PLM Global Collaboration

Problem Statement, with Use Cases, Objectives,
Desired State, and Go Forward Plan

Release 2.1

August 2022

AEROSPACE & DEFENSE PLM ACTION GROUP

Abstract

Collaboration among Original Equipment Manufacturers (OEMs) and their product design and manufacturing engineering partners and suppliers is a key aspect of any major aerospace and defense (A&D) program execution. Process analysis by the A&D PLM Action Group (AD PAG) project team has shown that many different data formats, PLM software systems, and enabling infrastructure technologies exist across the OEMs and their supply base. This paper explores the need to enable frictionless operation between OEMs and their suppliers. In its second release, this position paper builds upon Release 1.0, which offered the problem statement, including (As Is) current state use cases. This new Release 2.0 is expanded to include objectives, a description of the desired state (To Be), expected business impacts, and a go-forward.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Table of Contents

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Revision Record

Revision	Date	Description
1.0	**June 2019**	Initial Release (Edition 1 of Project Phase 3)
2.0	**March 2022**	Edition 2 of Project Phase 3 includes objectives, the desired state (To Be), and a go forward plan
2.1	**August 2022**	Updated ISO-related footnotes based on ANSI guidance, and updated the About CIMdata section

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

PLM Global Collaboration

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 manufacturers within CIMdata's globally recognized PLM Community Program, which functions as a PLM advocacy group.

A key business issue or pain point, 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, a major business challenge identified is to achieve OEM and supply chain collaboration through bi-directional exchange of Technical Data Packages (TDPs) via digital tools and model-based processes.

In response, a project team of domain experts from the AD PAG member companies was established to evaluate current collaboration practices and recommend requirements to help the A&D industry reach its goal of simplified PLM global collaboration.

The four-phase project timeline is illustrated and described below. The team has just completed Phase 3, Edition 2.

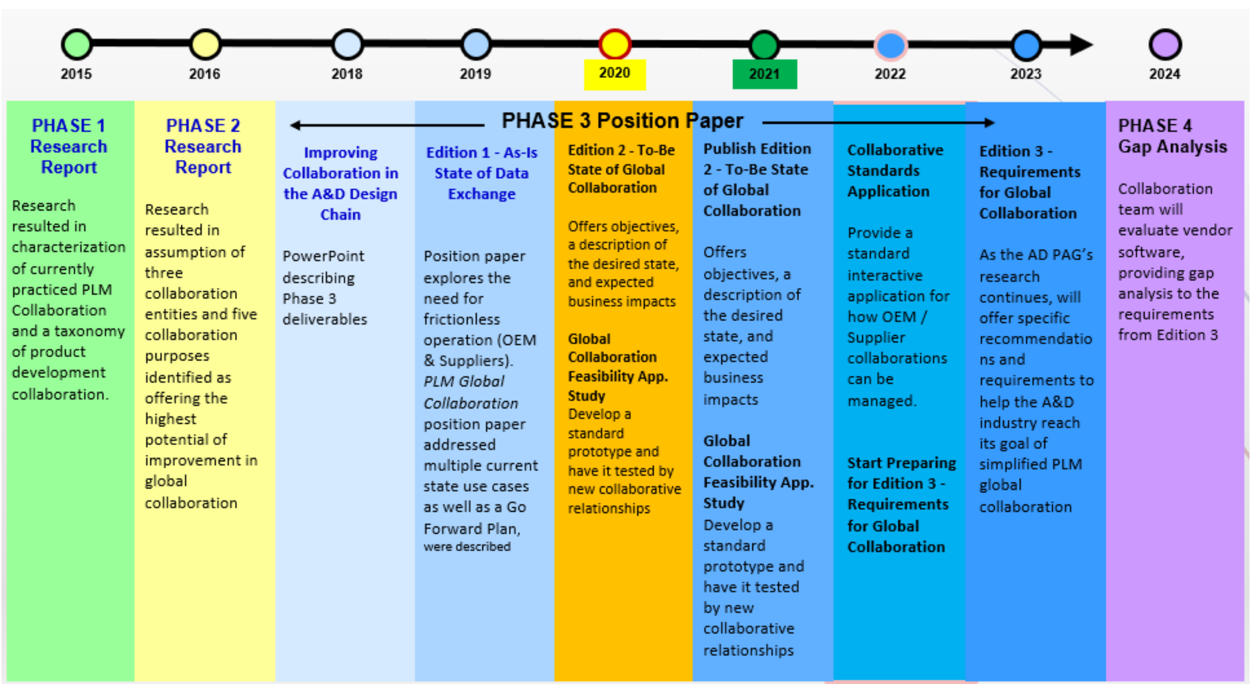


Figure 1 - Timeline and Status

- PHASE 1 – Research Report – Released June 2015

  Research resulted in the characterization of currently practiced PLM collaboration and a taxonomy of product development collaboration.

- PHASE 2 – Research Report – Released June 2016

Research resulted in the assumption that the three collaboration entities and five collaboration purposes were identified to offer the highest potential for improvement in global collaboration.

- PHASE 3 – In Progress – November 2016 - Current

  Investigation of the potential for improved collaboration between OEMs and suppliers is progressing as follows:

  – *Improving Collaboration in the A&D Design Chain* (Released November 2016) is a PowerPoint presentation describing Phase 3 deliverables.

  – **Edition 1** (aka Release 1.0) – Informally referred to as the "As-Is State of Data Exchange" (Released July 2019) is a position paper exploring the need for frictionless operation between OEMs and suppliers. This edition of the *PLM Global Collaboration* position paper identifies multiple current state use cases and provides detailed descriptions and challenges for each, includes business consequences and analysis of the root cause of current collaboration problems, and describes a Go Forward Plan.

  – **Edition 2** (aka Release 2.0 and 2.1) – Informally referred to as the "To Be State of Global Collaboration" is this current edition of the position paper and builds onto Edition 1. This newest information since Edition 1 begins with the *Objectives* section and includes a description of the desired state and expected business impacts.

  – Collaboration assessment and guidelines (Estimated Completion Date 2022) will address how OEM and supplier collaborations can be managed.

  – **Edition 3** – Informally referred to as "Requirements for Global Collaboration" (Estimated Completion Date 2023), will continue the team's research and offer specific recommendations and requirements to help the A&D industry reach its goal of simplified PLM global collaboration.

- PHASE 4 – Gap Analysis – Estimated Completion Date 2024

  The Global Collaboration team will evaluate vendor collaboration software, providing gap analysis related to the requirements presented in Edition 3.

Current research by the Global Collaboration team was focused on the following complex data flow processes of the product lifecycle:

- Requirements
- Technical collaboration contracts
- Initial design
- Configuration control and change management
- Manufacturing data
- Quality control data
- In-Service, aftermarket data (i.e., IPC, CMM, Service Bulletins)
- Regulatory data exchange

A typical product lifecycle is illustrated in the following figure.

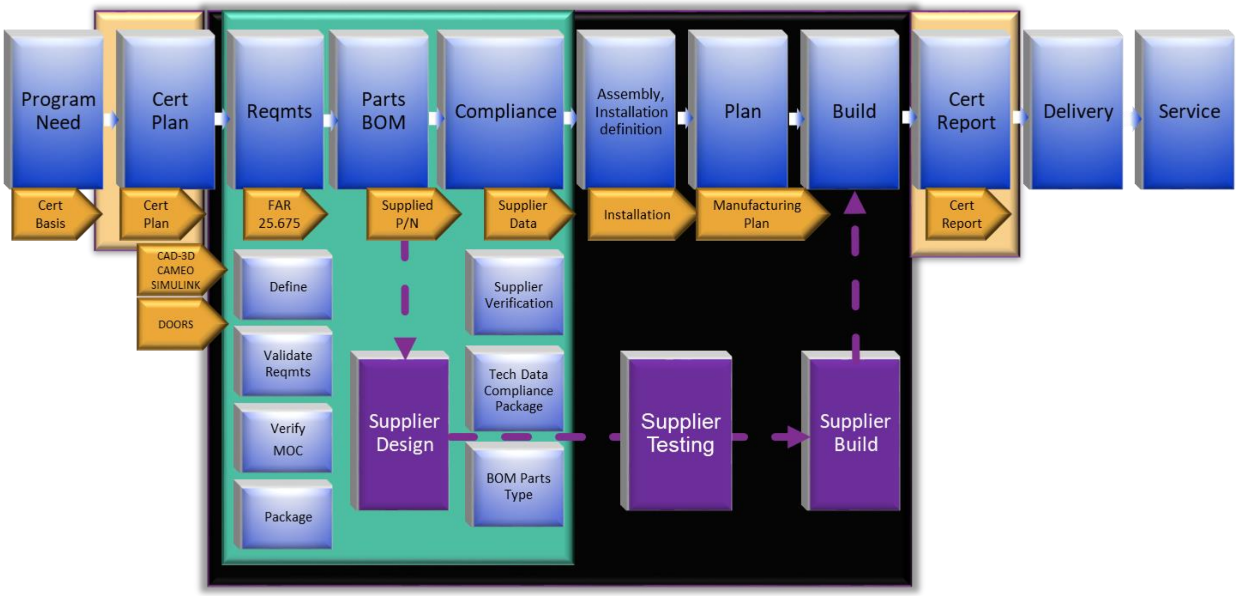


Figure 2 - Typical Product Lifecycle

A key topic addressed here is a global collaboration that defines a baseline for data exchange processes and standards. In the context of this document, global collaboration is **the mechanism by which a group of participants work together.** The participants can include all divisions, subsidiaries and affiliates, customers, suppliers, and risk-sharing partners who directly or indirectly collaborate throughout the product lifecycle.

Today, many companies using a PLM system provide collaborative workspaces for exchange and collaboration with their partners. Yet, efficiency remains limited, and the exchange offers poor performance to cover their necessary industrial processes. As global collaboration and standards are introduced across the A&D industry, participants must realize the many factors that need to be addressed for success. Key global collaboration elements that should be considered include the following:

- Ensuring that the most up-to-date data is available and consistent across sites/companies is critical.
- The primary challenge of the data exchange process is to reach a bi-directional agreement about the work content, the information transfer mechanisms, and the process for solving issues and escalations.
- The data exchange agreement needs to include the alignment of common attributes in supplier systems.
- Intellectual Property (IP) data protection and export regulations must be managed within the platform solution.
- Until a synchronous solution is available, the asynchronous collaboration needs to be optimized.

Introduction

In March 2016, executives from the AD PAG member companies met with the intent that informal discussions would lead to consensus on priorities and plans for remediation of their common PLM pain points. These discussions resulted in the agreement of the members 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 special project, which was initiated in 2017, is PLM Global Collaboration, a pain point of friction, complexity, and/or instability that erodes the productivity and quality of product information flow through A&D system programs and inflates the cost of system sustainability. The overall scope of the PLM Global Collaboration project is to provide guidelines for a data integration/exchange setup and process and practice protocols consistent with industry standards. This document and other material published by the AD PAG Global Collaboration team (also referred to as a *workgroup*), details the mechanics of configuring and integrating a supplier in an ideal/optimal/desired state. The intent is that this position paper will aid OEMs in setting up contracts with their suppliers.

The team, now in Phase 3 of the Global Collaboration project, has been focused on describing the As-Is state of collaboration, their vision of a To Be future state, and the requirements for reaching that goal. Over time, this “working” position paper is being developed in three editions (or releases). The scope of Edition 1, published in July 2019, focused on the current As-Is state of the data flow process during initial design, detailed design, configuration control, and change management. Those areas within the overall product development process were identified as offering the greatest potential for improvement in earlier stages of the Global Collaboration project and were described in the project’s first position paper release. Edition 2 of this paper develops objectives, a description of the desired To-Be state, and expected business impacts. After additional research, the team will publish Edition 3 to offer specific recommendations and a set of requirements for a future approach to global collaboration.

Terms and Definitions

Commonly used terms and their definitions are included in the following table. This information is extracted from the *AD PAG Glossary*, available at ad-pag.com.

Table 1 – Terms and Definitions

Term	Definition
Asynchronous Collaboration	A work methodology which allows a team to work serially on something such as an approval, where the data being worked on is sent from one person to the next until the process is complete.
Collaboration	A work methodology which allows for the management, sharing, and processing of files, documents, and other types of data, among several users and systems, anytime and anywhere in real time. Including the exchange of ideas/knowledge and interaction among several project stakeholders for product introduction where design engineering, manufacturing engineering, and other functions are integrated to enable the product lifecycle. The two main types of collaboration are asynchronous and synchronous.

