for the attaching (e.g., a ring post, clamp, spacer, figure eight Panduit, hold-down tape) of a harness or groups of harnesses to the vehicle and is used to control the installation routing path	Modelled in the CAD system, spatial coordinates, part number and version

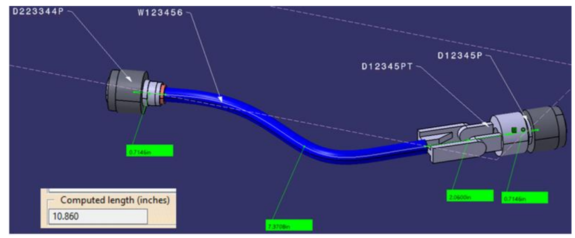
Minimum Data Element	Description	Example
Keying, Master Keyway, Alternate Keyway **Patterns in the connector designed to prevent unintended mating of same series connectors**	Master keyway is a channel-like feature located on the inner ring of the mating end of a circular connector that is used to align the connector-to-receptacle coupling, as well as to prevent incorrect mating to another circular connector Keys are grouped in multiple configurations that are unique; this uniqueness prevents the mating of a plug and receptacle of different key groups In conjunction with the master keyway, alternate keyways provide protection against connector rotation and vibration Keys molded into a connector shell are not adjustable	Feature that is physically represented on the part in a CAD system Alternate Keyway is any controlled keying device position which differs from the accepted "normal" position for the device 
Label (Harness ID, Reference Designators)	Identification tape used for both harness and connective equipment identification	Points re-identified with engineering intent, annotations, metadata, or parts placed on the harness model
Marker Tape	Special sleeve or tape imprinted with information about the harness and its installation location within the product. It is placed on the harness during manufacturing; a harness may have more than one marker applied to it	Points re-identified with engineering intent, annotations, metadata, or parts placed on the harness model

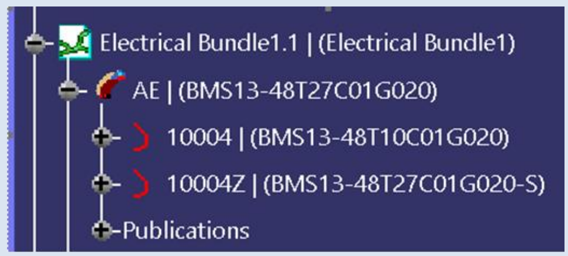
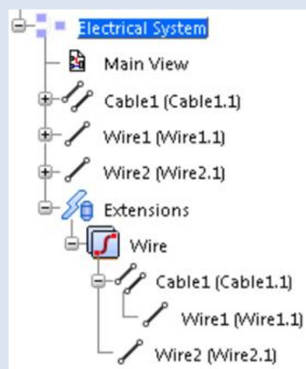
Minimum Data Element	Description	Example
Notes	General Notes – Pre-formatted notes that apply to an entire part or specific area/features in the model Part Notes – Locally defined notes applicable to the entire part or features in the part Specific Usage Notes – Locally defined notes applicable to a specific area in a design. Administrative Notes – Non-technical (e.g., company address, proprietary notes) Process Control Notes – Notes for process and procedures identified within the assembly or individual parts	Points re-identified with engineering intent, annotations, metadata, and pre-formatted notes
Part Number & Revision Level of the Assembly/ Installation	Unique identifier and version of the assembly/installation	Part number in the logical PDM and part number and version in the physical PDM; part number identifies the harness  
Protection (Sleeving)	Mechanism installed around a group of wires to ensure harness separation Protects a harness mechanically or electromagnetically; a non-metallic tube surrounding a wire harness that provides protection for the cable or wire harness; sleeving may be applied during harness assembly or installation	Points re-identified with engineering intent, annotations, metadata, protective sleeving parts with part number and version

