ARC STRATEGIES

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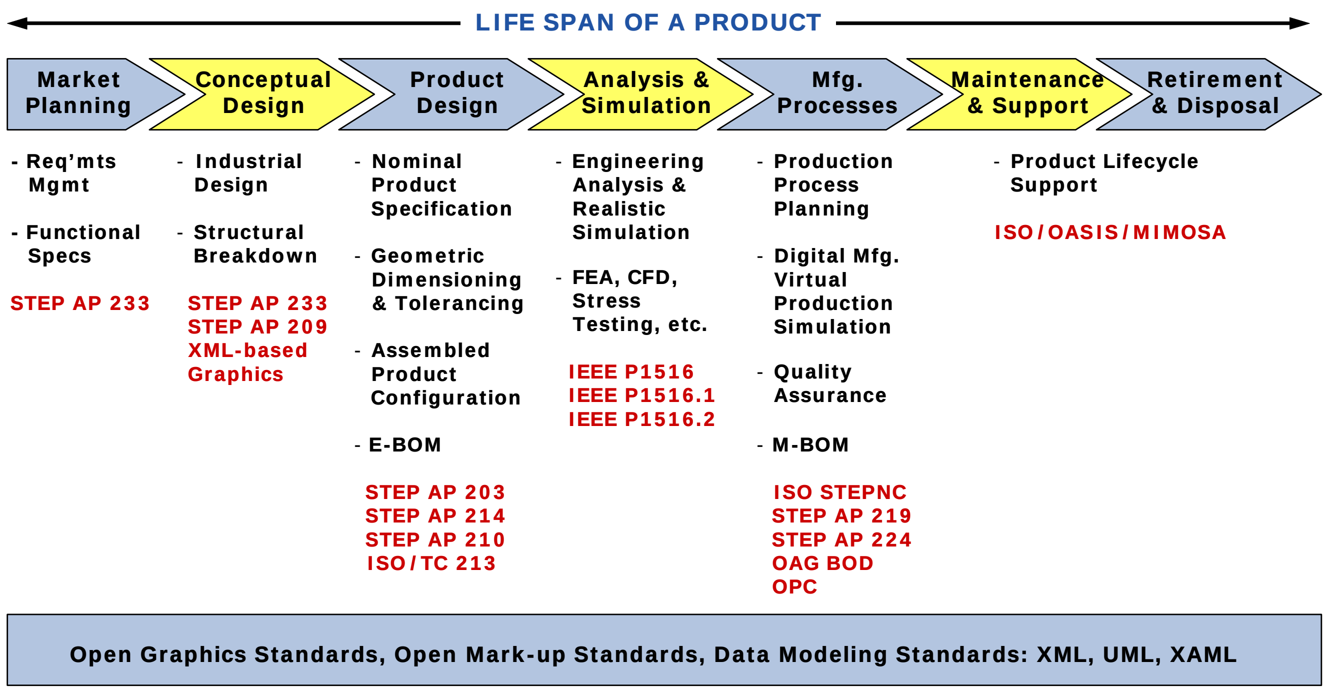
Interoperability and Openness across PLM: Have We Finally Arrived?

ARC Advisory Group



Product Lifecycle and Standards

Executive Overview

Exchange and accessibility of digital representations of product designs, plant design, manufacturing processes, engineering analyses, and product data management is a critical issue for product lifecycle management (PLM) solutions. PLM includes a heterogeneous set of applications and tools and the inability to effectively share information has been one of the primary constraints to efficient design/build processes.

Today, PLM information from concept and design, through manufacturing processes, engineering analysis and simulation, ERP, supply chain, product support, and asset management must be shared across the enterprise.

Today's manufacturing enterprise is faced with shorter product lifecycles and increased pressure to rapidly get new products to market. In many cases, this must be accomplished across a global engineering supply chain that demands tight collaboration and seamless exchange of product data. This new environment has elevated the importance of accessing engineering product data and has introduced additional requirements for the exchange of this data.

