PLM Obsolescence Management Phase 2 Research Report

Exploring the Impact of Advanced CAD Capabilities on Integration and Standards for Storage and Exchange

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Sponsored by
Aerospace & Defense PLM Action Group

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INTRODUCTION

PLM Obsolescence Management for the purposes of this research is defined as the ability of an A&D company to upgrade and transition their PLM solution to new technologies in multiple increments over a period of several decades without loss of data and without incurring excessive cost and effort.

PLM Obsolescence Management is a major topic of concern in industries where the lifecycle of the company's product information is longer than the lifecycle of the PLM solution technology used to manage that information, and where the cost of a complete technology change is very high. Both conditions apply within the A&D industry. Key motivations for member investment in this topic include:

- The ability to refresh PLM enabling technology incrementally over time instead of a complete and costly swap out
- The ability to access and interpret product definition information over decades of technology refresh projects.

Within its 2014-15 research agenda, the A&D PLM Action Group identified PLM Obsolescence Management as a high priority topic. The Group commissioned CIMdata to conduct research to identify the most important causal factors contributing to the negative consequences of PLM technology obsolescence; solicit and document historical experiences; and research current strategies and tactics for managing technology obsolescence.

For its 2015-16 research agenda the A&D PLM Action Group decide to focus on three key elements identified in the 2014-15 project. "Numerous and Complex Integrations, "Standard Data Formats for Storage and Exchange", and "Advanced Features Embedded in Native Data Structures", as shown in Figure 1 below.

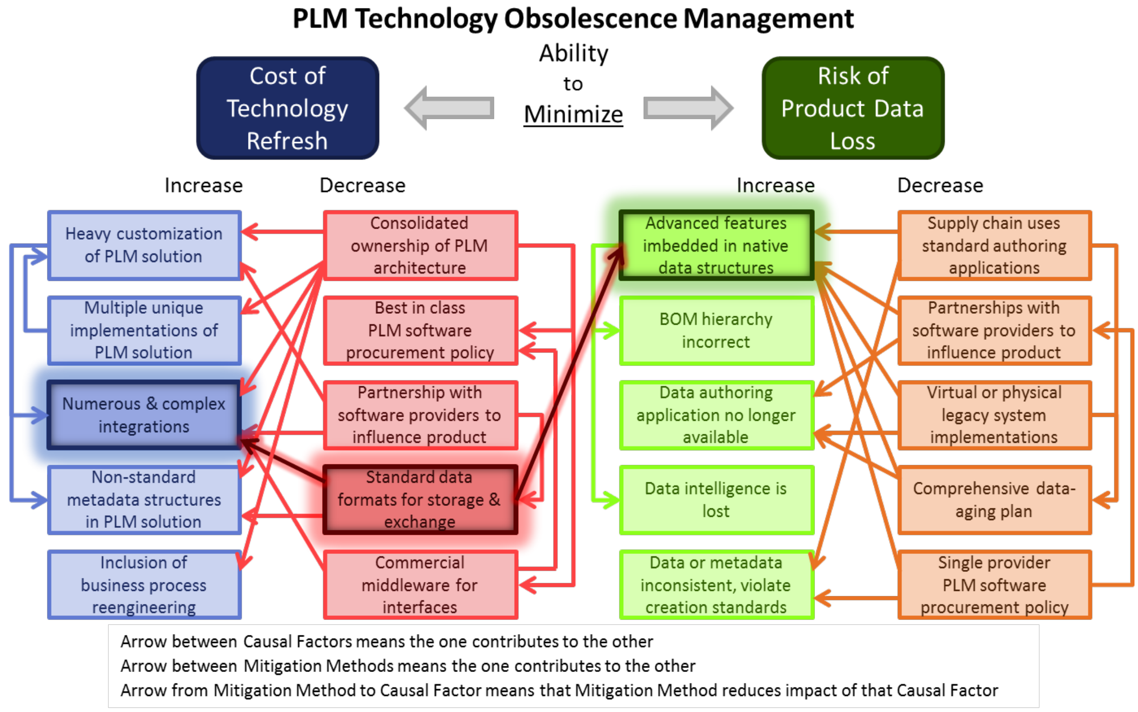

Figure 1– Elements and Relationships within the PLM Technology Obsolescence Management Model to be Investigated in Phase 2