Minimum Data Element	Description	Example
Reference Designator	Unique identifier for each equipment usage. Applies to wire harness, harness, and non-harness equipment **Important:** If the equipment is used on a commodity and the commodity is used in multiple locations (e.g., lavatory or galley), then a reference designator is unique only to that commodity; the commodity may be used multiple times in a vehicle or other product in the context of that vehicle	Points re-identified with engineering intent, annotations, or metadata in the CAD system
Seal Plug	Part used to seal an unused contact cavity of a connector, terminal module, or relay socket; sealing plugs are inserted in the grommet holes of unused contact cavities in environmentally sealed connectors	Can be parts with part number and version, points re-identified with engineering intent, annotations, metadata, or not shown in the model and only contained within the logical database  
Shell Size	Size of a connector shell and backshell diameter	Parts modelled in the CAD system, part number, and version, reference designator; shell size can be identified within the part number format
Shield	Group of conductive filaments woven or wrapped over a wire or cable to prevent signal leakage or interference	Can be represented in the model as parts or only contained within the logical database
Signal	Voltage or current that conveys information between equipment	Can be represented in the CAD model or only contained within the logical database

Minimum Data Element	Description	Example
Slack – Distributed Slack	Slack distributed over the length of a harness to ensure fit in the vehicle during installation	Slack is represented in the model as an extra length and/or percentage values that are entered into the CAD system to control distributed slack between harness segments routing through harness supports and up to harness terminations (e.g., movement of hinged joints, removal of face-mounted equipment, allowance for thermal expansion/contraction, preventing mechanical strain on wires, providing drip loops)
Local Slack	Local slack is applied to specific bundle segments to control slack	
Slack – Drip Loop	Prevents fluids from entering junction boxes, connectors, or other enclosed items by providing a drip loop in the wire or harness just before it enters the equipment	Drip loop is represented in the model as an extra length and/or percentage values that are entered into the CAD system to control drip loop shape and fit
Slack – Service Loop	Slack in the harness that allows removing face–mounted equipment	Service loop is represented in the model as an extra length and/or percentage values that are entered into the CAD system to control service loop shape and fit 

Minimum Data Element	Description	Example
Splice – External Splice, Internal Splice, Sealed Butt Splice	Termination device used to join the conductors of two or more wires to create an electrical termination and mechanical bond Sealed butt splice is a butt splice with a heat shrinkable sealing sleeve supplied as a kit; the sealing sleeve's sealing material bonds the sleeve to the wire as the sleeve shrinks when heat is applied	Can be represented in the model as parts with part number and version, re-identified points with engineering intent, annotations, or metadata
Standard Notes	Non-engineering notes used to convey business information (e.g., company address, per ASME/ISO)	Annotations, metadata, or points re-identified with nomenclature for note identification
Terminal Lug **Terminal Lug – Angled** **Terminal Lug – Two Holes**	Used to terminate electrical wire(s) to a device or piece of equipment Terminal lug that has its tongue bent to either a 30-, 45-, or 90- degree angle Terminal lug with two holes on the tongue and issued in high vibration areas; also provides for increased contact surface	Parts modelled in the CAD system, part number, and version, reference designator 
Wire Harness Tie	Lacing tape, plastic tie, or tie tape used to hold groups of wires or cables together	Can be represented in the model as parts with part number and version; defined as a point re-identified with engineering intent. and indicates the position/location on the harness; can be annotations or metadata Shown on a formboard; can be stored within the logical database

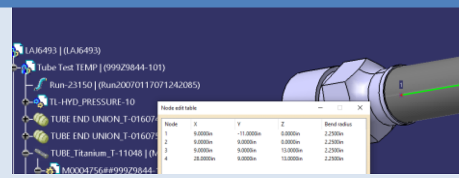
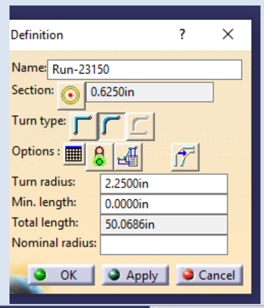
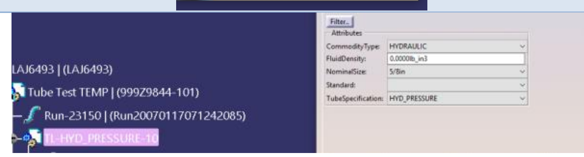
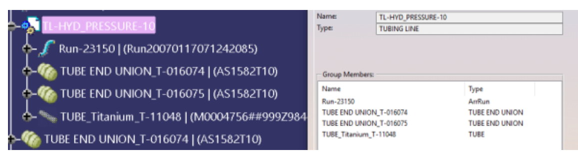
Minimum Data Element	Description	Example
Wire Lengths	Length of wiring from termination to termination	Harness segments modelled in the CAD system; length, bend radius, segment diameter, and shape. When the harness segments are linked together they define the length of the harness between two or more terminations 