The scope of PLM solutions has also been rapidly expanding across the manufacturing enterprise. While data exchange and collaboration was traditionally confined to product design geometry and cutter path information for CAD/CAM, today's manufacturer must share PLM information from concept and design, manufacturing processes, engineering analysis and simulation, ERP, supply chain, product support, and asset management across the enterprise. This has expanded the challenge of product model data interoperability to include the needs of multiple domains across the product lifecycle. To address this need, PLM providers are increasingly using open Internet standards and XML as the basis for representing product design, manufacturing simulation, and other digital definition data.

Effective interoperability across the expanding product lifecycle, plant lifecycle, and value chain is costly to all manufacturers. The National Institute of Standards and Technology (NIST) reports that the North American automotive industry alone pays out more than $1 billion each year due to their inability to freely share and reuse product data across the supply chain. While, the road to standards-based interoperability of digital design and product data began decades ago, we are hopeful that it may be finally reaching the point where pervasive exchange of PLM information is a realistic possibility.

Open Standards Enable PLM across the Global Enterprise

When applied to systems, software, and standards, the term "Open" often evokes a new round of discussions of what really constitutes openness within an environment and to users who have to exchange data and applications across heterogeneous environments. The reality is that "Open" is open to interpretation and interpretations vary according to one's role in the value chain. Supplier's marketing campaigns generally include the message that they are open and interoperable. Users, however, may still find severe limitations for their specific needs and unique PLM solution portfolio.

> The reality is that "Open" is open to interpretation depending on whether one is a supplier or user, IT or operations, enterprise architect or member of the value chain.

Openness Driven by Standards and Industry

Within the domains of information technology and the industries that they serve, there are three categories of openness: open standards, industry standards, and de facto standards. These categories have been arrived at through consensus in the PLM community, among both suppliers and users. It should be noted that open standards, whether established by organizations or industry, do not always guarantee interoperability in the PLM sector.

Open standards refers to the basic notion of interoperability and integration. Typically, it is an agreement that suppliers and users make so that products, applications, and systems developed by different providers can perform together at a level that meets the users' functional requirements. Open standards are not software applications. They represent only the agreed upon specifications that describe levels of detail of how the information should be presented to the end user. Generally, open standards are developed by consensus in the context of an industry group, such as the World Wide Web Consortium (W3C) which has established standards like XML and WDSL. Other examples of open standards would include engineering standards from groups like ISO (STEP), IEEE, and IEC; information technology groups like OAG (OAGIS), OMG (UML), and OASIS; and industrial standards organizations like ISA.

The second category of openness is represented by an industry standard. Industry standards are technologies that are very commonly used but are not associated with a standards body or committee. These types of standards are not open or democratically managed by a group of users, but are technologies that come from a supplier. The Java language would be an example of an industry standard that is a technology developed and maintained by a supplier, in this case Sun Microsystems. Even though there are many suppliers that offer products and applications based on Java, Sun wields a significant amount of control over Java's use.

De Facto standards represent the third category of openness. Typically, these are technologies that have been adopted pervasively across all industrial sectors and businesses, and are considered to be open by virtue of the fact that they are so widely used. Often the open value of these technologies is their associativity with other technologies, not that they were produced by a standards body. The best current example of a pervasive de facto standard is the Windows operating system for the PC platform. Today, the majority of PLM applications will run on a Windows platform.

Open Standards for PLM

CAD/CAM models are at the heart of PLM solutions and each supplier has developed proprietary data models and formats to capture the richness of their product design tools. While translators have been developed to enable file exchange across supplier products, translations between different representations generally lose some degree of model fidelity. Completing or "healing" such partial translations can be difficult and time consuming and has limited efforts to implement more efficient design/build processes.

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The scope of PLM solutions has been rapidly expanding across the product and plant lifecycle. While traditionally data exchange and collaboration was confined to CAD/CAM product design geometry and cutter path information, today, PLM information from concept and design, manufacturing processes, ERP, supply chain, product support, and asset management must be shared across the enterprise. Again, proprietary formats and varying data models have impeded progress towards integration of product related activities.