As the Phase 2 project progressed, the researches decided upon two terminology changes. The researchers determined that “Advanced CAD Capabilities” would be a more accurate descriptor for the causal factor originally titled “Advanced features Embedded in Native Data Structures” in the Phase 1 report. This naming substitution has been applied throughout this Phase 2 report, except for the Phase 1 model representation shown in Figure 1 above. The researchers also decided to use “data exchange” instead of “data transfer” as a term more accurately aligned with industry convention.[1]

The intent of this project was to explore the relationships between advanced CAD capabilities and integrations that enable downstream use of the CAD data, and how data standards impact these integrations. The ultimate goal is to provide a base of information and insights from which the A&D Action Group can develop direction statements to guide the efforts of solution providers and standards organizations to produce more sustainable solutions.

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[1] **Data exchange** is the process of taking data structured under a source schema and actually transforming it into data structured under a target schema, so that the target data is an accurate representation of the source data.

Data transfer is the process of copying data from a storage device to memory, or copying data from one computer to another. When a network is used, data are technically "transmitted" over the network, rather than transferred; however, the terms transfer and transmit are used synonymously.

CIMdata's research relied on the A&D Action Group members as sources to be surveyed and interviewed. Methods were applied to avoid disclosing each company's product and process strategies to other members. A similar approach was used to obtain perspectives of the three major PLM software providers, five major systems integrators, two A&D thought leaders, and two automotive companies.

This report presents research results that identify the areas where data generated by advanced CAD capabilities is difficult to access and use in downstream solutions. It also explores the mitigating impact of standards on the complexity of integrations and other means utilized to facilitate CAD data exchange for consumption by downstream applications. The research results are followed by a summary of findings, conclusions, and recommendations.

RESEARCH GOALS AND METHODOLOGY

The following goals and methodology were defined and agreed with the Members and documented in the project plan in advance of project approval and initiation.

Goals

The overall goal of this research was to acquire insights and supporting evidence for formulation of a direction statement regarding the interrelated subjects of *Advanced features imbedded in native data structures*, *Standard data formats for storage & exchange* and *Numerous & complex integrations* that the members can use to influence solution providers, their supply chains, and standards bodies. The intent is that the directives will be clear, to the point, and sufficiently supported to merit serious consideration and action, leading to improved process flow, and a reduction of factors contributing to cost and risk of data loss. More specific goals for this research, to be pursued within the constraints of the specified scope, were to:

- Describe patterns of advanced CAD capability usage
- Understand benefits for the design team of advanced CAD capability usage
- Understand cost and risk issues for downstream users due to advanced CAD capability usage
- Characterize impact of advanced CAD capabilities usage on integrations between CAD and enterprise systems
- Characterize current practice and trends in mitigation methods to reduce the cost and risk of advanced CAD capability usage
- Characterize current state and future trends in application of CAD data standards
- Support development of a direction statement or statements for solution providers and standards bodies that, if adopted and implemented, will preserve the benefits while mitigating the cost and risk associated with the use of advanced CAD capabilities.

Methodology

Central to the methodology was identification of highly specialized subject matter expects (SMEs) and collection of information from them through highly targeted survey questions. The specific SME specialties important to this research were:

- CAD methods experts who can identify the types of advanced CAD capabilities used, and the benefits provided to the organization
- Data exchange specialists who can provide input on issues and special methods in place to support advanced CAD capabilities, and how well they are supported in downstream applications
- LOTAR specialists who can provide input on the state of standards usage within their companies

A significant refinement to the methodology based on lessons learned during Phase 1 was that the research participants were to provide information in two rounds of surveys. In the first round, participants were to validate and expand the selections within an initial open-ended survey. In the second round, respondents were to make selections and rank their selections within a refined survey with expanded but closed lists of choices.

Researchers took all necessary steps to avoid disclosing any A&D PLM Action Group member's practices or strategies to other members or research participants. The same was be true for all non-member participant companies.

Each major step of the proposed methodology is described and discussed below.