Term	Definition
Collaboration Foundations and Controls	Details the necessary foundations for collaboration with multiple partners or suppliers on projects.
Collaborative Communities	Consists of two or more people from different groups, or companies working jointly on a project.
Collaborative Workspace	Location where data is stored, processed, exchanged, and managed facilitating interoperability between project stakeholders
Computer-Aided Engineering (CAE)	The use of computer-based tools to assist in analyzing one or more aspects of a product design, such as structural and mechanism analysis. Related term: Simulation & Analysis.
Digital Thread	The digital thread refers to the communication framework that allows a connected data flow and integrated view of an asset's data (i.e., its digital twin) throughout its lifecycle across traditionally siloed functional perspectives.
Extended Enterprise	An enterprise that logically includes a network of contractors, suppliers, business partners, and customers involved in creating, defining, producing, operating, or supporting a common product. A supply chain is considered part of an extended enterprise.
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. For example, interoperable tools have access to and use the original data, not translated data or copies of the data.
Product Lifecycle Management (PLM)	A strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise and spanning from product concept to end of life—integrating people, processes, business systems, and information
Synchronous Collaboration	A secure digital work methodology which allows a team to work simultaneously on a process, seeing each other's data and comments, allowing the team to reach a consensus quickly.
Technical Data Packages (TDPs)	Any collection of information as defined by the recipient requirement obligations. The collected technical data is gathered at a specific lifecycle stage. The technical data package will describe the contents in an organized way. This information may include but is not limited to (engineering data, purchasing data, manufacturing data, certification data, test data, service data, etc.). Some examples of these types of data are design definition, test reports, administrative agreements, installation instructions, component maintenance manuals, etc.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Associated AD PAG Papers

Copies of the following published position papers are available for download at ad-pag.com.

Table 2 - AD PG Position Papers

Action Group/Team	Latest Published Paper
Model-Based Definition (MBD) and Bill of Materials (BOM) Definition	*Minimum Model-Based Definition for Type Design Certification*
Model-Based Systems Engineering (MBSE)	*MBSE Data Interoperability - Architecture Model Exchange Solutions*
Multi-View Bill of Materials (Multi-View BOM)	*Multiple View Bill of Materials (BOM) Solution Evaluation Benchmarks*
Standards	*Product Data Exchange Standards*

Problem Statement

This section of the position paper identifies, through current state use cases, the common roadblocks that limit simple, rapid, and reliable OEM PLM to design partner PLM data exchange for Digital Mock-Up (DMU) in the A&D industry today. Each use case is presented in a table format that includes the use case name, description, actors involved (by general title), challenges, and preconditions/prerequisites.

Context

The exchange of Product Data Management (PDM) to PDM Computer-Aided Design (CAD) and Bill of Materials (BOM) data within the A&D industry among airframers, engine manufacturers, and other partner companies can best be described as tedious. Each company has different PLM software systems, versions, customizations, and different CAD software systems and versions. Exchanging data between any two companies requires bi-directional agreements of exchange—how to handle errors and expansion of the exchange process, as well as how to protect Intellectual Property (IP) data.

No single standard for either CAD or PLM data exchange exists. Each company has its own exchange requirements; therefore, exchanging data requires independent and exclusive processes, each unique and complicated, to support the long-term future of collaboration. Consequently, each company is required to agree on a CAD and PLM proprietary data format or a neutral format, naming and revision schemes, configuration control, and how to provide synchronization of the data between the two companies. This leads to lost time and delayed deliverables as each company works to establish the basis for an exchange.

The development and availability of exchange standards that all software vendors and companies adhere to would greatly facilitate and optimize the evolvement of the future collaboration process.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Use Cases (As Is)

This initial phase of the Global Collaboration project has been limited to the process of data flow during initial design, detailed design, configuration control, and change management of data. The concepts behind the use cases have been conceived and arranged to form a collaborative process environment in which the tasks of the work, such as work content (contracts), design, and review, are undertaken within the controls of configuration and change management and supported by the DMU (Model-Based) which are serviced by a data exchange activity (illustrated in the following figure). These use cases and associated data types represented serve as examples and demonstrate the issue where OEMs and suppliers are working on disparate and disconnected systems.

The following current state use cases (i.e., As Is scenarios) are intrinsically linked and interact with each other, utilizing a common set of data.

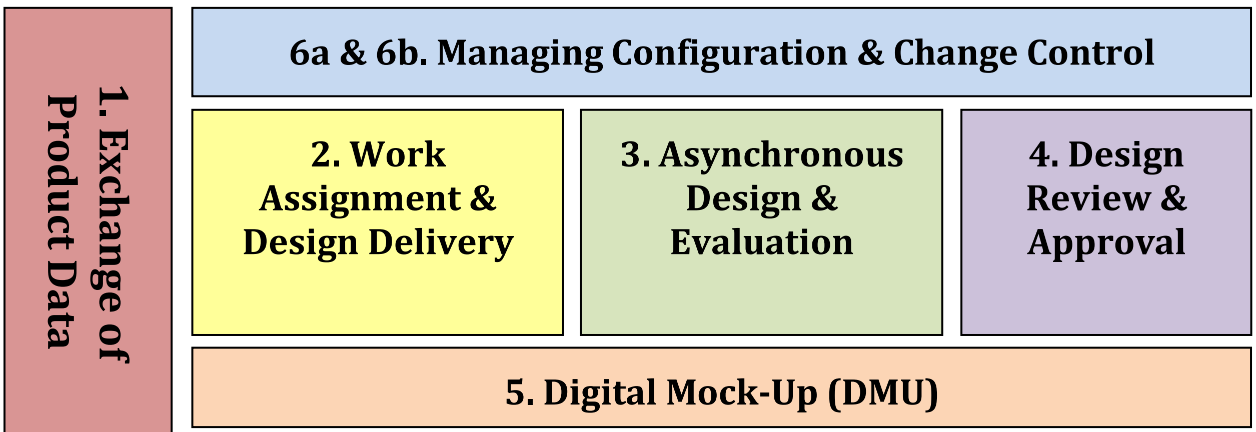


Figure 3 - As Is Use Cases

Exchange of Product Data is the activity to Extract, Transform, and Load (ETL); that is, first extract data from the source system, if needed convert the data to the target system, and at the end integrate the data into the target system. Such data exchange could be done for different types of data (e.g., CM, CAD, DMU, etc.) and during different phases of the product lifecycle. Normally, the source and target are at different locations, and a TDP is used to transfer the data. Data exchange is always an asynchronous process. The several steps should be controlled and, mainly in case of conversion, validation should be done.

- **Work Assignment and Design Delivery** encompasses the information and data required to do the following:
  - Enable the definition of the work content, timescales, and costs for the product deliverables
  - Set up the exchange, control, and change mechanisms that enable the work to be undertaken
- **Asynchronous Design and Evaluation** involves providing the data and information (i.e., engineering methods, requirements, and rules) to enable a fully engineered solution for a product, which has evaluated and validated as fit for purpose against a set of requirements.
- Design Review and Approval
  - **Design Review** ensures that the proposed product solution satisfies the agreed upon requirements, customer expectations, and specifications with due regard to an optimized design, considering safety, performance, cost, reliability, maintenance, and ease of manufacture.

   - **Approval** is the formal acceptance by the Technical Authorities/Experts that the engineering solution has met all requirements. The collaboration between OEMs and suppliers provides enough information and data to successfully conduct a specific review.
- **Digital Mock-Up (DMU)** is a 3D representation of a precise, complete assembly and interfacing hardware, including partner/customer parts, tooling, instrumentation, keep-out zones, and other modeling that can be visualized using 3D CAD software or integrated into a target PLM system. The DMU consists of geometrical representations of the product, resources, or production environment (preferably lightweight 3D data) to enable integration into a target PLM system. Usually, this implies conversion activities for 3D and structural data.
- **Managing Configuration and Change Control** is essential to ensure that all information used by both OEMs and suppliers is understood in terms of its completeness, standard, status, revision, and relevance for the product. This can be considered in two parts: first, the rules to control the product data and its standing as part of the product (e.g., naming, effectivity, etc.) and second, the control of the data packages transferred between parties, such as the data standard and its status.

The seven specific As-Is use cases addressed in this section are as follows:

1. Exchange of Product Data
2. Work Assignment and Design Delivery
3. Asynchronous Design and Evaluation
4. Design Review and Approval
5. Digital Mock-Up

6a. Managing Configuration and Change Control of the Product Data
6b. Managing Configuration and Change Control of the Data Package

For easy reference, each use case begins on a separate page.

Use Case 1: Exchange of Product Data

The current method/activity for sending or receiving engineering information is via the Data Exchange process.

Table 3 - Use Case 1

1. Exchange of Product Data (As Is)	
Use Case Name	Exchange of Product Data
Description	**Manage the request of export of all data from an OEM to a supplier:** A data exchange request triggers the export of CAD data from the PDM system to suppliers. After the request is analyzed, the data is extracted from the PDM vault or from the folder to a local file system. Afterwards, a packaging process is performed. The resulting TDP is delivered to the supplier in an acceptable format on the agreed-upon exchange medium, which could be a server or storage medium. A notification email is sent to confirm the sent information. This process may be executed manually or with full or partial automation. • Request to send from user • Data extraction • Data conversion (if required) – CAD conversion formats (or neutral) ▪ 2D ▪ 3D – Product Manufacturing Information (PMI), including Geometric Dimensioning & Tolerancing (GD&T), notations, and views – Attribute data – Documents • Quality check • Package data • Notify and send to receiver **Request the import of all data from a supplier to an OEM:** The On Request import of CAD and PDM data from another supplier into the PDM system is a manual process. The exchange is triggered by a data exchange request for the sender. The sender delivers an On-Demand TDP, which is integrated into the PDM system. A CAD conversion is done for non-convenient native formats, and a product structure conversion is done from supplier to PDM. A data quality check secures the import of valid CAD models. To ensure the correct

1. Exchange of Product Data (As Is)	
Use Case Name	Exchange of Product Data
	geometry after conversion, it is a requirement to **manually check** for any errors. • Request from OEM/supplier • Notification and receipt of package from sender • Data extraction • Data conversion (if required) – CAD conversion formats (or neutral) ▪ 2D ▪ 3D – PMI, including GD&T, notations, and views – Attribute data – Documents • Quality check • Data integration into PDM • Notification to receiving user
Actors	Designer(s) and Data Exchange Expert(s)
Challenges	• Bi-directional agreement • Asynchronous exchange • Data conversion errors • Data size and growth • IP (Intellectual Property) data protection • Connectivity optimization • Leveraging best practices (See descriptions below.)
Preconditions/ Prerequisites	• Data types • Connectivity • Exchange frequency • Data selection • Data formats • Conversion validation • Additional principles, including program and leadership support (See descriptions below.)

Challenges Detail

- **Bi-directional agreement.** When suppliers work for multiple OEMs, this leads quickly to separate and independent systems installations and customization. The same data is exchanged multiple times due to several receivers or different formats. This translates into high costs for maintenance and support.
- **Asynchronous exchange.** As for data exchange, a package is generated, and the receiver is using this data asynchronously. On the sender side, development is still ongoing, and this presents a high risk that data within the TDP is very quickly out-of-date.
- **Data conversion errors.** Data conversion is not error-free. How to guarantee consistent and complete data is a continuous challenge. Each conversion needs to be validated with appropriate mechanisms, such as geometrical comparison of volume, surface, and center of gravity.
- **Data size growth.** Due to the evolution of CAD systems and the content managed within 3D data, data size is growing with each CAD release and year by year.
- **IP data protection.** In most cases, only neutral data is exchanged, but as mentioned earlier, each conversion could introduce errors and create negative impacts, such as in geometrical differences or in assembly positioning. For several use cases, native/proprietary data may be requested for update and may not contain protection of IP. In addition, the exchanged data could be simplified by removing all inner geometry and exchanging only the outer shape (shrink wrap).
- **Connectivity optimization.** The limitations of current connectivity technology affect the speed and timeliness of data availability. Typically, the two parties agree on the availability, and the data exchange is synchronized at the minimum standard, phased-dependent supplier integration level. This integration level is determined by the IT infrastructure supporting each participant. When a supplier is working for multiple OEMs, many connections of varying complexities are required and should be simplified and optimized as much as possible.
- **Leveraging best practices.** All data exchanges should take advantage of the industry best practices and standards used for collaborating between the sending and receiving parties. Exchanging parties should avoid creating new pathways by researching existing methods and coordinating with IT to manage the exchange.