But the tide is changing. While virtually all PLM solution providers have supported the ISO 10303/STEP standard for exchange of CAD geometry, they are now adopting open internet standards, such as XML, SOAP, and WSDL, and development standards like the Unified Modeling Language (UML). This shift is rapidly enabling PLM information, whether in the form of product design data, manufacturing processes, or product data management, to flow seamlessly across global enterprises.

Interoperable CAD Formats: The Start of an Arduous Journey

The quest to exchange CAD design files began shortly after the technology to replace paper drawings with digitized design files emerged in the 70s. Mechanical CAD systems were just a few years old, with only a handful of products with any significant market penetration. Even at this early stage, users were overwhelmed by the inability to share data among the tools and with their own internally developed data bases. It became evident that the migration from paper drawings to a fully digitized design had begun and it was equally evident that interoperability between CAD products would be critical to the success of migration.

IGES Becomes the First CAD Model Standard

The fundamental unit of data in a CAD file is the entity. Entities are categorized as geometry and non-geometry. Geometric entities define the physical shape and include points, curves, surfaces, solids, and relations within the CAD model. Non-geometric entities define everything else from annotations and dimensioning to collection of metadata that completes the CAD model. Any standard for CAD authoring tools has to include geometric and non-geometric entities.

The first standard for this area, the Initial Graphics Exchange Specification (IGES), was established in 1980 to provide a neutral data format to transfer design geometry between dissimilar systems. Translators, developed to the IGES standard, are used to export native CAD design files into an IGES file for exchange and for importing the IGES file into the destination system.

However, neutral file formats such as IGES have significant limitations. Since IGES is more of a set of guidelines rather than a rigidly defined format, the way it is treated varies from software application to application. For example, different CAD products have different standards for tolerances so when native geometry is translated via IGES, the receiving application must be able to apply its own tolerances to the unresolved geometry. Further, IGES does not translate non-geometric entities. Because of this and related geometry translation problems, numerous IGES data exchange and conversion software applications have emerged over the years.

With IGES the quality of data produced by the translators (pre-processors) varies widely. One criticism that can be made of IGES is that there is more than one way to describe many of the geometric entities. In some cases, the data model of the sending CAD system is poorly matched to the IGES data model and the quality of the model is significantly degraded in its IGES representation. However, even with these limitations, the IGES standard has been steadily upgraded (current version 5.1) over the years to even include support for solid models, and both translators and users still abound.

STEP Emerges to Fill the Gaps

The deficiencies in IGES and the need to develop a truly 3D geometric representation motivated the development of ISO 10303 or the Standard for the Exchange of Product Model Data, better know as STEP. When the STEP effort began in 1984, it was envisioned as a more encompassing set of standards for the exchange of all product data that included CAD/CAM and Product Data Management (PDM) systems. It was to represent a viable alternative to the existing chaos of multiple, fragmented standards and proprietary data formats. The emphasis was on data models, as opposed to data formats, and was a direct consequence of developments in computer science at the time. IGES and STEP share a commonality in that both specifications are based on geometric entities. The STEP standards committee, however, set out to make their geometric entity definitions "canonical", or reduced to the simplest and most significant form possible without loss of generality. This was an effort to eliminate the entity variability problem of IGES.

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STEP is an effort to go beyond just defining geometry, and to extend the content of information about the digital model. Its architecture is modular and therefore more flexible than IGES. It not only includes support for digital product data and geometry, but also topology, tolerance, relationships, attributes, assemblies, configuration, and more. STEP seeks to include information about the attributes of the product model such as surface finish, material characteristics, and even manufacturing process steps. STEP was also designed to cover a product's entire life cycle.

The actual STEP standard is divided into many parts. These parts cover topics such as methods used to present the standard, implementation architectures, conformance testing procedures, resource information models, and application protocols. The last item, application protocols (AP), is one of the more important elements of STEP and represents the committee's intent to address the design/build processes across both functionality and specific industrial verticals. APs describe specific product data applications and manufacturing processes. There are 40 standard graphical and process definitions applicable to a variety of manufacturing applications and vertical industries including Automotive Design, Ship building, Composite Structures, Building Services, Electronic Printed Circuit design, Furniture Products, and CNC machining.