Participation Plan

1. CIMdata with guidance from the A&D PLM Action Group members develops a series surveys targeted and CAD method specialists, data exchange and integration specialists and LOTAR specialists within the Member and supplier community.
2. CIMdata and the Members jointly develop a strategy and communication plan to achieve a high level of participation. The process is to anticipate sensitivity of communication with partners and suppliers and include the following points:
   - Members inform their Supplier Management organizations that they will be inviting suppliers to participate as information sources for this research
   - Suppliers are informed that participation is clearly without obligation and voluntary

   During the planning process, methods to contact potential participants and means to increase the likelihood of their completing the survey are to include:
   - Personal invitation and follow-up by CIMdata and Members
   - Abbreviated custom report as a participation thank you
3. CIMdata and the Members make appropriate contacts and obtain agreement to participate.

Information Gathering

4. CIMdata develops an initial survey to capture the information described in the Research Goals. This first survey provides initial lists of items to be selected and ranked, and will allow for additional user entered items. CIMdata posts survey online, and offers to provide a document if necessary.
5. Research participants complete and return their survey responses.

Note: After the initial survey responses were received and analyzed, CIMdata had originally planned to develop a second survey with a consolidated list of initial and user entered items to be reconsidered, selected and ranked. However, in contrast to the experience with the Phase 1 research survey, respondents did not add "Other" items to the initial list provided in this Phase 2 research survey. As a result, the project plan was modified to eliminate the second survey and to instead increase the number and depth of follow on interviews.

6. After the surveys are completed, CIMdata conducts interviews with respondents to clarify and gather nuances related to their responses.

Analysis

7. The CIMdata team consolidates and analyzes responses from the survey to produce representations of current state and characterization of the relationships between advanced CAD capabilities and the integrations and standards that enable downstream consumption of the CAD data.
8. CIMdata develops observations, conclusions, and recommendations based on analysis of survey and interview results.

Final Report

9. CIMdata develops a full draft report on the findings, as well as a MS PowerPoint summary presentation.
10. CIMdata submits the draft report to the Members for their review and comment.
11. CIMdata incorporates the comments and publishes a final Report to the Members.
12. As a "thank-you" for participating, CIMdata e-mails to the research participant companies a custom report containing their survey response and its comparison to the overall aggregate response of all respondents.

Advanced CAD Capabilities Direction Statement

13. CIMdata drafts a direction statement on the subject of advanced CAD capabilities usage and standards, supported by the results of this research, that the members can use to influence the solution providers as well as their supply chains.
14. CIMdata submits the draft direction statement to the Members for their review and comment.
15. CIMdata revises the draft direction statement based on member comments.

INFORMATION GATHERING

Survey

The survey consisted of six areas related to advanced CAD capabilities and how they are used within A&D organizations. A seventh area was included to gather information related to technology upgrades and LOTAR.

- Parts A and B were used to identify which advanced CAD capabilities had the highest value and most severe problems
- Part C identified where downstream use was occurring and where issues were occurring
- Part D assessed how data was exchanged for the items in part C
- Part E identified the types of issues that occurred when data was exchanged
- Part F identified how the issues in part E were mitigated
- Part G was a short assessment of technology upgrade and LOTAR related activities

Prior to full distribution, the survey was tested with one member and revisions were made in response to that member's feedback.

Within the survey issue severity, benefits, and volume were measured as low, medium and high. In order to get better spread on the data, a weighted ranking of Low=1, Medium=3 and High=9 was used. The data was averaged across two groupings of respondents: all Members, and all solution providers and system integrators (SP & SI). If multiple responses were received from the same company, all were included in the average.

Interviews

After a survey response was received, the respondents were scheduled for a follow up interview. Interview questions were in two categories:

- Questions regarding use of and experience with standards within the respondent's job function
- Questions regarding items that were ranked highly with the survey response

Interviews with early responders occurred before all of the survey responses were received and analyzed. As patterns became apparent from analysis of the early survey responses, later interviewees were questioned about patterns even if the patterns did not show in their response.

Participation

All members completed the survey and interviews. PTC was the only solution provider to respond. Systems integrators Accenture, IBM, and TCS responded as well. Table 1 shows which companies were invited to participate and the status of their participation.

