Minimum Model-Based Definition (MBD) and Bill of Material (BOM) Definition with STEP AP242

Problem Statement, Direction and Preliminary Requirements

A&D PAG Position Paper (AD PAG PP01.1)

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AEROSPACE & DEFENSE PLM ACTION GROUP

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Revision Record

Revision	Date	Description
1.0	Feb 2017	Initial Release
1.1	Dec 2017	Revision to Introduction and Conclusion sections; additional content added to Requirements section.

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Introduction

Over the past few years, a new conversation has been taking place within the aerospace and defense community arising from a growing recognition that certain persistent pain-points are common across the industry. These points of friction, complexity or instability erode the productivity and quality of product information flow through aircraft and defense systems programs and inflate the cost of systems sustainment. In March 2016, executives from the Aerospace & Defense PLM Action Group (A&D PAG) member companies – Airbus, Boeing, Embraer, Gulfstream and Rolls-Royce – met with the intent that informal discussion of PLM-related issues would lead to agreement on common objectives, requirements and plans for remediation of their common PLM pain points. GE joined and contributed to this discussion in July 2017.

One of these common objectives is to facilitate interoperability across the product lifecycle based on open industry data standards. That is the topic addressed by this special project. The Model Based Definition (MBD) team evaluated the ability of ISO 10303-242 (STEP AP242) to support data exchange and interoperability requirements for existing MBD design processes. The evaluation was structured by part type as different part types have different data requirements and have different levels of support in translation tools. The evaluation was distributed across the participating companies using the modeling practices and resulting data that is representative of the company's MBD processes.

This document presents a set of requirements for exposure of MBD data in an open, vendor neutral format. Based on Direction Statement, AD PAG DS01.0 Product Data Exchange Standards, the open format selected for this evaluation is the ISO 10303-242 (STEP AP242) standard. Additional work may be done in future based on the scope and capability of ISO 10303-242, ISO14306 (JT), and ISO32000/14739 (PRC for 3D PDF).

The requirements are presented within the business context from which they were derived. First, the problem, or "pain point," is described including a characterization of the current negative business impacts. This is followed by a description of the desired future state including characterization of the resultant business performance improvement. Within this context, the business improvement objectives and preliminary requirements are put forth. The final sections lay out the go forward plan and response requested from the PLM software providers and other relevant entities within the PLM ecosystem.

Purpose of this Document

The intent of this document is to provide the basis for productive dialogue within the A&D PLM community. Initial distribution will be to a select set of PLM solution providers with a request for response and support. However, this is only the first in what will be a series of position papers that address the topic in ever increasing detail, ultimately resulting in a detailed requirements statement.

Through this progression, it is the intent of the A&D PAG members to engage the broader PLM community in dialogue.

Problem Statement

Context

The Aerospace and Defense (A&D) industry produces very complex products utilizing a broad and deep supply chain. Additionally, many A&D products have lifecycles much longer than the software tools used to create the design. These factors lead to a wide variety of software tools that create and consume MBD data based on different, often proprietary data formats. The complexity of creating and maintaining interfaces to a variety of data formats leads to data operability issues. The consistent use of open standard formats as the common language between these tools is a key strategy for A&D companies.

Explicit Semantics vs. Human Interpretation

One of the goals of STEP AP242 is to support a digital thread from design through analysis and into automated manufacturing. This requires computer interpretable information about the product, i.e., information encoded into a data structure related to the part. Some MBD methods are oriented toward human consumption, not automation. That is, information is encoded into visual annotation such as 3D notes and leader lines.

A company's MBD modeling methodology is based on the expected downstream use cases, which may be automation oriented or human oriented. Thus, the MBD data and the corresponding mapping to AP242 will be different. Human oriented MBD data using 3D annotation elements will be more completely supported than MBD data encoded semantically via attribute data or dataset structures, which will require a more complex mapping to AP242.

STEP AP242 edition 1 supports two use cases:

1. Exchange of 3D MBD with 3D PMI "graphic presentation," for human visualization
2. Exchange of 3D MBD with 3D PMI "semantic representation," for downstream process

There is the possibility to have exchange of 3D MBD with 3D PMI "graphic presentation" associated with "semantic presentation."