Preconditions/Prerequisites Detail

Before data exchange is launched, a bi-directional agreement between both partners—sender and receiver—needs to be defined and include answers to the following:

- **Data types.** The type of data that needs to be exchanged must be determined and agreed upon (e.g., CAD, visualization, 3D or 2D, metadata, etc.). Also, the development phase in which the data exchange is requested should be clarified (e.g., preliminary design, detailed design, in-service, etc.).

  Different types of DMU data may be exchanged as preliminary design data, type design data, etc.. Still, the data should be marked to indicate the data's lifecycle stage for better usage. This also makes it easier for the receiver to differentiate between read-only and modifiable data. In an ideal case, the modifiable data is locked in the sender system to avoid a parallel way of working. To enable better security, data should be classified in the system. However, special treatment may be required for export-sensitive data. The DMU is a representation of a specific deliverable that contains accurate interfaces and defines the space (volume) of the end product. The DMU product structure is not equivalent to the BOM. The BOM defines all the components of the physical product delivered to the end customer.
- **Connectivity.** The levels of collaboration are based on the connectivity between parties, must be agreed upon in the contract, and are determined by the volume, type, and nature of the data exchange necessary to undertake the activity. Depending on the connection needs and IT systems used by the collaborating companies, the exchange is currently operated via three methods: (S)FTP

Transfer, Remote Access to OEM Environment/Host, or Local Access to OEM Environment/Host. All data exchanged should be completed using the latest, approved IT security protocols.

- **Exchange frequency.** The frequency of exchange must be defined, such as:
  - Once–one-time full extract
  - On a regular basis (frequency) and if regular—full or delta/incremental data (i.e., only data changed since the last extraction)
  - Event-triggered, such as by a release process; for example, during the release process, an export is launched to deliver the dataset (e.g., build-to-print supplier)
- **Data selection (e.g., subscription list, assembly tree walk, zoning and boxing).** The data needing to be exchanged should be defined by part ID or assembly node or by a bounding box or geometrical.
- **Data formats.** Examples include proprietary CAD data (native CAD data), derived visualization data, and a converted neutral standard format (i.e., STEP, JT, IGES, DXF, etc.). In addition to conversion to a neutral data format, the data content should be protected by a mechanism that prevents the exchange of a complete product break down, allowing only an envelope or shrink-wrap and no inside geometry.
- **Conversion validation.** In the case of data conversion, all relevant model data needs to be validated for completeness and accuracy. A good example is the use of Geometric Validation Properties (GVP): before the conversion, calculate some values like volume and center of gravity, and then after conversion, recalculate the same values and compare the deviations. The allowable tolerance must be defined in the data exchange agreement.
- **Additional principles.** Two main principles that lead to data exchange can be distinguished—direct access (synchronous) and asynchronous. Asynchronous transfer currently offers two options: Push and Pull mode and whether a full send or a trickier incremental or delta exchange for the data exchange occurs each time. Due to security concerns, the infrastructure for such exchange or access should be located in a so-called *demilitarized zone (DMZ*) to better control internal and external access, etc. Instead of the DMZ, the infrastructure could be located in a private and secure Cloud. In addition, the TDPs could be encrypted to ensure better control of data access.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Use Case 2: Work Assignment and Design Delivery

This use case addresses the information and data required to define the work content, timescales, and costs for the product deliverables and set up the exchange, control, and change mechanisms that allow the work to be undertaken.

Table 4 - Use Case 2

2. Data Exchange of Program and Project Data (As Is)	
Use Case Name	Work Assignment and Design Delivery
Description	Set up the work activity between the OEM and the supplier • Definition of the work activity (Statement of Work) • Contract definition and agreement • Bi-directional information transfer route definition–ability to log and record dates and versions/revisions Monitor and manage the problems and issues
Actors	Program Manager(s), Engineering, and Procurement
Challenges	Agree to the work content, information transfer mechanisms, and process for solving issues and escalations.
Preconditions/ Prerequisites	• Additional principles, including program and leadership support • Contractual agreements are in place, IT agreements

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Use Case 3: Asynchronous Design and Evaluation

As noted previously, Asynchronous Design and Evaluation involves providing the data and information (i.e., engineering methods, requirements, and rules) to enable a fully engineered solution for a product, which has been evaluated and validated as fit for purpose against a set of requirements.

Table 5 - Use Case 3

3. Asynchronous Design and Evaluation (As Is)	
Use Case Name	Asynchronous Design and Evaluation
Description	The design activity is undertaken in separate locations using the latest requirements and data available at the time of the activity. The design consists of 3D modeling and 2D drawings to describe the product solution, providing the Form, Fit, and Function (FFF), including the materials and manufacturing processes and treatments. Discussion and decision-making are done remotely using email, WebEx, and/or telephony.
Actors	Designer(s) and Manufacturing Engineer(s)
Challenges	• Ensure that the most current data is available and consistent across sites/companies. • Have all actors available at the same time.
Preconditions/ Prerequisites	• Additional principles, including program and leadership support • Need contracts and people in place and data available

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Use Case 4: Design Review and Approval

As stated earlier, Design Review and Approval ensures that the proposed product solution satisfies the agreed-upon requirements, customer expectations, and specifications regarding an optimized design that considers safety, performance, cost, reliability, maintenance, and ease of manufacture. Collaboration between OEMs and suppliers provides enough information and data to conduct any specific review successfully. Approval is the formal acceptance by the Technical Authorities/Experts that the engineering solution has met all the requirements.

Table 6 - Use Case 4

4. Design Review and Approval (As Is)	
Use Case Name	Design Review and Approval
Description	This process is the formal review and approval of the product solution, using the technical data (e.g., drawings, documents, test plans, etc.) to allow in-depth review of requirements and evaluation of the design solution with validation and sign-off. Data is provided to support the delivery of the product, and the product delivery is scheduled in support of program milestones. **Process:** Define .... schedule meetings with engineering, supplier management, and the supplier to determine what data requirements need to be submitted for review and the appropriate schedules for each. Receive data............. ensure correct information at the correct standard and for the correct requirement–Configuration and Change Management. Conduct review........ review requirements, visualization of the DMU, and markup. Record the review.... capture discussion, results, and scope. Approval workflow.. obtain appropriate signatures. If the data is unacceptable, the supplier will make the necessary updates and provide the next revision for review. Publish results.......... provide the approved data to downstream users, such as Quality, Manufacturing, and/or authority systems. Engineering reviews and provides their evaluation back to the supplier. Supplier Management acts as the mediator between the supplier and engineering and monitors any changes to the scope.

4. Design Review and Approval (As Is)	
Use Case Name	Design Review and Approval
	Any changes to the FFF of the deliverable (i.e., part) must be provided for re-evaluation. (Refer to *Use Cases 6a and 6b: Managing Configuration and Change Control of the Product Data*.)
Actors	Engineering, Supplier Management, Manufacturing, and Quality
Challenges	• Export regulations (International Trade Compliance) • IP protection • Data size • Data recipient or sender limitations (See descriptions below, and also refer to *Use Case 2: Work Assignment and Design Delivery*.)
Preconditions/ Prerequisites	Data requirements must be determined before contracting with the supplier to finalize what design data is needed and to schedule when each data requirement is due.

Challenges Detail

- **Export regulations (International Trade Compliance).** Issues may arise if the user does not know what Export Control Classification Number (ECCN) or United States Munitions List (USML) codes to associate with the data, increasing the chances of mismarking the data design.
- **IP protection.** Refer to *Use Case 1: Exchange of Product Data* challenges for a description.
- **Data size.** If the transmitted files are too large, this can cause system time-outs and possible delays in the review process and downstream processes.
- **Data recipient or sender limitations.** Some companies may not have the bandwidth to submit larger files and have to depend on an alternate route for submitting the data.

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Use Case 5: Digital Mock-Up

Digital Mock-Up is a 3D representation of a precise, complete assembly and interfacing hardware, including partner/customer parts, tooling, instrumentation, keep out zones, and other modeling that can be visualized using 3D CAD software or integrated into a target PLM system.

Table 7 - Use Case 5

5. Digital Mock-Up (As Is)	
Use Case Name	DMU Data Exchange
Description	DMU data exchange provides a file-based, geometrical representation of the product, resources, or production environment (preferably lightweight 3D data) to enable integration into a target PLM system. Usually, this implies conversion activities for 3D and structural data. The frequency of data exchange depends on the need for utilization and ranges from on-off to hourly depending on program requirements or contracts. Recurring updates may contain incremental data only. Typical purposes are the support at any design level in context or technical release and the validation and optimization of prototyping.
Actors	DMU Integrator(s), Design Owner(s) and Author(s)
Challenges	• Size of the data • Fail-safe 3D conversion • CAD conversions/neutral data format • Non-standard data exchange • Synchronization process between collaborators • BOM formatting (neutral BOM format) • Cross-organizational boundaries and design team integration (See descriptions below.)
Preconditions/ Prerequisites	DMU protocol/data exchange agreement

Challenges Detail

- **Size of the data.** During New Product Introduction (NPI) programs, the DMU data exchange between the engine manufacturer and the airframer OEM is challenged by a very extensive volume of data. Usually, all the Federal Aviation Regulation Part 25 (FAR25) type design data (i.e., Pylon, Nacelle, EBU) plus FAR33 engine interface geometry (i.e., LRU maintenance) have to be made available in both directions to ensure proper design within the context. An estimated 30GB average of DMU data volume per year per program driven by approximately 30,000 native CAD files.

- **Fail-safe 3D conversion.** How 3D data is exchanged needs to be standardized. Currently, one AD PAG member company must deliver many different formats (i.e., everything from CATIA V4 to CATIA V5R28 to JT). Another works in Siemens' NX. Consequently, all incoming and outgoing data is converted back and forth, introducing the potential for errors and definitely slowing down processes.
- **CAD conversions/neutral data format.** For CAD conversion, quality control should be implemented. Calculate GVP before conversion, conduct a re-run after conversion, and compare (e.g., volume, surface areas, center of gravity, etc.). Instead of performing a direct conversion from CAD format A to B, a neutral data format like STEP, JT, etc., could reduce the effort. However, in most cases, an OEM wants to receive native CAD formats that fulfill the company's quality and methods, such as naming and numbering, layering, colors, etc. Compared to native CAD, a neutral format already includes some IP protection. Typically, history and design content cannot be retrieved (i.e., only "dump" and dead solids are exchanged, no features).
- **Non-standard data exchange.** Sometimes data that is not part of an engine/airframe is exchanged between engineers at collaborator companies, either because the data is not complete, is 2D and not 3D, or for other reasons. If the data is just emailed or stored and forwarded back and forth, there is nothing in place for version control, leading to potential confusion, misunderstandings, and wasted time and resources.
- **Synchronization process between collaborators.** It is difficult to synchronize what files are with which collaborator. For example, a company has been exchanging data for years, and then one day an engineer references a model that hasn't been used in some time. How does the company know if the *other* company already has that model or if the model needs to be converted and sent? For one AD PAG member company, it is common for each engine/airframer exchange to have a different convoluted synchronization process, usually involving CSV (Comma Separated Variables) files.
- **BOM formatting (neutral BOM format).** A neutral format for the BOM/parts list data exchange is unavailable. Each PLM vendor has its own "flavor" of PLM XML and STEP 242.
- **Cross-organizational boundaries and design team integration.** These organizational boundaries often inhibit concurrent engineering and data exchange and should be addressed using an integrated product team (IPT) approach to assure comprehensive data exchange. The IPT is a multi-disciplined team assigned with responsibility for a specific program, product, or subsystem that functions to resolve any potential issues and produces an integrated and validated product.