Table 1 – Contribution of Companies Invited to Participate in Obsolescence Management Phase 2 Research

Company	Response to Invitation	Survey Status	Interview Status
Members			
Airbus	NA	Complete	Complete
Boeing	NA	Complete	Complete
Embraer	NA	Complete	Complete
Gulfstream	NA	Complete	Complete
Rolls-Royce	NA	Complete (2)	Complete (1)
Solution Providers			
Dassault Systemes	Accepted	None	
PTC	Accepted	Complete	Complete
Siemens PLM	Accepted	None	
System Integrators			
Accenture	Accepted	Complete	Complete
Capgemini	Declined		
HP	None		
IBM	Accepted	Complete (2)	Complete
TCS	Accepted	Complete	Complete
A&D Thought Leaders			
Lockheed Martin	None		
Northrop Grumman	Accepted	None	
Automotive Thought Leaders			
Caterpillar	Accepted	Complete	Complete
General Motors	None		

RESULTS AND ANALYSIS

Survey results are presented here by topic in the same logical sequence as in the survey questionnaire. The survey explored the following 7 topics:

- Special CAD capabilities that cause issues for downstream users
- Benefits of special CAD capabilities for the design team
- Downstream use of CAD data

- Data exchange methods
- Data exchange issues
- Mitigation methods
- Software upgrades and long term archiving

Responses have been summarized within two groups of respondents

- Member responses, of which there were 6 responses from 5 members
- Solution Provider & System Integrators (SP & SI), of which there were 5 responses from 4 companies

The response summary groups are large enough to provide anonymity to the individual respondents. For most topics the results are ranked from the perspective of the members, with the results from the SP & SI respondents shown alongside as a contrasting perspective.

To facilitate analysis, QFD type scoring was applied to the subjective "Low", "Medium", and "High" responses to survey questions. A response of "Low" was converted to 1, "Medium" to 3 and "High" to 9.

Part A: Special CAD Capabilities that Cause Issues for Downstream Users

In Part A of the survey, a list of CAD software capabilities that are commonly used in 3D model-based design within CAD software applications was presented. Respondents were requested to indicate whether the capability was available within their company's CAD solution, and if usage of the capability was allowed. They were then asked to rate the severity of downstream issues caused by use of this capability. Table 2 shows the top 5 ranked CAD capabilities, as rated by member respondents for the severity of issues their use causes for downstream users. SP & SI scores for these CAD capabilities and for the others of their top 5 are presented for comparison.

Table 2 – CAD Capabilities that Cause the Most Severe Downstream Issues (ranked by severity of issue score)

Member Rank	CAD Capability	Member Score	SP & SI Score
1	PMI	6.7	- -
2	Assembly level feature	6.5	- -
3	Routed systems	4.7	3.0
4	Surface types	4.2	2.6
5	Assembly configurations	4.2	- -
- -	Constraints between models	- -	4.2
- -	Multiple bodies in a single file	- -	4.2
- -	Complex blends	- -	2.6

Severity of Issues: 1 – Low 3 – Medium 9 – High

Observations

There is some discrepancy between the perspectives of the members and SP & SI respondents. This is partially attributed to the fact that the SP & SI respondents were typically CAD/CAE/Design experts and did not appear to have much experience with manufacturing and broader downstream process related issues.

The member respondents focused on higher level process related issues that align more with manufacturing including Product & Manufacturing Information (PMI), Assembly Level Features (e.g., drill and pin after assembly), and Routed Systems (e.g., wire harness).

The SP & SI respondents focused on CAD data related issues including surface types, complex blends, and constraints between models (e.g., assembly positioning, hole mating patterns). Through the interview process, it was determined that most SP&SI respondents had deep CAD design or CAE backgrounds.

Part B: Benefits of Special CAD Capabilities for the Design Team

In Part B of the survey the same CAD software capabilities listed in Part A were presented again. This time, respondents were asked to rate the benefits provided to the design team by use of these capabilities. Table 3 presents the benefit scores alongside the severity of downstream issues scores from Table 2 above.