These results are based on the MBD methodology at the company assigned to that part type and may not be reflective of the MBD methodology at other companies.

Model Based Definition Content vs. Bill of Materials Content

There is no clear industry standard for when a product data object is included in the MBD dataset and when considered an attribute in the BOM. Each company's modeling practice will draw that distinction differently. For example, export control limitations could be represented inside the MBD dataset or as a BOM attribute or both, depending on the company's design practices. When the data object is in the MBD dataset, the support for a mapping to AP242 is dependent on the PLM (or translator) vendor.

Scenarios

OEM Submission of Technical Data Package to Authority for Certification

Prior to Model-Based Definition, the output of the design process was a drawing. Certification was performed by providing access to those drawings.

In MBD, the design is an annotated 3D model so certification would be performed by giving access to the 3D data in a format compatible to the Certification authorities' requirement for long term archiving and retrieval, as defined by the NAS / EN 9300 LOTAR.

Those LOTAR standards include:

- EN/NAS9300-120—"CAD 3D Explicit Geometry with Graphic Product and Manufacturing Information (PMI) Presentation"
- EN/NAS9300-121—"CAD 3D Explicit Geometry with Semantic Product and Manufacturing Information (PMI) Representation"
- EN/NAS9300-125—"CAD 3D Assemblies with Graphic Product and Manufacturing Information (PMI) Presentation"

Currently in MBD, however, the Certification authorities are given access to the 3D data either in a lightweight format (3D PDF, ISO 14306 JT or AP242) or as a native CAD model. This puts the burden of interpreting the native CAD model on the certification body that may be certifying multiple OEMs with different CAD systems. Additionally, a native CAD model often contains intellectual property beyond the final design such as construction methods, constraints, and relationships that the OEM may not wish to expose to the certification body. OEMs may want to strip this data out before they provide it to the certification body or only allow access via restricted thin client architectures, such as CITRIX.

Manufacturing and Support Enablement

OEMs need to communicate the full content of MBD data with their suppliers. Current limitations in the implementation of standard formats such as STEP result in critical information being lost. Part geometry is correctly exchanged but the tolerances and annotations are lost. This often requires that the native CAD model be sent to the supplier and the burden of interpretation is borne by the suppliers. Another approach is to use STEP to exchange the part geometry augmented by a lightweight geometry for viewing the annotations and notes. Add to this the number of OEM-to-supplier interfaces and supplier-to-supplier interfaces and the problem propagates exponentially throughout the supply chain.

Design Integration

Collaboration between design partners requires the exchange of geometry, materials, and functional interface data. Geometry needed for spatial analysis may not require the exact fidelity of native CAD geometry. Often a lightweight tessellated representation is better suited to spatial analysis methods such as interference detection and fit analysis. Additionally, the volume of data exchanged is often much larger than in the certification and supply chain use cases. Rather than exchanging parts and assemblies, design integration often exchanges collections of parts by spatial volume up to and including the entire aircraft.

Business Consequences

The lack of interoperability across the A&D industry results in substantial non-value added integration costs. These costs including manual re-entry and remodeling, conversion cleanup, the cost of maintaining multiple CAD licenses, etc., have been estimated by NIST in the hundreds of millions of dollars.[1] Many of these costs still exist but are not readily visible as they are incorporated into the costs of parts.

Additionally, one of the potential benefits of MBD, the ability to drive factory automation, is not being achieved due to interoperability issues. Suppliers that convert native models or re-master models to feed their CAM/NC processes incur costs and the risk of introducing errors.

Finally, a tactic commonly used to achieve integration is to compel the supply chain to use the version of software used by the OEM. In that situation, version level synchronization is required of both the OEM and supply chain, adding cost to the supply chain. These costs are often amortized across a supply base resulting in overall escalation of pricing for all OEMs and are difficult to itemize as an opportunity to capture.

Causal Analysis

Failure to meet the proposed interoperability requirements is largely based on two factors.