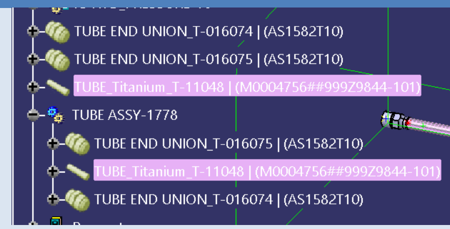
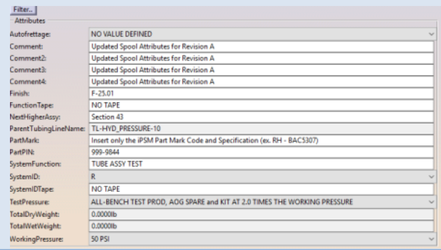
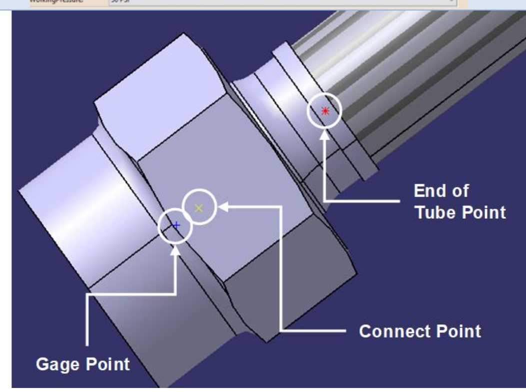
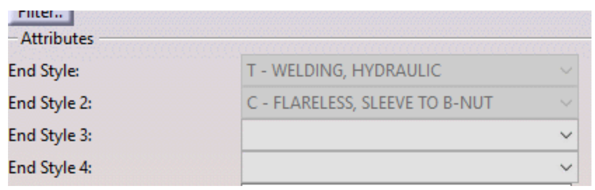
Minimum Data Element	Description	Example
Wire	Single current carrying conductor of one or more strands covered with a suitable insulating material	Can be represented as a wire type object in the model or only contained within the logical database and not represented in the model
Conductor	Material that offers little resistance to the flow of electrical current. Within wire, a single rod or filament or a collection of rods or filaments, of drawn metal (copper or aluminum) suitable for carrying electrical energy	Represented as parts modelled in the CAD system showing wire harness segments in their installed shape; model can be flattened and arranged on a 2D or 3D formboard for fabrication of a harness  
Wire – Twisted Pair	A twisted pair is two wires twisted together over the majority of their length	
Wire – Twisted Shielded Quad Lay	Is four twisted shielded wires twisted around each other to form a larger cable	
Wire – Twin Axial Cable	Two identical wires twisted around a common axis.	
Cable	Two or more solid or stranded conductors insulated from each other and twisted or molded together or enclosed by a common covering; or one conductor enclosed by, but insulated from another conductor, or from a metallic shield Sometimes used to designate a single large diameter stranded conductor	

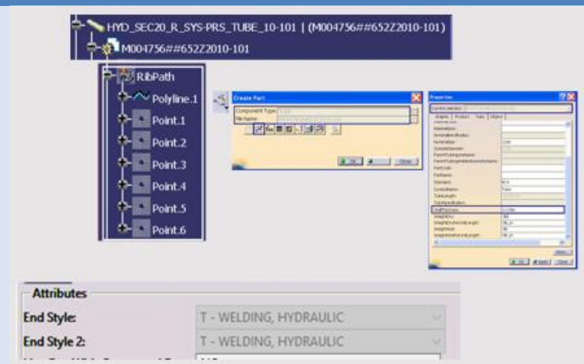
Minimum Data Element	Description	Example
Wireframe Geometry	Points, Lines, Planes, Curves, Splines The geometry that helps create features when needed; creating this geometry is a simple operation that can be performed at any time Two creation modes are available: geometry with its history or without; geometry with no history is called *a datum*	Points, Lines, Planes, Curves, and Splines modelled in the CAD system, Geometry with no solid representation