Table 3 also provides a count of the number of times each of these CAD capabilities was identified by respondents as being the only way to create a particular type of CAD data. PMI and Routed Systems capabilities stand out due to the complex information stored within the data types they create.

Table 3 – Level of Benefits Associated with CAD Capabilities that Cause the Most Severe Downstream Issues and the Uniqueness of those Capabilities

CAD Capability	Severity of Issues			Level of Benefits		Uniqueness *	
	Member Rank	Member Score	SP & SI Score	Member Score	SP & SI Score	Member Count	SP & SI Count
PMI	1	6.7	- -	9.0	9.0	67%	60%
Assembly level feature	2	6.5	- -	2.5	3.0	33%	40%
Routed systems	3	4.7	3.0	9.0	9.0	67%	60%
Surface types	4	4.2	2.6	8.0	9.0	0%	20%
Assembly configurations	5	4.2	- -	7.5	9.0	33%	20%
Constraints between models	- -	- -	4.2	2.3	1.0	33%	20%
Multiple bodies in a single file	- -	- -	4.2	2.7	3.0	0%	20%
Complex blends	- -	- -	2.6	7.7	9.0	0%	40%

Severity of Issues: 1 – Low 3 – Medium 9 – High
Level of Benefits: 1 – Low 3 – Medium 9 – High
* - Enables the creation of design content that is practically impossible without the capability

Observations

The members and the Solution Provider and System Integrator respondents were aligned on capability benefits, but not on the severity of issues they create. The SP & SI respondents were CAD/CAM/CAE focused rather than business process focused.

PMI and Routed Systems are unique capabilities that provide significant value while cutting across multiple areas of an organization.

PMI

Product Manufacturing Information (PMI), the representation of annotation and tolerances directly on the 3D model, was identified as the top capability in both benefits and severity of issue. 3D PMI data is important for several reasons, including:

- Process change–Tolerances are assigned associatively to geometric objects as an engineering function as the model is created rather than as a drafting function after the design is nearly complete. This enables stack up studies and manufacturing planning to be completed earlier in the design process.
- Drawing elimination–Views of annotations and tolerances are visible directly on the 3D model so formal 2D drawing creation can be reduced and sometimes eliminated. Lower cost viewers improve access to the 3D model and its associated PMI data.
- Machine to Machine (or software application to software application) communication–Since PMI is reasonably well supported by standards it is currently being leveraged in several areas including:

  - View and Markup
  - Tolerance stack analysis
  - Manufacturing planning

The major issue with PMI also occurs with paper-based geometric dimensioning and tolerancing (GD&T). Certain annotation and tolerance feature representations can be interpreted in more than one way, leading to ambiguity, confusion and rework. PMI authoring modules have functions to validate data, but they are not 100% accurate.

Assembly Level Features

While Assembly Level Features can cause severe issues, neither members nor SP & SI respondents rated the benefits as high. Proper management of assembly level features is necessary to get a complete digital representation of a configuration over the lifecycle but rating benefits as medium-low seems appropriate, because the physical implementation of the assembly level feature is managed reasonably well within manufacturing process documentation.

Surface Types

The Surface Types capability is interesting as shape is so critical in aerospace due its impact on simulation and manufacturing. This capability is rated medium-high for severity of downstream issues due to legacy surface data created with proprietary algorithms, i.e., data obsolescence. As surface modeling has standardized on NURBS representation, the proprietary data will eventually age out and the issues will reduce and ultimately disappear.

Routed Systems

Routed Systems capability typically supports wiring and hydraulic system data. Standard components (wire, connectors, electronic devices or fittings, tubing, and hydraulic devices) are connected in 3D paths that define systems that perform a function. Key capabilities of routed system capability include

- Defining type of material needed to connect devices
- Calculating run lengths of wire or tubing
- Enabling the generation of harness manufacturing tooling such as form boards
- Managing component BOMs

As products become more electronics and software driven, routed systems capability is critical to generating a complete digital representation of a product which is necessary to ensure smooth production.