First is the required information is not representable in the standard, i.e., a gap exists in the standard. An example is electrical wire harness data is not supported in AP242 edition 1.

The second is, while the standard contains the necessary representation, the translation tool to map the MBD to/from the standards is not complete and did not support the mapping. The A&D PLM Action Group members recognize that the tests performed in this case are a "snapshot" of the current state of the industry's support for AP242. While one member company's test may show that a required data element is supported or not based on the software they employed for the test, another data exchange tool may give different results. As these efforts proceed, the A&D PLM Action Group expects to rely on the testing done by already established standards bodies and testing groups, rather than duplicate those efforts themselves.

Objectives

The overall goal of this project was to develop a common specification for A&D of Model-Based Definition (MBD). The intent of this specification is to provide, and, if implemented, to enable the following:

- Common definition of the content of 3D MBD and BOM
- Minimum content in these to enable certification
- Industry standard for 3D MBD & BOM
- Regulatory "Technical Data Package"
- Requirements to PLM solution providers and standards bodies and projects

[1] NIST Planning Report 02-5. Economic Impact Assessment of the International Standard for the Exchange of Product Model Data (STEP) in Transportation Equipment Industries. December 2002.

Specific objectives defined by the project team are as follows:

- Produce a specification for "3D Model Based Definition (MBD) and Bill of Material (BOM)"
- Identify the minimum content of the above to
  - Satisfy certification requirements
  - Enable manufacturing & support
  - Support design integration
- Define the content of the "Technical Data Package" that the OEM proposes to its certification authority
- Identify and test current standards to verify if the standards enable the minimum content
- Test and assess capability of existing toolsets
- Provide recommendations to close gaps on standards and toolsets
- Issue industry requirements to PLM solution providers & standards bodies
- Develop guidance and considerations for deployment inside the member companies (e.g., update standards, update processes)

Content and Current State Assessment

Minimum Content Definition

The A&D PLM Action Group members collectively proposed a set of company specific MBD models that represent their individual modeling practices. This resulted in a list of eleven different part types as presented in Table 1 column 1. The Action Group then agreed that there was a list of minimum data elements that was common to all part types as presented in Table 3 column 1—Common MBD Elements. Subsequent Tables list the minimum data elements unique to that part type above and beyond the Common MBD Elements. The Action Group expects there will be revisions to these lists as additional review and testing are done in the future.

Current State Assessment

Methodology

Each A&D PAG company was assigned one or more part types. The company selected sample MBD models that were representative of their company modeling practices for their assigned part types. The native CAD models for the MBD data were converted to AP242 models, which were evaluated to determine how well the standard covered the required data content. The choice of tools for translation and evaluation of the AP242 content were left to the participating companies. Companies could employ a translation validation tool, such as ITI CADIQ or Kubotek, consume the AP242 file into another tool, round trip the data back into the source CAD system or manually inspect the AP242 data. Companies documented where the translation to AP242 met their MBD data requirements and where it did not.

Each part type was assigned to a single company and so a single CAD system was used in the initial evaluation. Subsequently, each set of part type findings were cross analyzed by a secondary company and CAD system. The following table shows the sixteen author and review part type assignments.

Table 1—Part Types and Their Assignment

Part Type	Initial Analysis			Secondary Analysis		
	Assigned To	Software Used	Translation Tool Used	Assigned To	Software Used	Translation Tool Used
Composite - Detail - Core Stiffened Bond	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation
Composite - Detail - Co-Cured/Co-Bonded	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation
Casting	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation	Gulfstream	CATIA V5 R25 SP2	CATIA V5 Internal Translation
Forging	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation	Gulfstream	CATIA V5 R25 SP2	CATIA V5 Internal Translation
Sheet Metal	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	Gulfstream	CATIA V5 R25 SP2	CATIA V5 Internal Translation
Machined	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation	GE	NX Rev 11	NX Rev 11 Internal Translation
Wire Harness	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	GE	NX Rev 11	NX Rev 11 Internal Translation
Tube Assembly - Flexible	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation	GE	NX Rev 11	NX Rev 11 Internal Translation
Tube Assembly - Ridged	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation	Rolls-Royce	NX Rev 11	NX Rev 11
Ducting - Metallic - Mechanically Fastened	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation
Installation	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation
Standard Part - Mechanical	Rolls-Royce	NX Rev 11	NX Rev 11 Internal Translation	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation