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

Use Case 6a: Managing Configuration and Change Control of the Product Data

Controlling and managing changes to the information shared between OEMs and their suppliers are essential to ensure that engineered solutions conform to the design requirements and that the standards/versions of the data being used are understood and reliable. Ensuring the traceability and pedigree of the master design definition is critical. Ensuring data pedigree ensures the health of a DMU and the engineering decisions made based on the DMU. Mechanisms must be in place to ensure the data integrity of the DMU. A lack of trust in the data can be very expensive for a business.

All product data changes by the OEM or supplier must be fully coordinated and authorized. Change agreements between business entities should be in place to support all change activities. Information exchange between OEMs and their suppliers must be managed and controlled precisely and falls into the following two categories:

- Control of the product data inside the TDP (this Use Case 6a)
- Control of the TDP itself (Use Case 6b)

Table 8 - Use Case 6a

<table>
<tr><th colspan="2">6a. Managing Configuration and Change Control of the Product Data (As Is)</th></tr>
<tr><td>Use Case Name</td><td>Control of the product data inside the TDP</td></tr>
<tr><td>Description</td><td>
The configuration of the technical data inside any data exchange system is critical to the engineering or manufacturing process and is governed by means of the modification system and the collaboration process/system or tools operated by the OEMs and their suppliers.
Typical attributes used to manage the data inside a data exchange package are as follows:
<table>
<tr><th>Attribute</th><th>Description</th></tr>
<tr><td>Model Number</td><td>Part or Assembly 3D model</td></tr>
<tr><td>Drawing Number</td><td>Drawing Number</td></tr>
<tr><td>Sheet Number</td><td>Sheet number(s) for the drawing to ensure sheet control</td></tr>
<tr><td>Part Number</td><td>Unique identifier of a part number</td></tr>
<tr><td>Revision/Issue/Version</td><td>Revision/Issue/Version of the part and/or drawing</td></tr>
<tr><td>Description</td><td>Description of the part (in English)</td></tr>
<tr><td>Modification/Change Number</td><td>Modification or change process control</td></tr>
<tr><td>Change Description</td><td>Full description of changes for new version of the part</td></tr>
<tr><td>Product Effectivity</td><td>Product for which the part is effective</td></tr>
<tr><td>Author</td><td>Designer responsible for the design</td></tr>
<tr><td>Date</td><td>Stored date of data/part</td></tr>
<tr><td>Maturity</td><td>Design maturity identified</td></tr>
<tr><td>Export/IP Classification</td><td>Register regulatory export classification (i.e., 9E991) IP protections</td></tr>
</table>
</td></tr>
</table>

6a. Managing Configuration and Change Control of the Product Data (As Is)	
Use Case Name	Control of the product data inside the TDP
Actors	Designer(s), Design Owner(s), and Configuration Engineer(s)
Challenges	• Sending/receiving systems must be aligned and validated to confirm the intent of the attribute exchange is synchronized. • Data must remain in version control for multi-party exchanges and storage.
Preconditions/ Prerequisites	• Data exchange agreement • Categorization and classification of data within the system, considering the extraction process. For example, EAR, ITAR data, etc. https://en.wikipedia.org/wiki/International_Traffic_in_Arms_Regulations. Another example is IP protection for suppliers' and customers' data.

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

Use Case 6b: Managing Configuration and Change Control of the Data Package

As indicated above, information exchange between OEMs and their suppliers must be managed and controlled precisely. This section presents a description and the many challenges of the second category of control—**controlling the TDP**.

Table 9 - Use Case 6b

<table>
<tr><th colspan="2">6b. Managing Configuration and Change Control of the Data Package (As Is)</th></tr>
<tr><td>Use Case Name</td><td>Control of the TDP</td></tr>
<tr><td>Description</td><td>Configuration control of the TDP is critical to ensure that the most recent information is always used by the engineering teams. This control is governed through the collaboration process/system or tools used to maintain the configuration control of the data across OEMs and their suppliers.

Typical attributes used to manage data required for a data exchange package are as follows:
<table>
<tr><th>Attribute</th><th>Description</th></tr>
<tr><td>File Name</td><td>Package name in the form defined by the naming convention - without split counter and extension</td></tr>
<tr><td>Time Stamp</td><td>Package creation date and time</td></tr>
<tr><td>Operating System</td><td>Windows, UNIX, etc.</td></tr>
<tr><td>CAD system</td><td>Format (including its version) of delivered data files</td></tr>
<tr><td>Description</td><td>Description of the data in the data exchange package</td></tr>
<tr><td>Position Matrix</td><td>Relative position to the next higher assembly</td></tr>
<tr><td>Revision indicator</td><td>Revision letter/number assigned to denote the package revision level</td></tr>
<tr><td>Revision description</td><td>Reason for change and description of change (in English)</td></tr>
</table></td></tr>
<tr><td>Actors</td><td>Designer(s), Design Owner(s) and Configuration Engineer(s)</td></tr>
<tr><td>Challenges</td><td>Alignment and synchronization of attributes in sending/receiving systems</td></tr>
<tr><td>Preconditions/ Prerequisites</td><td>Data exchange agreement</td></tr>
</table>

Preconditions/Prerequisites Detail

Refer to *Use Case 1: Exchange of Product Data* for a description of the preconditions and prerequisites (e.g., data types, exchange frequency, data selection, etc.) common to this use case.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Business Consequences

Exchanging CAD and BOM data between businesses is a complex topic. As discussed above, each business may have its own PLM software, CAD software, and different versions and customizations. Data exchange requires agreements about the CAD and BOM type and format to be in place.

Failing to resolve complexities that lead to a slowdown in data exchange of product, program, project, and design data prevents partner companies from effectively communicating about projects. If peer engineers at each company are unable to see the location or design of parts in place for each other's design, they are unable to perform their job correctly to account for positioning of other parts within the BOM.

Productivity decreases as the amount of time between synchronization increases. The longer each company's CAD and BOM definitions are not synchronized and drift apart, the lower the effectiveness of communication between engineers at each site. Furthermore, change management of product data and package data is impacted by the same data update drift, allowing engineers to communicate only during time periods directly after data synchronization effectively.

Finally, the business priority and resource requirements to support the items addressed in this paper must be understood and supported by leadership at OEMs and suppliers. Too often, these needs are not recognized and appreciated for their criticality to the business and the long-term success of a program. They must be sufficiently funded and supported over the lifetime of a program to avoid "hidden costs" to the business.

Causal Analysis

The AD PAG project team analyzed the seven use cases and pinpointed five primary categories of causal factors that contribute to the negative business consequences described above, i.e., the widespread complexities of CAD and BOM data exchange between an OEM and development partners, the potential breakdown of communication on projects, and the likely data update drift (i.e., less frequent CAD and BOM synchronization).

The AD PAG team identified Exchange, Conversion Validations, Reconversion Validations, Framework, and Governance as the five root cause categories leading to added complexity, potential confusion, and reduced productivity. The primary stumbling blocks in each category are described below.

Exchange

- As for data exchange, a package is generated, and the receiver is using this data *asynchronously*. On the sender side, development is ongoing, and this presents a high risk that data within the TDP is very quickly out-of-date.
- Non-standard data that is not part of an engine/airframe is exchanged between collaborator companies, either because the data is in work or because it is incomplete. If the data is just emailed or stored and exchanged back and forth. In that case, nothing is in place to manage revisions or version control, leading to potential confusion and misunderstandings, resulting in wasted time and resources.
- It is difficult to manage or synchronize what files are with various collaborators. For example, how the company that has been exchanging data for many years knows if the model is still current or if it needs to be converted and re-sent is a problem. It is common for each engine/airframer exchange to

have a different, convoluted synchronization process that is usually negotiated between collaborators.

Conversion Validations

- Single or multiple data conversion is not 100% error-free. Processes to guarantee consistent and complete data are a continuous challenge. Each conversion needs to be validated with appropriate mechanisms, such as geometrical comparison of volume, surface, metadata, and mass properties.
- The conversion process and methods for data exchange need to be standardized. A collaborator may be required to deliver many different formats (i.e., everything from CATIA V4 up to CATIA V5R28).
- Data conversions using neutral ISO standard data formats need to be developed to meet current collaboration and future regulatory requirements.
- Processes, methods, and tools need to be deployed to mitigate risk of any data loss independent of the number of data conversions.

Reconversion Validations

- Reconversion requires additional confirmation to assure that no data loss or corruption occurs to validate the integrity of the model.
- It is a best practice to avoid multiple conversions so that the original data remains the “source of the truth.”

Framework

- The primary challenge of the data exchange process is to reach bi-directional agreement about the work content, the information transfer mechanisms, and the process for solving issues and escalations.
- Due to the evolution of CAD/PLM systems, CAD data and metadata size is growing with each tool’s release.
- The volume of product data increases during the lifetime of the program.
- Ensuring that the most up-to-date data is available and consistent across sites/companies is critical.
- All actors must be available at the same time.
- Suppliers working for multiple OEMs experience many separate and/or interdependent systems installations or customizations, which lead to multiple connectivity instances and consequential challenges. The same data is available at multiple locations and/or converted due to several receivers and/or in different formats. This translates into high costs for process management, maintenance, and support.
- The data exchange agreement needs to include the alignment of common attributes in supplier systems.

Governance

- Potential export regulations issues may arise if the user does not know what export classification to associate with the data.
- An IP data protection process must be negotiated and enforced between collaborative parties.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Objective

The primary objective of the *PLM Global Collaboration* position paper is to document the AD PAG's collective vision for a common mechanism to support OEM/supply chain product development collaboration. Previously, Edition 1 (Release 1.0) detailed the existing As-Is mechanisms for collaboration and the negative business impacts that resulted. As stated earlier, that information has been incorporated into this current Edition 2 (Release 2.0), which has also been expanded to describe the mutually agreed upon future To Be (i.e., Desired State) mechanism for collaboration. Future Edition 3 will list the requirements for establishing the proposed To Be collaboration environment.

In addition to publishing this edition, the AD PAG will provide a methodology that includes guidelines for a data integration/exchange setup, process, and practice protocols consistent with industry standards that all participants in product development collaboration should follow based on the proposed To Be collaboration environment. The methodology will detail the mechanics of configuring and integrating a supplier in an ideal/optimal/desired state. The intent is that this methodology will assist participants in setting up and executing collaboration contracts with their suppliers in a consistent manner. The methodology will be delivered to users as a process app.

Desired State (To Be)

The previous use cases were related to the current As-Is state of collaboration, highlighting the pain points felt by the member organizations. Those seven use cases were considered, along with present and future technology, in the development of an enhanced, desired (To Be) collaboration framework. The focus of Edition 1 (Release 1.0) was engineering content; however, the end-to-end process between all stakeholders must be considered to understand collaboration to its fullest extent and define the desired state.

Collaboration Context

The original use cases and collaborative concepts listed in *Appendix A: Concept Solution*s were evaluated in the development of the desired collaboration framework. During initial brainstorming efforts, the team illustrated those concepts and issues as shown in the following "word cloud."

Figure 4 - "Word Cloud"

The concepts of the key items resulting from the "word cloud" are the primary topics of the following sections of this paper.

Overview of the Desired Interaction of Business Entities

The desired state is a global collaboration process where **multiple partners collaborate in a common workspace** on projects (new product development, industrialization, or post-development), observing the following general aspects:

1. One of the partners is the project leader, and the others are contributors.
2. The lead partner sets the pace of the project reviews and the pace and content of the changes in design.
3. Depending upon the lead partner's program requirements, each contributor may design in their own supplier's environment solution to have digital continuity from end-to-end in their own company or within the lead partner's environment, utilizing the tools, processes, and methodology provided by the lead partner.
4. Where applicable, partners keep their own IP and do not transmit the features of the 3D models (i.e., how they design).
5. The lead partner makes the requirements (functional and geometrical) available in a format usable by the contributors (i.e., can be seen and used by the contributors).
6. The contributors make their design and justification available in a format usable by the lead partner (i.e., can be used by the leader and integrated into the leader's own design).

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

7. There may be many changes in design/iterations: the leaders who will change the requirements and the contributors who will change their own design at identical requirements. Each change may be documented, and documentation must be shared with the partner(s). Configuration synchronization is compulsory and is organized by configuration managers. The state of all data in the global configuration and variant management is easily visible and understandable.
8. Virtual project reviews occur regularly (including DMU review).
9. The leader may provide guidance and instructions to partners, and partners may acknowledge/report about their actions (e.g., via workflows).