Application Protocol	Description
203	Configuration Controlled 3D Designs of Parts and Assemblies
213	Numerical Control Process Plans for Machined Parts
214	Core Data for Automotive Mechanical Design Processes
224	Mechanical Product Definition for Process Planning using Machining Features
238	Process Machining Features for CNC systems

Typical STEP Protocols for Discrete Manufacturing

The ultimate goal of STEP is to cover the entire lifecycle, from conceptual design to final disposal, for products across all industries. The accomplishment of this goal is yet to be fully realized, and remains an ongoing effort and exercise. The most significant advantage that STEP has brought to users today is the ability to exchange design data as solid models and assemblies of solid models.

PLM Standards Have Not Filled All Interoperability Gaps

Efforts by the design community to establish open standards for geometric digital product definition, like IGES and STEP, have made a major contribution to PLM interoperability. But unfortunately these standards do not address all of the issues of data exchange and geometric file conversion. The simple testament to this fact is the proliferation of companies and products dedicated to product design data sharing between heterogeneous CAD/CAM and PLM systems, conversion of surface definitions, resolution of topology differences between systems, and the various healing of models with geometry and tolerance discrepancies.

Company	Applications
Agile/Cimmetry	AutoVue
CoCreate	Designer Modeler, OneSpace
Elysium	CAD porter, CAD doctor
ITI Transcendata	Data Migration, Translation solutions
MatrixOne	Matrix PLM Platform
Procaess	DDX, eMMA, VilMA
Proficiency	Collaboration Gateway
Theorem Solutions	CAD Data Translation Products
Transmagic	I-STEP, Plus

Interoperability Providers and Solutions

The reality for many large to medium companies across discrete manufacturing industries, principally automotive, aerospace, heavy equipment, and some sectors of high-tech is that the PLM solution set for their design/build process remains a very heterogeneous mix of product authoring applications, PDM systems, portfolio management, simulation and validation systems, and manufacturing process management. Various organizations within these companies continue to deal with this reality on a daily basis. Marginal interoperability among high-end product authoring systems used by major manufacturing companies is a longstanding and well-documented issue.

Manufacturers have addressed the interoperability problem with a range of strategies. They have made huge investments in common product authoring and PDM systems and strive to deploy a common PLM solution across all of their enterprise. This approach has been inherently and historically difficult based on a number of factors that include evolving technology, dependency on legacy systems and processes, acquisition of companies and their PLM systems, and constant re-training of design engineering staff. Another strategy is to accept the fact that within the design/build environment across the enterprise there will always be degrees of heterogeneousness throughout PLM solutions. Companies deal with this multi-CAD interoperability issue by depending on conversion and translation solutions from the various providers of these applications.

To further exacerbate the interoperability dilemma, the globalization of manufacturing has caused companies to grow beyond a network of internal departments and now includes a diverse network of suppliers and customers. Success for these companies is predicated on how well they can orchestrate activities across this highly distributed value chain. For effective collaboration on complex projects, such as new product development or new plant design, companies need PLM solutions that are built to be open across all enterprise systems involved with product and plant lifecycles.

Manufacturers Want the Best Digital Design Tools

A key focus for most high-end product authoring providers in the 1990's was the development of the best technology for product modeling. Suppliers competed on the basis of having the best digital definition tools for design, the most accurate and efficient algorithms, the best surfacing and tool path tools for CAM, and the most sophisticated simulation tools for virtual manufacturing and structural analysis. They aggressively marketed their technology to a very receptive customer base that wanted to make the transition to a 100 percent digital design and mockup as expeditiously as possible. While those with foresight recognized the matter of data exchange, information sharing, and interoperability as an essential element of PLM, overall it did not register as a priority with many in either the user or supplier camps.

Initially, the matter of data exchange, information sharing, and interoperability, as an essential element of PLM, did not register as a priority.

Large discrete manufacturers in the Aerospace and Automotive sectors formed extensive partnerships with their preferred PLM supplier and in many cases contributed directly to improvement and enhancement of the product design application itself. The manufacturers were essentially locked into one PLM system for their design/build process. Model sharing, design collaboration, and overall data exchange was based on a sole source digital model repository, and interoperability did not emerge as long as the product authoring tools and PDM system were supplied by the same PLM provider.