Part Type	Initial Analysis			Secondary Analysis		
	Assigned To	Software Used	Translation Tool Used	Assigned To	Software Used	Translation Tool Used
Standard Part - Electrical (Connector, Back Shell, etc.)	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation	N/A	N/A	N/A
Supplied Part - Mechanical Systems (Pump, Actuator, etc.)	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation
Supplied Part - E/E Systems (Battery, LRU, etc.)	Airbus	CATIA V5 R27 SP2	CATIA V5 Internal Translation	Boeing	CATIA V5 R2015 SP2 HFX33	CATIA V5 Internal Translation

Desired State

Context

Aerospace and Defense companies are adopting MBD methodologies and need to support manufacturing, inspection operations, and certification using the MBD data. MBD is more than just 3D geometry. It is critical that a complete MBD model can be represented in a standard format since every aspect of the design is important. Requirements such as heat treatment are just as critical to create a conforming part as the geometric shape. So expanding translation capabilities beyond the traditional 3D shape models is required.

The A&D industry needs complete implementation of translation capabilities to represent all MBD data elements. It is the intent of the A&D industry to add contractual requirements to contracts with PLM vendors. The language will require that vendors support the entire suite of A&D data standards with the same level of fidelity as their own proprietary formats.

The existing AP242 standard covers many of the needed MBD elements in the A&D industry. However, many part type specific data elements still need to be addressed. Additionally, Recommended Practices are needed to ensure consistent interpretation of the standard in implementations. The A&D industry will collaborate with the appropriate standards groups to help develop Recommended Practices that meet the requirements of the A&D industry for the representation of all MBD data elements.

One key consideration is the detailed MBD representation of Geometric Dimensioning and Tolerancing (GD&T) by the data exchange tools for AP242. Because of the diversity of the worldwide aerospace industry, both the ASME and ISO standards for GD&T must be supported.

Scenarios

OEM Submission of Technical Data Package to Authority for Certification

We expect that the certification package content will be common across the industry and meet all certification requirements, independent of the software used to create the technical content. Further, we expect the regulatory agencies to be able to consume that standard format, regardless of OEM or supplier that provided the certification technical data package.

The A&D industry expects that the standard format will be compatible with the requirement of long term archiving and retrieval.

Manufacturing and Support Enablement

We expect a standard format for sending data to a supplier. The supplier shall have all the relevant design and manufacturing information conveyed in a format and configuration of data that is consistent regardless of the OEM providing it and independent of the set of design and manufacturing tools used to manage the data. Ingestion of data into a supplier shall be equivalent and traceable to the OEM data that generated the design and be free of translation defects.

Design Integration

We expect to have design houses use internal tools and not have to rely on our tool version control. Collaboration will be accomplished independent of the authoring methods of the design partner via standardized data interfaces.

Business Benefits

We expect to move MBD data to wherever the business needs it to be without incurring cost and flowtime impacts due to lack of interoperability. Businesses should have the agility and ability to move work quickly and partner with anyone regardless of their choice of PLM systems, i.e., a federated model of operation that is agile.

Requirements

Minimum MBD Elements

The following part types were deemed the minimum MBD elements to support the collective Aerospace and Defense business uses represented in the A&D action group. Each element was evaluated based on both the support by the standard and translation tool. Based on those results each element was categorized in one of the following five ways:

Table 2—Part Types Analysis Key

Category	Description	Associated Score
	Not Supported	0%
	Not Well Support	1-29%
	Partially Supported	30-85%
	Mostly Supported	86-99%
	Fully Supported	100%

Common MBD Elements

Certain data elements in MBD models are common across part types. These include geometry, 3D annotations (i.e., Product Manufacturing Information or PMI) such as notes, dimensions and tolerances, stored 3D views. Support for STEP translation of solid, surface and wireframe geometry elements have been in place for decades in both AP203 and AP214. Since AP242 inherits geometry elements from AP203 and AP214, it is equally well supported.