The following sections provide greater detail about the desired state of global collaboration as a whole.

The Proposed To Be Collaboration Environment

The AD PAG Global Collaboration team views the To Be (desired state) collaborative environment as a synchronous collaboration solution that works in parallel with industry CAD and data interchange standards to ensure control and bi-directional communication/sharing. The solution should improve interoperability between collaboration communities while minimizing manual intervention. The collaborative solution should provide a non-propriety data format to allow system-/solution-agnostic movement of data between organizations irrespective of the end point solutions used to create/maintain the data being collaborated.

Elements of Global Collaboration

The new, desired state is a global collaboration process where **multiple partners collaborate in communities**. These communities are a more open, collaborative, but secure environment.

The following illustration helps understand the elements of global collaboration, including the collaborative foundations and controls.

Figure 5 - Global Collabortion Elements

Foundations and Controls

Understanding the many communities actively participating in the product lifecycle is important. Two key aspects must be considered for a better long-term collaboration strategy solution between the PLM provider and the product development participants.

- The first is to understand the entire ecosystem evolving around product lifecycle activities and how all participants, such as the following, work together:
  - OEM business unit
  - Suppliers (categorization of supplier contractual level)
  - Authorities (regulatory)
  - Co-development partners (university, research center)
  - Enabling collaboration technologies
- The second aspect involves indirectly capturing the interaction type to understand the role of each lifecycle phase. Then, it will be possible to link the phases to one or more of the pillars—**coordination, cooperation**, and **collaboration**. Ultimately, a collaborative strategy based primarily on the role of each of the following entities, for example, should prevail:
  - Research and advanced design
  - Product development engineering
  - Final assembly line
  - Marketing
  - Manufacturing
  - Tooling
  - Procurement
  - Quality
  - Technical publications
  - Methods
  - Operations and services

By using the framework referred to in the *Step-by-Step Collaboration Framework* section, businesses can define the types and levels of engagement necessary to support the desired collaboration of the following:

- Classes of suppliers
- Data exchange levels
- Collaboration types
- Collaborative configuration and change control

Classes of Suppliers

A categorization of the collaborators is the set of criteria used to qualify the types of data exchange with the OEM. A classification for the collaborator is needed for the OEM to define methodology and tools for collaboration and integration, including exchange using industry standards and specifications. Collaborators can be categorized based on their business engagement, tools, and capabilities, which have been defined as three classes for this paper.

- **Class 1 -** A supplier who manufactures products in accordance with OEM engineering data and specifications. The OEM data must be rich enough to be efficiently used by the supplier in their process engineering software. The IP contained in the data belongs to the OEM. An example is a Build to Print/Model Supplier.
- **Class 2 -** A supplier that designs from OEM requirements, manufactures, assembles, and tests the product using their own engineering specifications and drawings. An example is an Equipment and System Supplier:

  The following deliverables are included if the supplier contracts with the OEM: 3D model/drawings of the assembled equipment, which can be easily integrated to the OEMs DMU, equipment performance data, and a spare parts BOM. The design IP belongs to the supplier. OEM product configuration and equipment configuration must be coordinated. Program reviews and DMU reviews must be performed in alignment with program milestones.
- **Class 3 -** A supplier that designs and manufactures products in accordance with OEM engineering specifications. An example is a Design and Build Partner supplier where the supplier contract with OEM includes the following deliverables: relevant design elements (e.g., certification and/or to a change in design (modification)) that can be easily integrated into the OEM's DMU. For that, they are accountable for one or more delivery milestones. Both program and DMU reviews must be performed in alignment with program milestones. The supplier must be involved in the change/modification workflows.
  - According to contract, a Class 3 supplier may design in their own environment to have digital continuity from product engineering to process engineering or in OEM's environment.
  - This class of supplier supports catalogue part integration, distribution & part definition data exchange to support part interoperability.

Data Exchange Levels

Levels of data exchange and their relative connectivity based on complexity and depth of collaboration are as follows:

- **Level 1 -** One-way data exchange by file transfer protocol (FTP) and/or read-only access to the collaborative environment. When transferred, data must be rich enough to be efficiently used for the process engineering. Low volume of data exchange.
- **Level 2 -**Data exchange: the exchanged data is usable in each party's environment. Data is exchanged in agreed-upon format and according to delivery milestones. Medium volume of data exchange.
- **Level 3 -** Data in agreed-upon format is continuously exchanged to accelerate concurrent engineering. Even nonfrozen data may be exchanged. Medium or High volume of data exchange.

Collaboration Types

Collaboration types are used in conjunction with the supplier class definitions to help understand the level of contract definition to support the business relationship between the OEM and suppliers. There is no single combination supplier class to collaboration level relationship. Any combination of the relationships can be created to support the business need.

Table 10 - Collaboration Types and Data Exchange Levels

Collaboration	Type 1	Type 2	Type 3
Contents of Technical Data Package (examples)	- 3D/2D Geometry with tolerancing data and/or assembly requirements (torque, gap, …) - DMU: selected volume - BOM - Documents - Metadata - Export controls - Catalogue part definition	- Requirements - Functional diagrams (e.g., fluidic or electric) - Supplier technical data - Quality data - In-service data - - 3D/2D geometry with tolerancing data and/or assembly requirements (torque, gap, etc.) - DMU: selected volume - BOM - Documents - Metadata - Export controls	- Architecture models, multi-physics models, simulation - Co-design, co-simulation - Partner design organization sharing, design collaboration - Requirements co-authoring - In context design collaboration - Functional diagrams (e.g., fluidic or electric) - Assembly - Change/Modification documents - Supplier technical data - Quality data - In-service data - IP controls - 3D/2D geometry with tolerancing data and/or assembly requirements (torque, gap, etc.) - DMU: selected volume - BOM - Documents - Metadata - Export controls
Data Exchange Level	**Level 1**	**Level 1 or 2**	**Level 2 or 3**

Collaborative Configuration and Change Control

Collaborative Configuration and Change Control is a foundational topic. After the supplier class and collaboration level (i.e., data exchange level) have been determined, controls are needed to manage the data being exchanged. These collaborative controls include user accessibility and security, such as the following:

- Private/Proprietary: Sensitive data, OEM internal activities
- Public: Common documentation, best practices
- Project: Common project with suppliers, other OEMs, authorities, and co-development partners
- Region: Geo-location and nationality of participants

This collaboration around large collections of data must guarantee the following features:

- Provides security for access, control, traceability, and data
- Organizes data (configuration level, maturity level, options)
- Does not directly affect the data (release versions)
- Provides Change Management traceability
- Provides schedule alignment and visibility
- Provides synchronization with existing data owners (OEM)
- Provides software version data translation exchange constraints

Collaborative Platform Solutions

A collaborative platform solution is where two or more people from different groups, communities, or companies work jointly on a project. The main objective of the collaboration is to simplify exchanges, enable concurrent engineering, and increase overall efficiency. Several key elements are required for an effective collaborative platform solution. These elements can be quite complex and belong to sophisticated industrial processes. A high-level list includes the following aspects:

- Facilitates exchanges quickly to increase the speed and convergence of ideas and concepts being developed
- Strengthens the dynamic between the different “actors” for the different communities—whatever their origins—to interact together through a collaborative platform solution
- Groups all elements participating into an effective collaboration
- Updates/synchronizes and manages data
- Establishes links between the data
- Securely organizes communities using roles, groups, and organizations
- Manages timelines, the schedule, and milestones to stay well-aligned
- Provides secure interoperability for data

The global architecture of a collaborative platform solution must establish the rules (i.e., the processes) of concurrent engineering. Other topics needing consideration as indirect objectives of a collaborative platform solution to ensure fluid continuity between the different communities include proper alignment with legal obligation and respect of legal contract scope and operational objectives with strict honoring of the best practices. A collaboration solution should provide a non-proprietary data format to allow system- or solution-agnostic movement of data between organizations irrespective of the end point solutions used to create or maintain the data being collaborated. **Contracts play a key part in ensuring that collaboration data format standards are agreed upon by all parties before entering any collaborative arrangement.**

Collaborative platform solutions are needed for product development and university projects where applications and services replace large platform solutions using a document repository, data transfer point-to-point, or cloud exchange technology. Platform solutions must offer support for collaboration and guarantee milestone alignment to reach the business targets in an efficient and cost-effective manner.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Considering the interoperability across these communities and platform solutions, it is important to recognize also how data moves across the enterprise as described by the types of global collaboration.

For more information about interoperability, refer to ISO 11354-1 and ISO 11354-2. "ISO 11354 focuses on but is not restricted to enterprise (manufacturing or service) interoperability. It is intended for use by people who are concerned to assess capabilities for enterprise interoperability and identify areas where those might need to be improved to meet the needs and ambitions of the enterprise."[1]

Collaborative Workspace for Extended Enterprise

The collaborative workspace must be effective for the entire lifecycle of the product, beginning in the first phases and continuing until the end-of-life phase.

The following three major pillars should be considered to ensure effective collaboration between the participants, which can include the various OEM PLM players and the counterparts at the supplier's side.

Table 11 - Collaborative Workspace Pillars

Coordination	Cooperation	Collaboration
Project Management Process Workflow Schedule Engineering Review	Digital Mock-Up MBSE - RFLP Concurrent Iterative Design Development Assurance	Repository, Data Vault Change Documents Engineering Documents Supplier's Portal Shared Workspace

- **Coordination** is a process in which communities make a commitment to ensure that each one of them acts in a coherent way to ensure alignment with a common schedule and workflow.
- **Cooperation** refers to relationships between two or more organizations that aim to achieve a common deliverable or goal. Cooperation is the action of producing an element requiring several fields of expertise concurrently.
- **Collaboration**'s main objective is to share information in a controlled and safe environment between the different industrial ecosystem participants through a data-sharing mechanism. This aspect should also provide elements on the progress of a project or a program of activities, such as using a dashboard.

Interoperability across all disciplines, including these three pillars, is essential to fully embrace digital thread deployment.

[1] ©ISO. This material is extracted from ISO 11354-2. All rights reserved.

Collaborative Communities

A collaborative community is two or more people from different groups or companies working jointly on a project. As shown in the following figure, a collaborative community's main objective is to efficiently design, manufacture, and support components throughout their lifecycle.

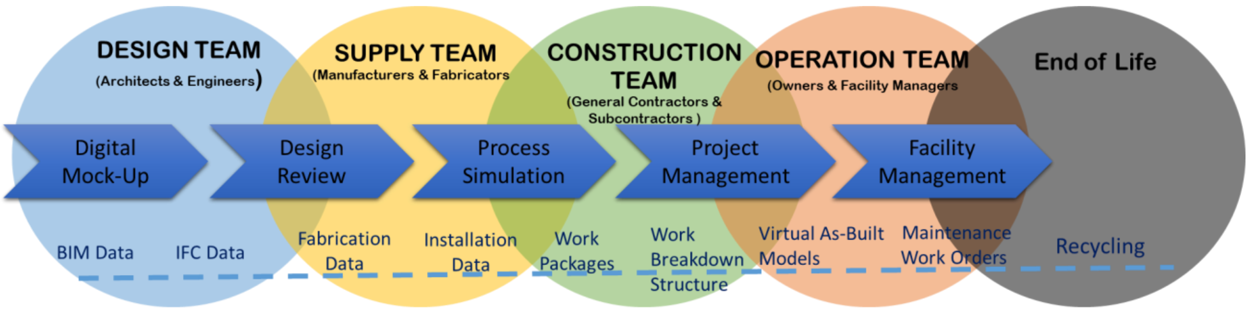


Figure 6 - Collaboration Community Along a Lifecycle

Collaborative communities must support collaboration, brainstorming, and innovation in real-time. As stated in the *Overview of Desired Interaction between Business Entities* section, collaborative community participants must also respect a common agenda to reach program milestones.

Types of Global Collaboration

Global collaboration aims to improve interoperability between collaboration communities while minimizing manual intervention. PLM providers must consider interoperability with other PLM providers and CAD software versions as a **MUST** requirement of industry.

The two major streams of collaboration are *synchronous* and *asynchronous*. Fully synchronous collaboration is the recommended method for the future of global collaboration. However, it is recognized that asynchronous collaboration may still exist in minimal, unique situations and should be taken into consideration. The challenges and the business benefits of synchronous collaboration are addressed in later sections of this paper.