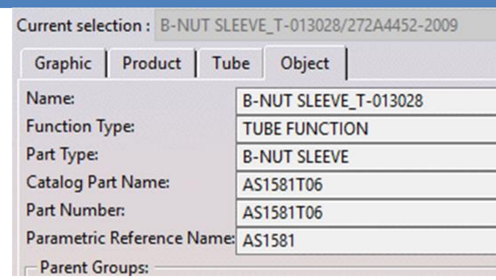
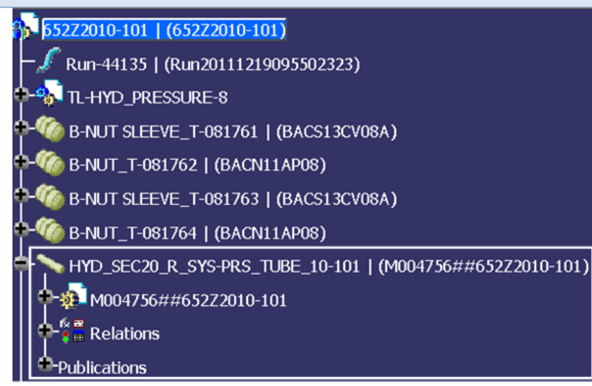
Mechanical Systems – Tubing Transport Elements

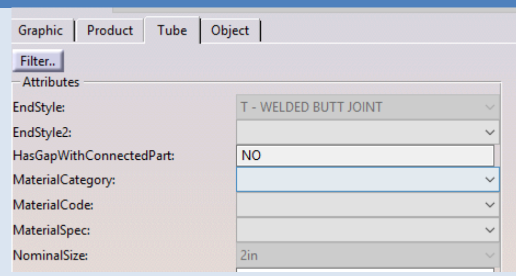
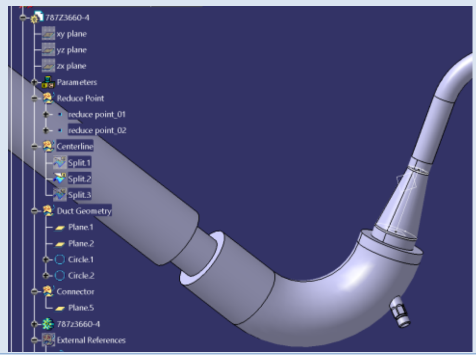
These specific requirements include the required elements, files, and digital format of the objects that represent a transport element assembly dataset.

Minimum Data Element	Description	Example
Run	Physical transport element path used to define the tubing space reservation and routing centerline; tubing runs must be created from pre-approved tubing lines; there is no part reference or document in the vault for V5 for the RUN	 
Tubing Line	Required for Tube Assembly; manages the equipment connectivity and collects the parts placed using a tubing line, the function, and diameter. For design, assigns pre-defined characteristics of the Run, such as function type, size, and pressure rating; no actual geometry is involved	 

Minimum Data Element	Description	Example
Spool	Grouping of parts that make up the tube assembly for manufacturing; manufacturing information was added to attributes of the tube assembly and not as a parameter set	 
Key Characteristics/ End Fittings	Key points on the connective equipment identify key locations of the tube interface Minimum Straight Point – Identifies the minimum straight length required by the tube as it interfaces with the End Fitting Connect Point – Represents the connect point with the mating part/end fitting End of tube point – Represents the termination point of the mating Tube Gage Point (Blue Cross) End Style – Attribute that defines the tube end preparation during manufacturing	 

Minimum Data Element	Description	Example
Key Characteristics/ Tube Bendable	Key points on the connective equipment identify key locations of the tube interface Bend Points – Automatically created after a bendable is placed on the run; the bend points are part of the resulting rib path (poly line) Tube Centerline – Physical form given to the bendable and is exposed by the Rib Path in the bendable. The Rib Path resembles a spline. It can either be a collection of points, lines, arcs and planes, or a poly line.After a bendable is placed on the run, the bendable's rib path can be used to generate a centerline Wall thickness – Nominal wall thickness of the material End Style – Attribute that defines the tube end preparation during manufacturing Flow Direction – Defined by the run creation process; utilized by manufacturing and quality. The flow direction must match the Function tape arrow	

Minimum Data Element	Description	Example
End Fitting	Parts attached to the tubing run; they are assigned a part type, such as Union, Tee, B-Nut, etc; they will have smart connectors (refer to Key Characteristics)	
End Style	Identifies the connection type for a tubing connector and tube; is used mainly for a compatibility check during design and also Manufacturing	
Tube Bendable	Representation of the physical tube part (i.e., a hollow cylinder without fittings) **Note:** Dimensioning and annotation are not required for tube and duct bendable and assembly; this information is automatically extracted via a report in V5	