Many elements common across part types have an explicit representation in AP242. In some cases there is not an explicit element in the CAD system to represent the information, rather a generic data element is used in a company specific way. The CAD to STEP translator does not recognize the company specific data structure so no mapping is implemented.

Table 3—Common MBD Elements and Their Support Level

Minimum Data Element	Evaluation Comments	Score:
Part Number & Revision	Typically encoded in file naming convention	
Solid Definition	Well supported	
Material Description	No recommended practice to guide vendor mapping	
Engineering Definition		
Marking Requirements – Export Control	Company specific representation	
Marking Requirements - Approval	Company specific representation	
Axis System		
Part Notes		
Dimensions		
Tolerances		
Annotations		
3D Views		
Roughness / Surface Conditions	AP242 ed1: only graphic presentation AP242 ed2 plans to cover the semantic representation	
Visibility by 3DViews		
Limited Area Application Indicator	Annotation supported, no semantic linkage	

Composites Design - Core Stiffened Bond and Co-cured

The following composite design elements are required for MBD composite part models. Table 4 documents their support in AP242.

Certain producibility features were not supported including manufacturing simulation data such as start points, guide curves and draping order. Not all Rosette types are in AP242 Edition 1. These findings were consistent with the 2013 National Institute of Aviation Research report (SCRA 2012-807 STEP testing of Composite Parts by Shawn Ehrstein and Nathan Shipley, published 02/07/2013).

Table 4—Composite Part MBD Elements and Their Support Level

Minimum Data Element	Evaluation Comments	Score:
Butt Splice Zone	Partially Supported	
Contour	Fully Supported	
Core Object	Fully Supported	
Definition Surface	Fully Supported	
Edge Of Ply	Partially Supported	
Flatten Geometry	Partially Supported	
Length Parameter	Partially Supported	
Material Object	Fully Supported	
No Splice Zone	Partially Supported	
Orientation Feature	Fully Supported	
Parameter	Fully Supported	
Plies Group	Fully Supported	
Plies Group Draping Direction Parameter	Fully Supported	
Ply	Fully Supported	
Ply Orientation	Fully Supported	
Engineering End of Ply	Planned for AP242 ed. 2	
Manufacturing End of Ply	Planned for AP242 ed. 2	
Rosette	Fully Supported	
Sequence	Fully Supported	
Solid Geometry	Fully Supported	
Stacking	Fully Supported	
Supplemental Geometry	Fully Supported	
Surface Geometry	Fully Supported	
Volume	Fully Supported	
Wireframe Geometry	Fully Supported	
Composite Part Definition	Fully Supported	
Edge of Part [LAAI]	Fully Supported	
Part Orientation Symbol [LAAI]	Fully Supported	
Core Ribbon Direction [LAAI]	Fully Supported	
Potting/Edge Fill [LAAI]	Fully Supported	
Composite Fabrication Process Requirements	Fully Supported	
Ply Edge Location Tolerance [LAAI]	Fully Supported	
Core Edge Location Tolerance [LAAI]	Fully Supported	
Fiber Orientation Tolerance [LAAI]	Fully Supported	
Perforation Areas [LAAI]	Fully Supported	

Minimum Data Element	Evaluation Comments	
Ply Wrinkle Allowance [LAAI]	Fully Supported	
Stitching [LAAI]	Fully Supported	
Splicing Requirements [LAAI]	Fully Supported	
Edge Sealing [LAAI]	Fully Supported	
Core Sample		
Porosity Acceptance Criteria [LAAI]	Fully Supported	
Minimum Flat Area [Faying\Interface Area [LAAI]	Fully Supported	
Potting/Edge Fill [LAAI]	Fully Supported	
Producibility Features	Not Supported	

Casting/Forging

Casting and forged parts are comprised primarily of common MBD elements. The data objects unique to these part types are listed in Table 5.