Synchronous

Synchronous collaboration includes multiple areas that establish a collaborative community and platform solution as described below:

- Data is referenced or linked across multiple platforms/environments.
- Technical data package is systematically transferred (no manual transfer).
- Remote access to the system is direct (i.e., direct access to the PLM or central platform solution).
- Conversion and validation are automatic, using common standards (i.e., STEP242).
- Data interoperability exists between PLM environments.
- Optimized, concurrent co-authoring is possible.
- Multi-party collaboration is available.
- Increased performance efficiencies are implemented.
- Controlled copies of master data are maintained.
- Data transfer across organizations is secure.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

The synchronous collaboration solution would work in parallel with industry CAD and data interchange standards. The collaboration solution provides the platform to ensure control, bi-directional communication/sharing, and standards ensuring compatibility.

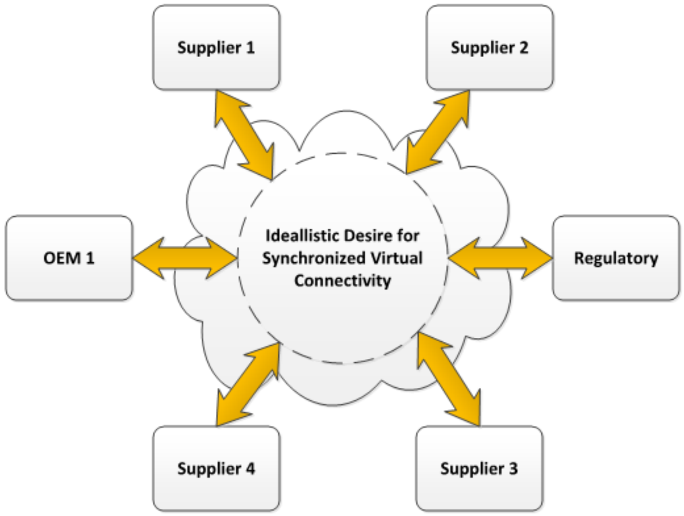


Figure 7 - Synchronous Collaboration Protocol (Different PLM Platforms)

This concept supports the following examples of data exchange:

- The OEM provides a cloud-based collaboration space to which the OEM–PLM workflow replicates TDP content. Once data is available, the solution notifies the supplier of availability and updates. Again, this approach offers bi-directional collaboration in that any form of upload from the supplier could be used to trigger a notification to the OEM.
- The PLM infrastructure allows one collaborative workspace for multiple communities or projects. This approach requires a network connection to the PLM environment, which can be challenging depending on the policies and procedures of the OEM and/or the supplier.

Asynchronous

Asynchronous collaboration also includes several areas that establish a collaborative community and platform solution as described below:

- A copy of the data is created.
- Data exchange is triggered by an event.
- Ad-hoc exchanges can occur frequently.
- Point-to-point data exchange is possible.
- Manual data preparation and exchange are available.
- Multiple iterations are difficult to track.
- Custom data conversion is an option.

An asynchronous collaboration solution would work in parallel with industry CAD and data interchange standards; however, it involves manual intervention and is not optimal for concurrent product development. This type of collaboration is typical of sequential transfer, which can lead to data distribution and consumption delays. The following figure illustrates asynchronous data distribution.

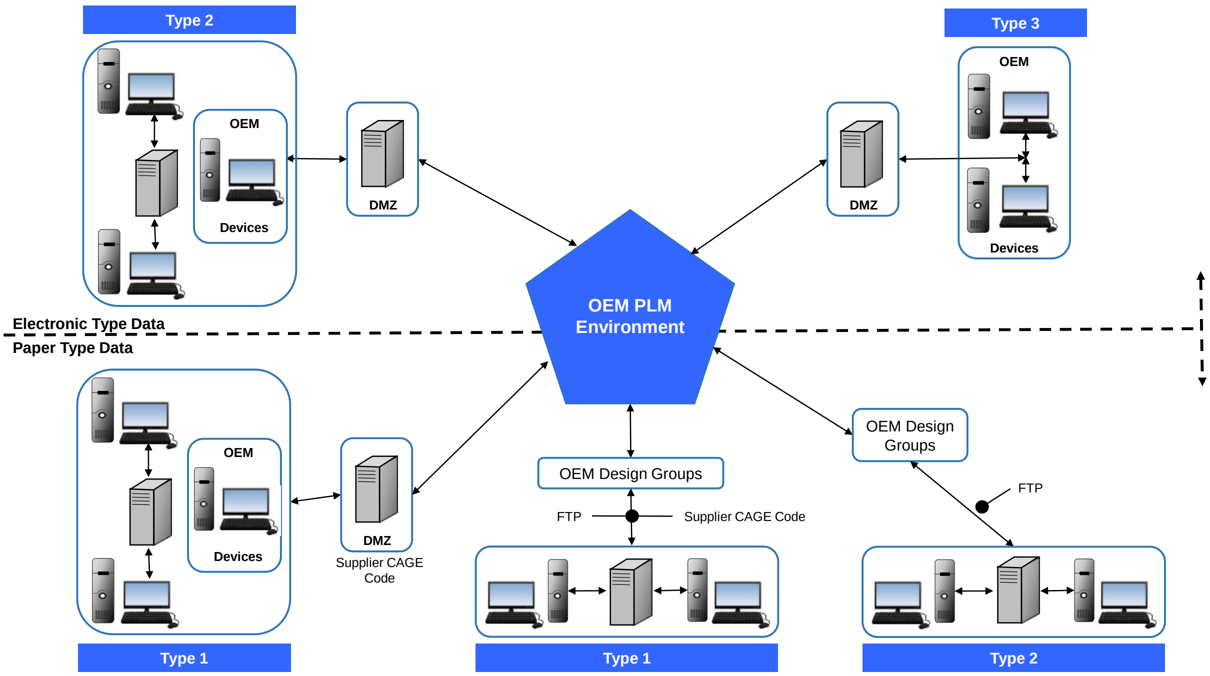


Figure 8 - Asynchronous Data Distribution

The asynchronous type of global collaboration supports the following examples of data exchange:

- Consider the Type 1 class of supplier (i.e., one that is manufacturing product in accordance with the OEM's engineering data and specifications). This is sometimes known as *the make-to-print model*. The engineering data is the drawing or model, and it references multiple specifications and standards to enable compliant manufacture.
- The combination of engineering data, specifications, and standards (i.e., TDP), and this extended content must also be managed across the collaboration solution and the product definition. The manufacture of the product in these scenarios is typically distributed between primes and tiers, with primes offloading partial content to the tiers.

  The further down the tiers a supply chain penetrates, the greater the potential of change management impact/risk (e.g., many manufacturing process definitions will be created to realize a single product for collaboration) and the greater potential for a number of non-PLM solutions coming into play.
- The supplier operates as a guest on the premise of an OEM PLM solution, securely accessing the TDP content when notified to do so, exporting content to supplier CAE and document management solutions. This approach offers bi-directional data movement from OEM to supplier and from supplier to OEM, which is particularly useful during early product development when considering producibility.

Collaboration Methodology

A work methodology allows for managing, sharing, and processing data among several users and systems at anytime and anywhere in real-time. The recommended collaboration methodology includes the exchange of ideas/knowledge using standards and interaction among several project stakeholders, who are following an implementation strategy to enable collaboration throughout the product lifecycle. This strategy is supported by a collaboration framework that ensures consistency across the enterprise and the supporting industries for the project. The supporting key topics in this section can be used to better understand the full intent of a collaboration methodology.

Collaboration methodology should consider any disruptive technologies, ensuring that these technologies can be integrated into the collaboration workflow. These disruptive technologies should be assessed against the requirements to address the pros and cons of use during collaborative engagements supporting the system-of-systems and product lifecycle.

The AD PAG Global Collaboration team developed an eight-step guideline for collaboration. While reviewing industry standards, the workgroup discovered the ISO Collaboration standards, which define a similar eight-step process. Whether consisting of ISO standards or other guidelines, a framework that supports global collaboration allows the relationship between business entities to consistently support business exchange capabilities. Both collaboration approaches are outlined in the following sections.

AD PAG Global Collaboration Team Guidelines

These guidelines take a look at having a consistent method while also supporting engagement between businesses and creating an interoperable exchange. An illustration and description of the guidelines follow:

Figure 9 - AD PAG Global Collaboration Team Guidelines

1a. **Prepare Recommended Collaboration for the Data Exchange Process -** Define and describe data to be exchanged, capabilities required for an efficient collaboration, and project management rules

1b. **Assess Supplier Capabilities -** Select a supplier based on their data exchange and project management capabilities (all other criteria are not part of Step 1) or to define what is awaited from the supplier already selected

2. **Commercial, Contractual, and Legal Relationship -** Establish all commercial, contractual, and legal relationships about data exchange and project management
3. **Set Up Governance -** Define and understand all rules and regulations before any interaction with any supplier where non-public data will be shared
4. **Project Management -** Establish a common means of collaborating and managing engineering activity, including activities scheduling, delivery, and performance measurement
5. **Set Up Interfaces and Organization -** Clearly define the interface between participants to enable clear and efficient collaboration between the OEM IT services and the supplier from deployment to the run mode. This requires that the supplier shall nominate key IS/IT representatives strictly in a timescale to meet the contract requirements
6. **Setup Collaboration Environment for Program Life -** Implement a system-neutral collaborative platform and determine the IT administration environment setup, configuration, and maintenance
7. **Program Review Process -** Cover the product and its constitutive products for both the make and the buy activities in the frame of the Product Development Plan. Ensure the product satisfies the agreed upon requirements and customer's expectations by checking solution compliance against the technical, cost, and schedule objectives. This step decides the closure of the Design phase and also permits or denies transition to the next phase of the Design-Build process
8. **End State (LOTAR) -** Define a method of operation once the program has reached maturity or end-of-life

Collaboration Using an ISO Industry Standard

The ISO organization developed and published the ISO 44001 *"Collaborative business relationship framework detail"* standard. This standard established the requirements of a strategic lifecycle framework to improve collaborative business relationships in and between organizations of all sizes. Collaborative business relationships in the context of the ISO can be multidimensional; they can be one-to-one relationships or networked relationships involving multiple parties. The following figure illustrates the importance of collaborative relationship management during global collaboration.

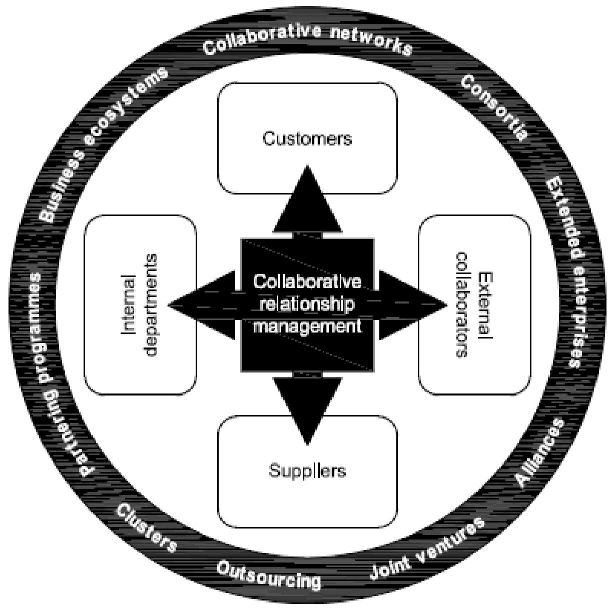


Figure 10 - ISO Framework[2]

ISO 44001 Collaboration Framework[2]

In the context of collaborative relationships, a lifecycle model outlines the key steps to an effective management process from concept adoption to disengagement.