The problem was that as the design/build process moved to a value chain of suppliers, sub-contractors, outsourcing partners, and the food chain of job shops, interoperability and openness became critical to support efficient data exchange and information sharing. Many smaller suppliers would typically use a variety of PLM solutions. Further, within large manufacturing companies, pockets of different CAD/CAM applications sprung up to satisfy specific production requirements.

Interoperability Finally Becomes a Priority for Major PLM Suppliers

Globalization of design chains has been the straw that broke the camel's back and finally made it clear that interoperability between competing PLM application sets is in the best interest of all parties. In 2002, two major PLM suppliers, UGS and PTC, signed an interoperability agreement that allowed data sharing between their respective modeling kernels. This signaled a major direction change for the industry and was the precursor to the forming of the JT Open Consortium.

JT Open Gains Momentum

Since UGS established JT Open in November 2003, basically at the request of their customer base, it has grown rapidly to support more than four million JT- enabled software seats that represent other major PLM vendors. JT Open is a consortium of manufacturing users, ancillary technology providers, PLM vendor members, and academic partners. Users include companies like GM, DaimlerChrysler, Ford, Siemens, Proctor & Gamble, Caterpillar, and Boeing. Technology provider advocates members include companies like Microsoft, Intel, HP, and SAP. Actual PLM provider members include UGS, PTC, Autodesk, Bentley, and Adobe and others. If nothing else, the JT Open Consortium lends substantial credibility to UGS' overall openness initiatives and direction.

JT Open
PLM Open

The JT Open format is CAD-neutral and can be created from most mainstream MCAD applications, which allows full representation of CAD-native model information. A JT Open model is typically a lightweight (in terms of data) model containing minimum facet data that is easily transported. For more high-end CAD applications the JT format provides a richer 3D model, with more precise geometry and other structural attributes. The JT Open Consortium's aim is to make the JT Open format a de facto standard. However, another major PLM player, Dassault Systemes/IBM offers their own openness technology and strategy, and this will have significant bearing on what neutral formats will become de facto standards.

Dassault Systemes Offers an Alternative

Dassault Systemes' (DS) openness strategy arose when they began working on the CATIA V5 architecture and technology base in the mid 90s and utilized object-oriented concepts throughout the entire V5 solution set. This approach enabled openness across the V5 environment that included a standard communication infrastructure, software components, a multilayered application architecture, and a common data model for all V5 applications. Another element of the V5 environment is a complete API with thousands of public methods that enable access to every piece of information, process steps, and multiple execution environments for severs and end users' access. The major benefit of this vision and overall strategy, in terms of openness, was largely directed at the V5 user base and Dassault's total PLM solution set of Solidworks, ENOVIA, and SMARTEAM. Actual interoperability outside of this environment could still be an issue. Dassault's ultimate response to UGS' PLM XML and JT format was 3D XML.

From Concept to Consumer: The End-to-End 3D Experience

There are three basic areas that define the requirements for collaboration across the complete PLM environment: Visualization & Collaboration, Interoperability, and Publish & Viewing. Each of these areas represents an array of standard data formats, data exchange and conversion applications, and desktop publishing formats. The direction of major PLM providers like UGS, Dassault Systemes, PTC, and even SAP is to establish open PLM architectures by leveraging technology that enables the most open environment of all: the Internet.

In an effort to establish open leadership, UGS developed their PLM XML transport protocol that enabled collaborative data sharing between heterogeneous applications throughout the product lifecycle. This approach was based on XML schemas that defined content, format, associativity, and access for geometry and structure. Users still had the choice to use other third party visualization and collaboration applications, but PLM XML delivered interoperability based on the openness of XML. JT Open was complimentary to PLM XML, and also satisfied visualization and collaboration needs. Additionally, their 3D viewer, JT2Go provides publish/view functionally by interfacing with 2D and desktop publishing formats like Adobe's PDF, Autodesk's DWF, and Microsoft's Office suite. UGS envisions this as a "democratization" of 3D availability across the extended PLM environment.