These data elements are supported as annotation elements, e.g., an arrow to indicate grain direction. However, there is no industry accepted Recommended Practice on the exact encoding of the semantics for these elements.

Table 5—Casting/Forging MBD Elements and Their Support Level

Minimum Data Element	Evaluation Comments	Score:
Grain Direction - Complex Detail Forging	Annotation supported; no semantic linkage	
Grain Direction - Forged Block	Annotation supported; no semantic linkage	
Test Specimen	Annotation supported; no semantic linkage	

Sheet Metal

Sheet metal parts have unique features and design parameters in addition to common MBD data elements. Parameters include those defining constraints on the design such as bend allowance and K-factor. Sheet metal MBD models may include a flat pattern representation as well as a final form. AP242 allows for multiple geometry representation for a part, however there is no semantic linkage between elements of the flat pattern and final shape of the part.

Features specific to sheet metal include bends, cutouts, holes, joggles, beads, etc. AP242 contains a module, Form feature in panel (10303-1806) that supports a subset of features. The geometric representation is well supported.

Table 6—Sheet Metal MBD Elements and Their Support Level

Minimum Data Element	Evaluation Comments	Score:
Bend Allowance	Not Supported	
K-Factor	Not Supported	
Web	Partially Supported	
Flange	Partially Supported	
SM Features	Partially Supported	

Machined

The following machined product design elements are required for MBD part models in addition to the common data elements listed above in Table 3. Table 7 documents specific data element support in AP242.

Table 7—Machined Part MBD Elements and Their Support Level

Minimum Data Element	Evaluation Comments	Score:
Assembly & BOM Structure Management	Multiple child/parent body errors in translation	
Part Attribute Data	Annotation supported; no semantic linkage	
URL Data	URL feature attribute data did not translate	
Security/Classification Attributes	Annotation supported; no semantic linkage	
Symbolic Thread Representation	Thread representation did not translate	
Drilling Features	Defined in STEP AP242 but not implemented	
Milling Features	Defined in STEP AP242 but not implemented	
Turning Features	Defined in STEP AP242 but not implemented	
Pattern Feature Attributes	Multi-instanced feature PMI did not translate to multiple faces	
Tabular Data	NX limitation; PMI based table not available	
Lightweight Cross Section Views	Resulted in multiple additional geometry bodies originated from component part and translated into an assembly part file	

Minimum Data Element	Evaluation Comments	
Key Product Characteristics	Annotation supported; no semantic linkage	
Wave Linked Body	Linked bodies did not translate	

Wire Harness

Electrical wire harnesses are not explicitly supported in Edition 1 of AP242. The geometric representation of the physical layout of the harness is supported. Significant work has been done in Edition 2 to support the definition of the components of a harness assembly (connectors, splices, sleeves, etc.) as well as the connectivity and signal model. See "STEP AP 242 Electrical Harness XML Tutorial" from LOTAR International for details on support in Edition 2 for wire harnesses.

Table 8—Wire Harness Part MBD Elements and Their Support Level

Minimum Data Element	Comments	Score:
Local Axis System	Well supported	
Wireframe Geometry	Well supported	
Solid Definition	Well supported	
Neutral Fiber of Harness Segment	Well supported	
Harness Segment	Not supported	
Harness Node	Not supported	
Connectivity	Not supported	
Harness Segment Protection	Not supported	
Thickness of the Protection	Not supported	
Protection Type (laving, tape, rigid…)	Not supported	
Outer Diameter	Not supported	
Inner Diameter	Not supported	
Bended Radius	Not well supported	
Wire	Not supported	
Cable	Not supported	
Signal	Not supported	
Length	Not supported	
Forced Length	Not supported	
Cut Length	Not supported	
Marking Label	Not supported	
Identification Label	Not supported	
Localization Label	Not supported	
Segregation Code	Not supported	
Manufacturing Tolerances (bending, length)	Not supported	
Electrical Device	Not supported	
Reference Designator	Not supported	
Terminal	Not supported	
Support/Fixing	Not supported	

Tube Assembly

The design of tube assemblies contains both the physical definition of the tube and parameters that define its functional characteristics as well as the raw material and bending instructions needed for manufacturing.