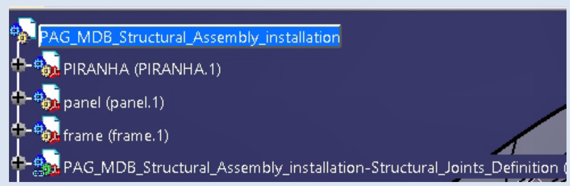
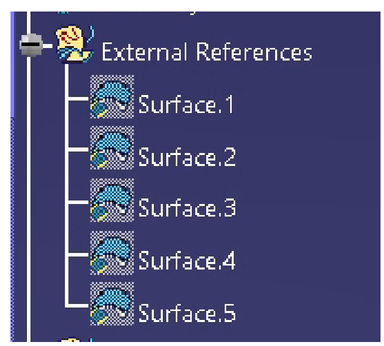
Minimum Data Element	Description	Example
Duct Transition	A tubing part	 
Duct Pullout	The identification of where two runs intersect and a pull out is required	

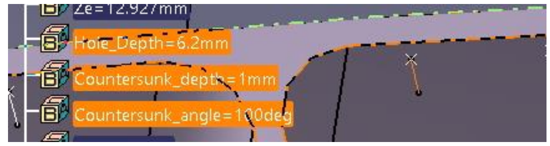
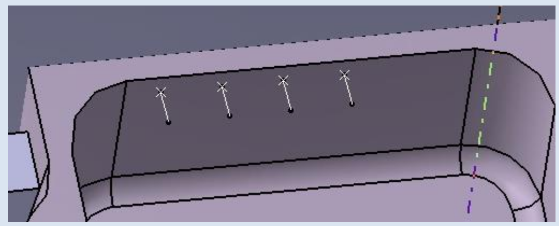
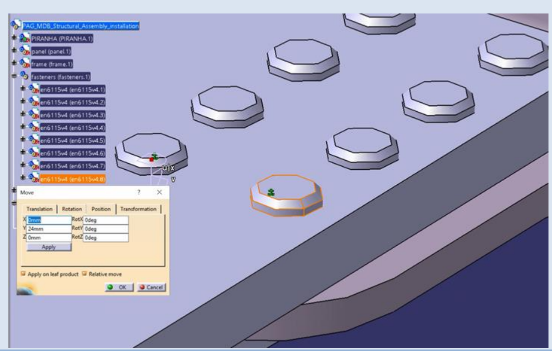
Structural Assembly/Installation

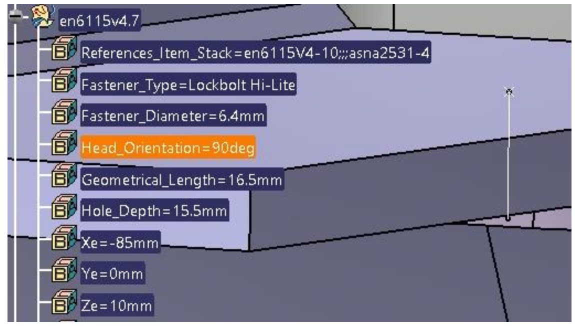
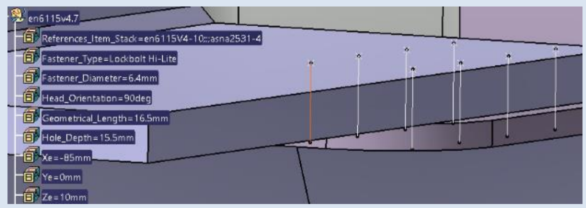
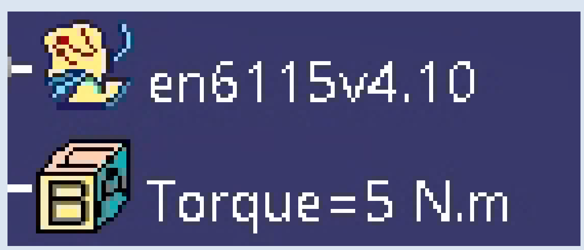
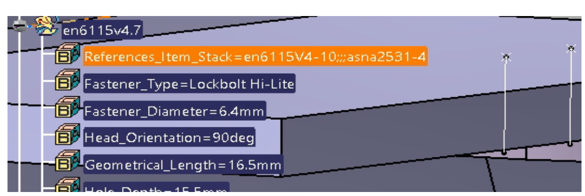
This section describes a set of information that applies to a structural assembly and installation. It is defined by joints and mating material. The joint is a relationship between two or more instances of components in an assembly. The mating definition is implemented by a hardware (e.g. fastener) definition and their associated hole features.