Dassault Systemes made a strong response to the UGS openness initiatives and JT Open with a strategy to advance the distribution of product information from the CATIA V5 suite of products. In October 2004 they announced their new 3D XML product which is based entirely on open XML schemas for collaborative data sharing. For this initiative DS and Lattice Technologies, Inc teamed to architect the next generation of the previous Lattice XVL format. The new format, owned by DS, uses a sophisticated 3D graphics compaction algorithm that outperforms the more commonly used tessellated graphic data formats and expresses this in XML schemas. DS claims that 3D XML is a lightweight, standard XML-based format that enables users to easily share 3D data. Further, DS uses the 3D XML format across its entire PLM suite including CATIA, DELMIA, ENOVIA, SMARTEAM, and Solidworks. Dassault Systemes vision extends beyond the design/build world of PLM to the notion of "3D for All", where 3D models will be accessible to not only design and manufacturing engineers, but marketing, sales, supply chain, and even the consumer.

Microsoft WPF Provides a Platform for the Future

On the horizon for PLM openness and interoperability is the next-generation Windows Vista platform that will include the new Windows Presentation Foundation (WPF) (formerly code-named "Avalon") subsystem. WPF will provide native support for Microsoft's new Extensible Application Markup Language (XAML), making it easier for developers to enrich their Windows-based applications with 3D elements. This basically means that any Windows Vista platform will be able to render 3D models without running a CAD application or 3D viewer on the PC, combining openness of a Web-based mark-up language with the de facto openness of the Windows platform.

Both UGS and Dassault Systemes have announced collaborations with Microsoft for supporting XAML in their respective 3D data formats. UGS will provide XAML support to their JT and PLM XML formats, while DS will provide support to align their 3D XML format. Microsoft appears to be in somewhat of an agnostic position, being able to provide a technology and new platform in the form of Windows Vista and WPF that will enable the widespread proliferation of 3D viewing.

For now the common denominator for openness and interoperability in the PLM world appears to be based on XML and Internet standards that allow for the exchange of information across all systems and platforms irrespective of native data formats. The PLM suppliers have staked claim to and have leveraged this technology to extend PLM information throughout the product and plant lifecycles and beyond.

Recommendations

- PLM providers continue to roll out end-to-end PLM solutions that are addressing the issue of interoperability. While it is often a challenge for manufacturers to constantly upgrade and migrate to new versions and improved technologies offered by their PLM providers, companies should establish new version and emerging technology migration paths with steady incremental steps.
- Identify and resolve product design model problems up front in the design stage. By adopting a model quality initiative, interoperability and quality are built into the product model eliminating manufacturability issues and potential downstream rework.
- Encourage or even require customers and suppliers along your value chain to take advantage of the new technologies available today to maximize the PLM investments that have been made.

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Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Community/terms/terms.htm

AP	Application Protocol
CAD/CAM	Computer Aided Design/ Computer Aided Manufacturing
CFD	Computational Fluid Dynamics
CNC	Computer Numeric Control
E-BOM	Engineering Bill of Materials
ERP	Enterprise Resource Planning
FEA	Finite Element Analysis
IEC	International Engineering Consortium
IEEE	Institute of Electrical & Electronic Engineers
IGES	Initial Graphics Exchange Specification
ISA	Instrumentation, Systems, and Automation Society
ISO	International Organization for Standardization
M-BOM	Manufacturing Bill of Materials
OAG	Open Applications Group
OASIS	Organization for Advancement of Structured Information Standards
OLE	Object Linking & Embedding
OPC	OLE for Process Control
OpX	Operational Excellence
PDM	Product Data Management
PLM	Product Lifecycle Management
RPM	Real-time Performance Management
SOAP	Simple Object Access Protocol
STEP	Standard for Exchange of Product Model Data
UML	Unified Modeling Language
WPF	Windows Presentation Foundation
WSDL	Web Services Description Language
XAML	eXtensible Application Markup Language
XML	eXtensible Markup Language

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