Table 9—Tube Assembly Part MBD Elements and Their Support Level

Minimum Data Element	Comments	Score:
Local Axis System	Well supported	
Wireframe Geometry	Well supported	
Solid Definition	Well supported	
Neutral Fiber of Tube	Well supported	
Material Description	Not supported	
Thickness of the Tube	Not supported	
Outer Diameter	Not supported	
Inner Diameter	Not supported	
Bended Radius	Not well supported	
Welded T-shape	Not supported	
Function	Not supported	
Identification Label	Not supported	
Pressure	Not supported	
Manufacturing Tolerances (bending, length)	Not supported	
Connectivity	Not supported	
End Point (port)	Not supported	
Way Point	Not supported	
Cut Point (for manufacturing process)	Not supported	
Design Tolerances (general tolerances, specific tolerances dimensions)	Not supported	
Flow Direction	Not supported	
Marking Label	Not supported	
Mass of Tube	Not supported	
Repairable Parameter	Not supported	

Ducting

NOTE: Minimum requirements for this section are under consideration and will be published in a future revision of this report.

Installation

Installation models define how component parts or assemblies are installed into a product. The unique aspects of installation models include fastener information, definition of shims, process requirements on the joining of parts and the ability to include reference geometry. Reference geometry is defined as parts that the installed parts are attached to in the product but where the authority definition for them is in another model. For example, an installation model may define that a bracket is attached to a bulkhead with two fasteners. The installation would include the definition of the bracket and fasteners but reference the bulkhead definition.

MBD modeling practices for installation model vary.

Standard Part

The properties of Standard Parts are specific to the family of standard part being reviewed, i.e. the mechanical standard part family properties vary from the tubing standard part family's. This paper recognizes the complexity of the standard part topic and acknowledges the below definitions only represent an analysis of a subset of the families. Future versions of this paper will add analysis of further families as well as additional detailed analysis (existing and new).

Mechanical Standard Part Family

The design and translation of standard part definitions are represented through similar requirements to machined parts with similar constraints.

Tubing Standard Part Family

The design and translation of standard part definitions are represented through similar requirements to Tubing assembly regarding the connectivity between tube and tubing standard part with some similar constraints.

Table 10—Tube Standard Part MBD Elements and Their Support Level

Data Element	Comments	Score:
Local Axis System	Well supported	
Wireframe Geometry	Well supported	
Solid Definition	Well supported	
Dimensions	Well supported	
Tolerances	Not supported	
Mass	Not supported	
Angle	Not supported	
Fire Resistance	Not supported	
Material Code	Not supported	
Marking	Not supported	
Surface Treatment	Not supported	
Serial Number	Not supported	
Class	Not supported	
Identification	Not supported	
Connectivity	Not supported	
End Point / Port	Not supported	
Type of Fluid	Not supported	
Pressure (nominal, max)	Not supported	
Flow	Not supported	
Function	Not supported	

Electrical Standard Part Family

Mechanical (physical) properties of a standardized electrical wiring components are considered equivalent to mechanical standards parts from a data content view. Additionally, the electrical properties define in the context of the Wire Harness assembly they are used in. Reference both of these sections for the full definition of standard part – electrical.

Table 11—Electrical Standard Part MBD Elements and Their Support Level

Data Element	Comments	Score:
Local Axis System	Well supported	
Wireframe Geometry	Well supported	
Solid Definition	Well supported	
Dimensions	Well supported	
Tolerance	Not supported	
Mass	Not supported	
Angle	Not supported	
Fire Resistance	Not supported	
Material Code	Not supported	
Marking	Not supported	
Surface Treatment	Not supported	
Serial Number	Not supported	
Identification	Not supported	
Termination	Not supported	

Supplied Part

Mechanical Systems Supplied Part Family

NOTE: Minimum requirements for this section is under consideration and will be published in a future revision of this report.