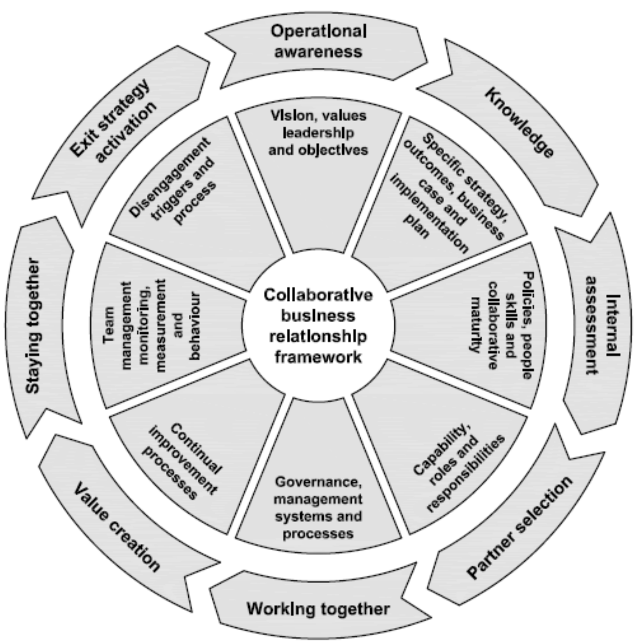


Figure 11 - ISO 44001 Lifecycle Model

[2] ©ISO. This material is adapted from ISO 44001:2017, with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization. All rights reserved.

The following eight stages of the ISO 44001 lifecycle model should be incorporated to establish global collaboration:[3]

1. **Operational Awareness -** Establishing the organization's propensity for collaboration
2. **Knowledge -** Evaluating specific collaborative benefits and business case
3. **Internal Assessment -** Assessing the organization's capability to collaborate
4. **Partner Selection -** Establishing an appropriate selection process
5. **Working Together -** Establishing a joint governance model for collaboration
6. **Value Creation -** Establishing a joint process for continual improvement
7. **Staying Together -** Managing, monitoring, and measuring the relationship over time
8. **Exit Strategy Activation -** Establishing a joint approach for disengagement and/or the future

In a collaborative relationship, effective operation relies on specific, mutually agreed upon joint interfaces, processes, roles, and responsibilities that can require specific variations to in-house processes. In ISO 44001, it can appear that certain requirements are duplicated. However, efforts have been made to distinguish between an organization's processes and requirements specific to the development and implementation of a specific joint relationship.[3]

[3] ©ISO. This material is adapted from ISO 44001:2017, with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization. All rights reserved.

Implementation Strategy[4]

ISO 44002 explains what is intended by each requirement of ISO 44001, describes why each is important, and recommends approaches to take for practical implementation. How to meet the requirements is individually evaluated and applied in the context of each organization. The following figure shows the high-level implementation flow.

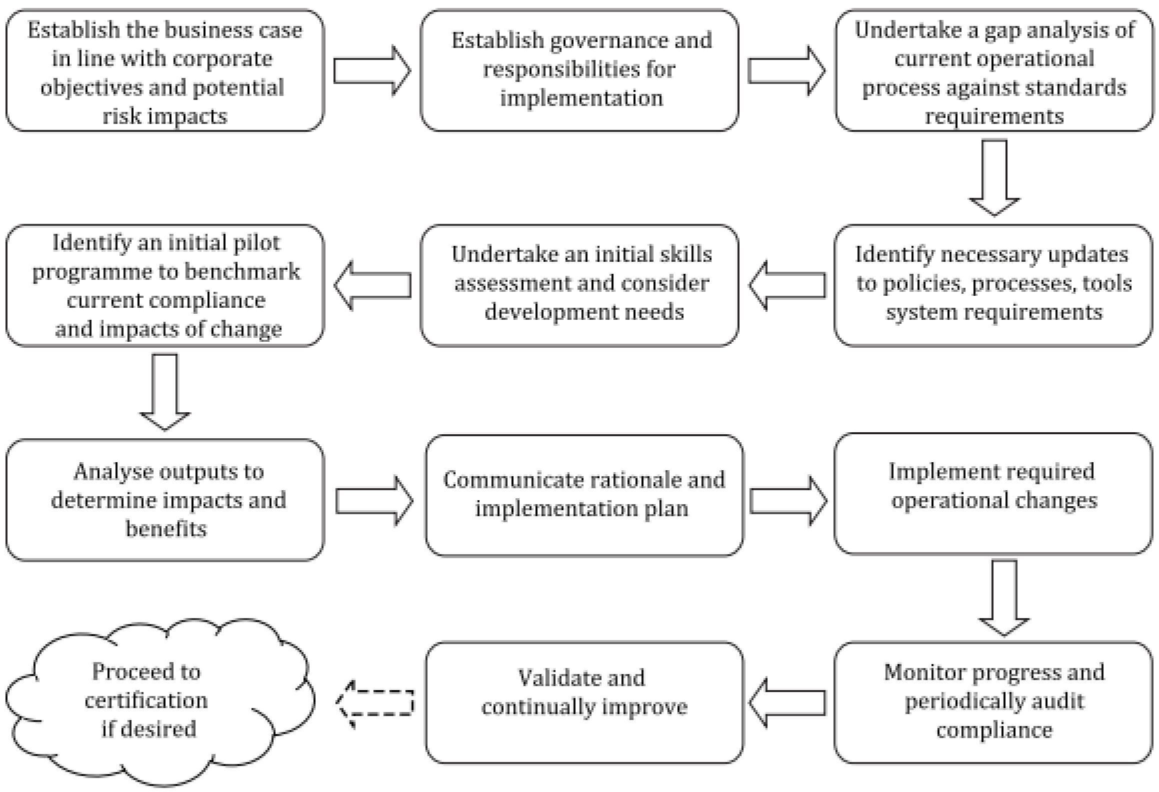


Figure 12 - High-Level Implementation Flow from ISO 44001[4]

[4] ©ISO. This material is adapted from ISO 44002:2019, with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization. All rights reserved.

Available Collaboration Standards

The following table provides the appropriate standards version to be used to support collaboration.

Table 12 – Collaboration Standards

Standard	Publication Year	Title
ISO 11354	2011	*Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability*
ISO 11354-2	2015	*Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability — Maturity model for assessing enterprise interoperability*
ISO TR44000	2019	*Principles for successful collaborative business relationship management*
ISO 44001	2017	*Collaborative business relationship management systems — Requirements and framework*
ISO 44002	2019	*Collaborative business relationship management systems — Guidelines on the implementation of ISO 44001*
ISO 44003	2021	*Collaborative business relationship management — Guidelines for micro, small and medium-sized enterprises on the implementation of the fundamental principles*
ISO 44004	2021	*Collaborative business relationship management — Guidelines for large organizations seeking collaboration with micro, small and medium-sized enterprises (MSMEs)*
Mil Std 31000	Rev - 2009 Rev A - 2013 Rev B - 2018	Provides requirements for the deliverable data products associated with a TDP and its related TDP data

ISO Standards Versus AD PAG Guidelines

These two methodologies reveal the importance of using a universal and consistent method when collaborating. Both methodologies examine key elements of collaboration, allowing business entities to consistently deploy techniques and provide opportunities for performance efficiencies during collaboration.

In a simple example, looking at Step 8, the ISO identifies an exit strategy, and AD PAG references the need to store data using LOTAR (LOng Term Archiving and Retrieval) standards. Both final steps show the benefit of using a standard method when closing out collaboration events.

It is important to recognize that as global collaboration continues to grow across industries, clear value exists in understanding the different methodologies available for executing global collaboration. A detailed analysis of the ISO standards and AD PAG guidelines will be published at a later date.

Collaboration Management System (CMS) Application

The AD PAG Global Collaboration team is backing the development of an automated Collaboration Management System (CMS) application that supports the best practices for information exchange across OEMs, partners, suppliers, customers, and academia. (The CMS application will be detailed in a separate paper.)

The CMS application will strengthen standard practices to provide consistency in the business use of collaboration standards. The specific practices of the CMS focus on guidance and implementation steps within the application to provide tracking and monitoring during collaboration lifecycle activities in alignment with program milestones. Companies can be confident in their collaboration readiness and organizational consistency by having these features set in an application.

Challenges of Synchronous Collaboration

Synchronous collaboration can create many challenges as participants use new collaboration methodologies to enhance business performance. Several key areas that can create challenges for global collaboration include standards, data exchange, security, cost, configuration management, and PLM and CAD software.

Standards

Standards-related challenges include the following:

- Inconsistent business participants and vendor (CAD/PLM) adoption and implementation of common and open standards
- Adaptation of business processes to implement complex standards
- Project agreement for standards being used
- Industry optimization of collaboration standards between the multiple standards organizations

Data Exchange

Data exchange-related challenges include the following:

- Implementation of data exchange agreement to synchronize data as quickly as possible
- Eradication of complex, multiple data conversions, as well as re-work and labor-intensive manual data conversions, including native versus neutral exchange format
- Alignment and validation of sending/receiving systems to confirm the intent of the attribute exchange is synchronized, taking into account the extraction process
- Collaboration with multiple types and levels of suppliers
- Ownership/responsibility/accountability of data integrity

Security

The primary security-related challenges are ensuring that all digital rights, IP protection, export control requirements, and data security protocols are in place for effective sharing, including archiving until end-of-life.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Cost

Cost considerations can be categorized into the following three areas:

- **People** are key to the success of a global collaboration effort. User training and effective communication are essential to enable the culture change of optimizing the solution.
- **Processes** must be mapped and adapted to understand internal and external interdependencies and opportunities to facilitate adoption of collaboration solutions, resulting in significant transformation costs. The time necessary to adopt and train users must also be considered.
- **Tools** investment in collaboration infrastructure to address the challenges of enhanced user experience, cyber security, data validation and migration, system interfaces, and long-term archiving are essential ingredients to achieving successful implementation, resulting in considerable implementation costs

In addition, before launching a collaborative program, it must be considered that once implemented, a collaboration solution requires ongoing costs to ensure the solution is sustained during its lifecycle across the people, processes, and tools areas.

Configuration Management

Configuration management-related challenges include the following:

- No known international standards for naming convention or version iteration exist to support data configuration management and change.
- Definition and agreement of configuration management plan, including any preconditions or special conditions enable a protocol for data configuration management and change process aligned to implementing the contractual collaboration agreement.
- Managing lifecycle/workflow for varying external suppliers, this element of collaboration can be custom and complex.
- Configuration of all data must remain in version control for multi-party exchanges and storage, especially during the early product development phase during which product definition iterations are likely to be many if operating concurrent engineering approach.
- Configuration of collaboration infrastructure supporting vault, repositories, and shared workspaces.

PLM and CAD Software

PLM and CAD software challenges include the following:

- Understanding the variety of PLM and CAD solution versions of each participant, as well as recording and maintaining this understanding to optimize and ensure robust collaboration throughout the life of the program
- Data interoperability, data synchronization, data validation, and data version compatibility between PLM and CAD solution providers
- Hardware and software obsolescence during the life of the program, including data mapping, migration, and possible data conversion to newer versions
- Software vendor and participant adoption of common industry standards to enable federated platform solutions

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

Business Benefits of Synchronous Collaboration

Synchronous global collaboration benefits focus on optimizing digital data exchange, configuration management, quality, and cost. To realize these benefits, digital transformation and integration between participants is necessary. Utilizing global collaboration methodologies across internal and external organizations will result in the opportunities outlined in the following sections.

Process Optimization and Quality

Process optimization and quality benefits of synchronous collaboration include the following:

- Systematic digital exchange of data and documents, which enhances communication through reduced email and meetings, results in improved communication efficiency, productivity, and a reduction in human intervention while optimizing approval timelines.
- A common environment allows multiple organizations to rapidly make informed decisions based on real-time data, enabling participant efficiency and virtual product reviews.
- Consistency created in data exchange methods reduces design iterations, compresses lead-time, and reduces development errors, resulting in improved quality and lower cost of late changes.

Data

Data-related benefits of synchronous collaboration include the following:

- Accelerated data availability reduces development lead time and minimizes iterations for optimal design solutions, ultimately enhancing product development through transparent interoperability.
- The OEM and supplier work simultaneously on active in-work data that is immediately available for all the partners in a format usable across the product lifecycle.
- Improved traceability, tracking, control, and ownership of authoritative data (i.e., master, single source of data) provides secure access to the latest in-work or released data version.
- Downstream applications access a single data source to minimize conversions or re-work.
- Enhanced interoperability eliminates manual data conversion.

Cost

Cost benefits of synchronous collaboration include the following:

- An optimized design process due to enhanced collaboration results in reduced time to market and zero defective products.
- A reduced-participant PLM infrastructure minimizes implementation and operational costs (e.g., Type 1 supplier in an asynchronous setup).