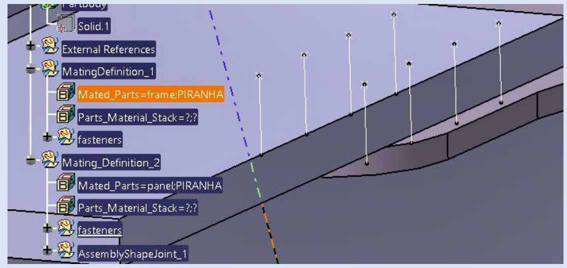
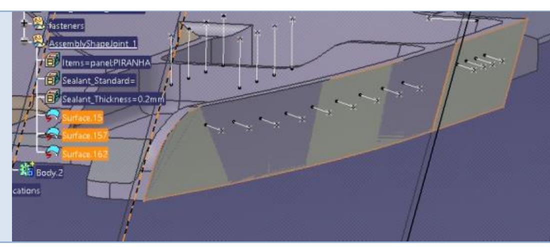
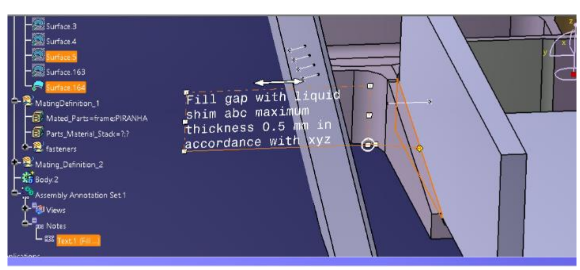
Geometry representing hole and/or fastener part shape may be explicitly modeled or used as a simplified representation (e.g., a point and orientation). The manufacturing processes for drilling a hole, inserting a fastener, and completing the installation (e.g., riveting or tightening a nut) affect the structural and functional properties of the joint. The processes with specifications or standards for how to perform the task are associated with the holes and/or fasteners as part of the engineering design.

DISCLAIMER: The descriptions are meant to define the information requirements at the atomic level. The information may be represented in a singular file or multiple files depending on the implementation. Also, the examples are not meant to imply the only way to model requirement.

Minimum Data Element	Description	Example
Assembly/ Install Prod Structure	The assembly structure of all the components and their sub-components	
Reference Geometry	Geometry used to define the structural context of the installation; on drawings these are the “phantom lines.” *ASME Y14.41* identifies them as *transparent.* *NOTE: While the physical representation of the mating geometry is required, how it is provided may vary.*	
Drill On Assembly/ Installation – Hole Location	Location of the hole represented as a point	

Minimum Data Element	Description	Example
Drill On Assembly/ Installation – Hole Properties	Properties of the hole represented as PMI or attributes/parameters in the model tree	
Drill On Assembly/ Installation – Hole/Drill Direction	Drill direction of the hole represented as a line/vector	
Drill On Assembly/ Installation – Hole/Drill Requirements	Activities associated with the drill of the hole; activities include a verb that requires action during preparation, drill, or clean up; requirements are represented as PMI, attribution or parameters in the model tree and can reference a company specification	
Mating Requirements – Fastener Location	Location of the fastener used to join components; represented as a point or surface/solid/volume/ brep in the context of an assembly coordinate system	 

Minimum Data Element	Description	Example
Mating Requirements – Head direction and Placement	Location of the fastener head and direction for installation; represented as a point and linked to the surface of the part and installation vector	
Mating Requirements – Fastener Install Direction	Defines the installation direction of the fastener; represented as line/vectors or solid/brep	
Mating Requirements – Fastener Properties	Properties of the fastener represented as PMI or attributes/ parameters in the model tree; typical proprieties include fastener identification, grip length, type, material, diameter, etc.	
Mating Requirements – Fastener Install Requirements	Activities associated with the installation of the fastener. Activities include a verb that requires action during preparation, installation, or clean up; requirements are represented as PMI or attributes/parameters in the model tree and can reference company specifications	
Mating Requirements – Fastener Stack up	Ordered set of fastener hardware (e.g., parameters, attributes or relationships)	