E/E Systems Supplied Part Family

NOTE: Minimum requirements for this section is under consideration and will be published in a future revision of this report.

Requested Response

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 need to work together to successfully meet this challenge.

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 representative of your company, respond in support 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.
- Recognizing that the content of this paper are directional and incomplete, state whether you will support and participate in further refinement of the requirements.

Summary and Conclusions

The A&D PLM Action group and aerospace industry recognize the integral and growing role of MBD within the business. The analysis within this paper represents the collective voice of the aerospace and defense industry in regard to the minimum MBD elements required to support the business and the current level of support of those elements. Below are the summarized results of this analysis by Part Type. Scores indicate the percentage of required data elements of the Part Type represented by the standards and/or translation tools.

Category	Description
(dark red)	Not Supported
(red)	Not Well Support
(yellow)	Partially Supported
(orange)	Mostly Supported
(green)	Fully Supported

Table 12—Overview Part Type MBD Elements Analysis and Their Support Level Score

Part Type	Data Element Support Score
Common MBD Elements	Partially Covered
Composite - Detail - Core Stiffened Bond and Co-Cured	Mostly Covered
Casting/Forging	Partially Covered
Forging	Partially Covered
Sheet Metal	Partially Covered
Machined	Not Well Covered

Part Type	Data Element Support Score
Tube Assembly - Flexible & Ridged	Partially Covered
Wire Harness	Not Well Covered
Installation	N/A
Standard Part - Electrical (Connector, Back Shell, etc.)	Not Well Covered
Under Evaluation for Revision 2 of this Paper	
Ducting - Metallic - Mechanically Fastened	
Standard Part - Mechanical	
Supplied Part - Mechanical Systems (Pump, Actuator, etc.)	
Supplied Part - E/E Systems (Battery, LRU, etc.)	

The A&D industry recognizes the important role of open, vendor neutral format for MBD data interoperability. The A&D PAG MBD team evaluated STEP AP242 to enable the digital thread across the collaborative enterprise, but the identified gaps in the existing tools and standard limit robust adoption for the requested scope. The position of the aerospace industry is to demand the vendor and standards communities to implement full-bodied solutions bridging these gaps in both the tools and standard.

A representative(s) of the 3D MBD WG of the A&D PLM Action Group will participate to the CAx IF and will provide requirements and test cases for the planning of interoperability test rounds by the CAD editors and for development of the AP242 recommended practices to be enhanced. This representative(s) will be responsible to represent the interests and voice of the working group and be a conduit for communications between CAx IF and 3D MBD WG. The exact details of this coordination and operating procedures will be documented separately from this White Paper.

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group is an association of aerospace OEMs and aircraft engine providers 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.

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Appendix

Appendix 1: Term Bank

Term	Definition
A&D	Aerospace and Defense
AP	Application Protocol
ASME	American Society of Mechanical Engineers; a professional association promotes the art, science, and practice of multidisciplinary engineering. https://www.asme.org/
BOM	Bill of Material
CAD	Computer Aided Design
CAx IF	The CAx Implementor Forum is a joint testing effort between AFNeT, PDES, Inc. and prostep ivip. The objective of the forum is to accelerate CAx translator development and ensure that users' requirements are satisfied. https://www.cax-if.org/
GD&T	Geometric Dimensioning and Tolerancing
ISO	International Standards Organization; develops high quality voluntary International Standards which facilitate international exchange of goods and services, support sustainable and equitable economic growth, promote innovation and protect health, safety and the environment.
LAAI	Limited area application indicator; ASME standard object.
Model Based Definition (MBD)	Defining a product using the 3D Modeling, ie using PMI and dimensioning, in 3D space. A traditional 2D drawing is not involved.
PAG	PLM Action Group
PLM	Product Lifecycle Management
PMI	Product and Manufacturing Information

STEP	Standard for the Exchange of Product model data
AP242 (ISO 10303-242)	Application Protocol 242 “Managed model based 3D engineering”
3D	3 Dimensional