Configuration Management

- Configuration management benefits of synchronous collaboration include the following:
- Improved configuration management and optimized release processes and change implementation using the same baseline for every partner or supplier enables concurrent engineering in a configured environment.
- Synchronization and effectivity implementation enable end-to-end digital continuity (i.e., not designing twice) and product design data supporting DMU and simulation across the product lifecycle.

Go Forward Plan

This position paper addresses Phase 2 of the AD PAG Global Collaboration project and includes objectives, a description of the desired state, and To Be use cases. Following this Edition 2 paper (Release 2.0), an application supporting the collaboration methodology checklist is being developed to assist with global collaboration implementation and will be made available as a separate AD PAG Global Collaboration team publication.

Future Edition 3 of this paper will define specific recommendations and requirements to help the A&D industry reach its goal of simplified PLM global collaboration. The intent is that the next position paper release will aid a discussion with the software suppliers and OEMs to deliver the objectives for a collaborative environment.

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group (www.ad-pag.com) 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, an independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design, deliver, and support innovative products and services by identifying and implementing appropriate digital initiatives. For nearly forty years, CIMdata has provided industrial organizations and providers of technologies and services with world-class knowledge, expertise, and best-practice methods on a broad set of product lifecycle management (PLM) solutions and the digital transformation they enable. CIMdata also offers research, subscription services, publications, and education through certificate programs and international conferences. To learn more, visit www.CIMdata.com or email info@CIMdata.com.

Appendix A: Solution Concepts

This appendix provides examples of current exchange solutions and concepts considered by the Global Collaboration team during the content authoring of this paper. The following are some solutions considered to be Collaborative Communities:

Using a PLM System

- Same PLM solution provider but not connected
- Same PLM solution provider connected
- Same PLM solution provider but not connected and a different software level (CAD and/or PLM)
- Same PLM solution provider connected and a different software level (CAD and/or PLM)
- PLM to PLM
- PLM to "cloud" to PLM
- PLM to "cloud" to supplier w/o PLM
- Supplier direct access to PLM via web portal
- Neutral PLM formats and multi-CAD conversion
- Use of different PLM systems (Existing Method)
- Different PLM solution communities/collaboration/interaction requirements

Without a PLM System

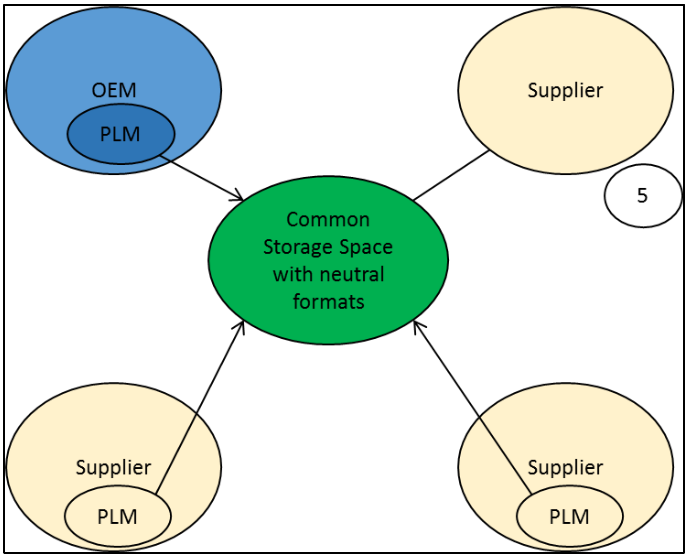
- Point-to-point data exchange
- One collaborative shared workspace for all communities involved

Hybrid

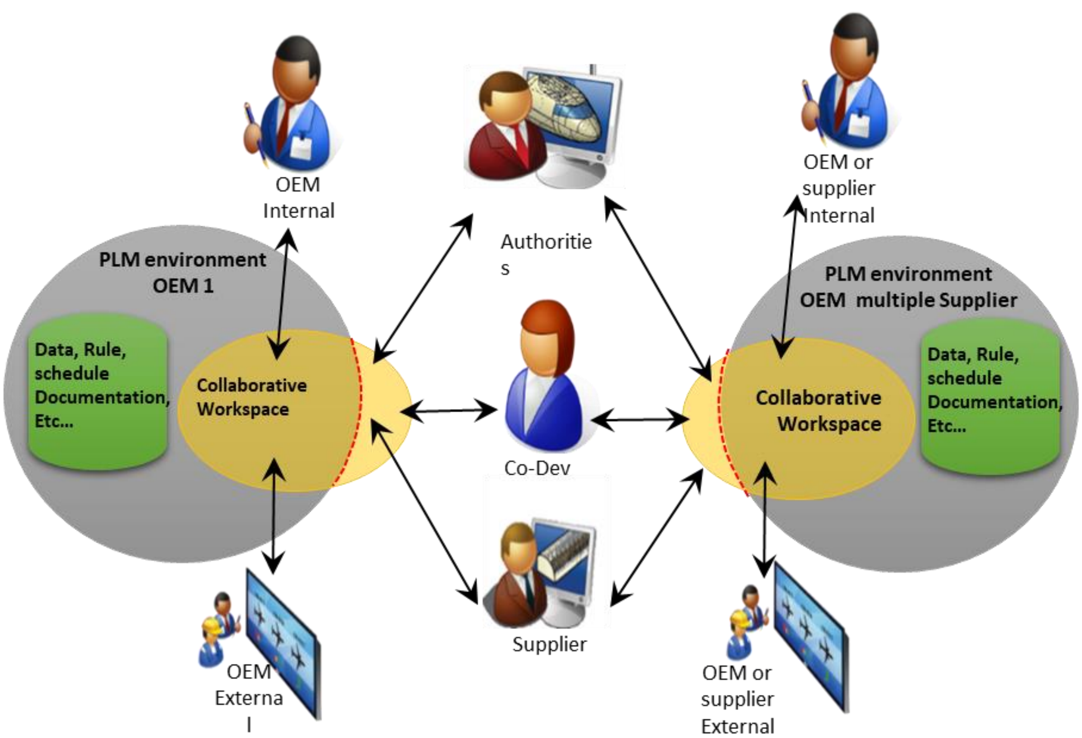
- PLM to non-PLM system
- Supplier direct access to PLM via web portal

© 2022 copyright CIMdata, Inc. | Other trademarks belong to their respective owners

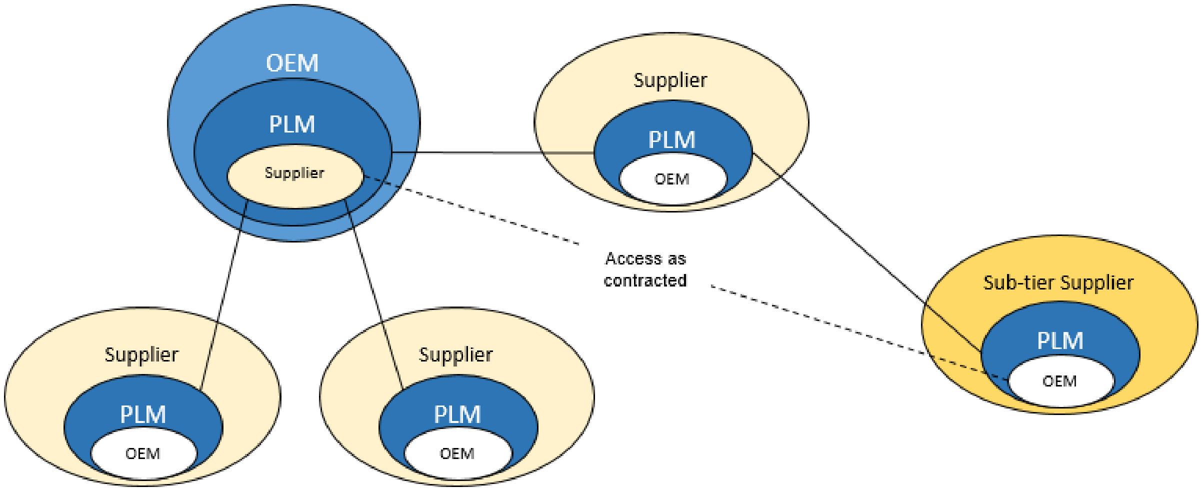
The following graphics illustrate some of the PLM solutions considered.



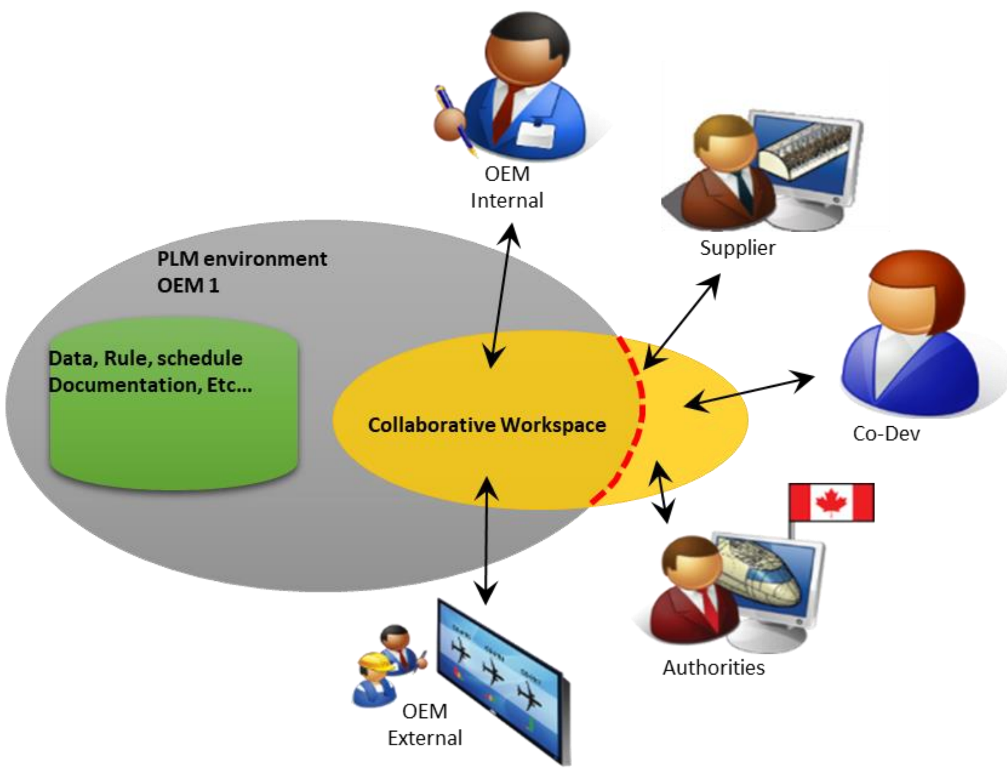
Common Data Source



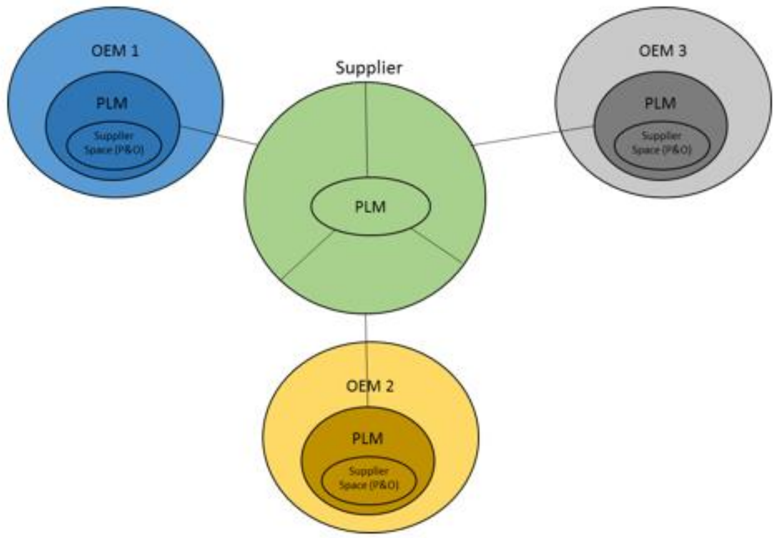
Multiple Collaborative Workspaces for Multiple Communities and/or Projects



Common PLM System (Same PLM Solution)



OEM PLM Hosted Collaborative Shared Workspace



Supplier Paradigm Working with Multiple OEM PLMs