Minimum Data Element	Description	Example
Mating Requirements – Joining Parts	Ordered set of components being joined. Additional information can include material type and thickness ordered from the head side of the fastener; represented as attributes/parameters or relationship	
Mating Requirements	Clearance between parts	
Mating Requirements – Sealant Properties	Properties of the sealant, such as sealant identifier and type; represented as PMI or attributes/ parameters in the model tree - both associated with the geometry representing the sealant area	
Mating Requirements – Sealant Application Requirements	Activities associated with the preparation, application, and clean-up of sealants Requirements are represented as PMI or attributes/parameters in the model tree - both associated with the geometry representing the sealant area	
Mating Requirements – Sealant Location	Sealant application area; represented as solid, curve, or surface	
Mating Requirements – Shim Properties	Properties of the shim, such as shim identifier, type, thickness, etc.; represented as PMI or attributes/ parameters	
Mating Requirements – Shim	Activities associated with the preparation, installation, or clean-up of the shim;	

Minimum Data Element	Description	Example
Application Requirements	Requirements are represented as PMI or attributes/parameters in the model tree, both associated with the geometry	
Mating Requirements – Shim Location	Geometrical representation of the shim; represented as a curve, surface, or solid/volume	

Compliance

Model-based Definition and Bill of Material are big concerns within the A&D industry that will likely never go away. To address these issues, the A&D industry needs its solution providers to support the principles and requirements defined in this document. Many of the minimum requirements for standard data exchange have already been embraced and are being implemented within the latest versions of commercial product solutions from the PLM software providers. However, ensuring that these data exchange requirements are complete and able to support our legacy data and processes is a complex challenge. We must work together to successfully meet this challenge.

Requested Response from Industry

The A&D PLM Action Group wrote this paper to demonstrate our understanding of the issues and communicate our intent. We ask that you, as a representative of your company, respond in support of our effort with the following actions:

- Provide your comments and suggestions for improvement of the Problem Statement, Overall Objectives, Desired State, and Requirements as documented in this paper.
- State whether you accept each of the data exchange requirements documented in this paper. For those that you do not accept, provide an explanation for your position, and if appropriate suggest an alternative.
- Describe in what fashion and to what degree your current products and future product roadmaps comply with the data exchange requirements documented in this paper.
- As information requirements for MBD continue to evolve, state whether you will support that evolution and participate in further refinement of the requirements.

Go Forward Plan

The next planned phase of this effort has the A&D PLM Action Group working with the solution providers, who choose to participate, to obtain detailed information about their solutions for each of the specific requirements identified in this paper. The results will be confidential to the A&D PLM Action Group members and not made publically available.

The A&D PLM Action Group will work with established Interoperability Forums, such as the MBx Interoperabilty Forum (https://www.cax-if.org/). The A&D PLM Action Group will engage the Interoperability Forum to prioritize test rounds with a focused list of requirements from the A&D member companies. In addition, the A&D PLM Action Group will urge standards bodies to extend to their definitions and solution providers to include in their implementations.

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group (www.ad-pag.com) is an association of aerospace and defense companies within CIMdata's globally recognized PLM Community Program, which functions as a ***PLM advocacy group*** to:

- Set the direction for the aerospace & defense industry on PLM-related topics that matter to members (*including promoting, not duplicating, the work of standards bodies*)
- Promote common industry PLM processes and practices
- Define requirements for common interest PLM-related capabilities
- Communicate with a unified voice to PLM solution providers
- Sponsor collaborative PLM research on prioritized industry and technology topics

CIMdata administers Group operations, coordinates research, and manages the progression of policy formulation.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding over thirty years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM-enabling technologies.

CIMdata works with both industrial organizations and providers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution providers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certification programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia-Pacific.

To learn more about CIMdata's services, visit our website at www.CIMdata.com or contact CIMdata at: 3909 Research Park Drive, Ann Arbor, MI 48108, USA. Tel: +1 734.668.9922. Fax: +1 734.668.1957; or at Oogststraat 20, 6004 CV Weert, The Netherlands. Tel: +31 (0) 495.533.666.