Assembly Configurations

Assembly Configurations provides the capability to represent alternative component configurations or alternative component positioning. The alternate component may be the same item in a different state, such as a hose in its free state or installed state, or a similar component with a different item number needed to satisfy a slightly different requirement. CAD assembly applications can manage multiple configurations at the same time within a CAD session, and communicate the configuration data to PDM and downstream BOM and other configuration dependent applications. As a consequence, these capabilities provide high benefit. However, variability in how they are applied can cause significant issues with interpretation by downstream users.

Part C: Downstream use of CAD data

In Part C of the survey, a list of downstream Discipline/Application combinations that commonly consume CAD models and or data from CAD models was presented. The combinations were sequenced roughly in the order that they occur in the product lifecycle. Respondents were requested to indicate the volume of CAD data consumed, rate the severity of issues associated with the data, and indicate whether customizations or other measures have been put in place to mitigate the issue. Summary results for each of the 22 downstream Discipline/Application combinations are presented in Table 4 below.

Discipline/Application combinations that are of greatest concern, or conversely that offer the greatest potential for improvement, are highlighted in bold font. These 10 points of downstream consumption are subject to relatively high severity issues (rating greater than 4.0), often without mitigations in place (less than 50%).

Table 4 – Assessment of Downstream Uses of CAD Data by Business Disciplines and Applications

Downstream User		Members Score			SPs & SIs Score		
Business Discipline	Application	Volume of Data	Severity of Issues	Mitigation (%)	Volume of Data	Severity of Issues	Mitigation (%)
Engineering Analysis	**FEA (Finite Element Analysis)**	**5.0**	**5.0**	**33%**	**4.8**	**5.6**	**50%**
Engineering Analysis	**CFD (Computational Fluid Dynamics)**	**4.0**	**5.0**	**33%**	**3.0**	**5.4**	**33%**
Engineering Analysis	**Other CAE**	**4.0**	**4.0**	**33%**	**4.2**	**5.4**	**33%**
Systems Engineering	Linkage of RFLP (Requirement, Functional, Logical, Physical)	1.0	1.5	0%	2.0	2.0	0%
Engineering Design	Digital mockup	5.0	3.7	60%	4.8	4.8	100%
Engineering Design	Faceting/simplification	6.2	4.8	100%	1.4	1.4	50%
Engineering Design	**Interference Detection**	**8.0**	**4.2**	**67%**	**3.0**	**5.4**	**33%**
Electrical / Electronic Engineering	**3D Geometry integration**	**7.5**	**6.2**	**60%**	**1.8**	**3.0**	**33%**
Mechanical Design Collaboration	**Data Exchange for Collaboration**	**6.2**	**3.0**	**40%**	**4.4**	**4.4**	**50%**
Manufacturing Engineering	Animation	4.0	4.0	50%	1.4	1.4	33%
Manufacturing Engineering	**Toolpaths: milling, turning**	**7.7**	**5.2**	**50%**	**3.2**	**4.4**	**100%**
Manufacturing Engineering	Stamping	2.2	2.5	33%	2.0	2.0	50%
Manufacturing Engineering	Molds & Dies	2.0	2.0	50%	2.6	3.8	33%
Manufacturing Engineering	Manufacturing planning	7.5	3.7	40%	1.2	1.2	0%
Manufacturing Engineering	Additive manufacturing	2.2	3.8	40%	1.2	1.2	0%
Procurement	**Collaboration**	**3.5**	**4.7**	**50%**	**2.6**	**3.8**	**33%**
Test Engineering	Data linkage to requirements	2.5	1.0	33%	1.2	0.8	0%
Quality Engineering	**Linkage of 3D geometry to quality applications e.g., inspection, FMEA, etc.**	**7.0**	**5.5**	**67%**	**1.2**	**2.4**	**0%**
Service Engineering	Maintenance Planning	6.5	4.2	60%	0.8	1.2	0%
Service Engineering	**Technical publications**	**8.0**	**5.2**	**67%**	**1.4**	**1.4**	**33%**
Marketing	Rendering for publications	2.3	1.3	25%	0.8	0.8	50%
Finance	Costing	2.0	1.0	50%	0.8	1.2	0%

Volume of Data: 1 – Low 3 – Medium 9 – High
Severity of Issues: 1 – Low 3 – Medium 9 – High

Observations

Of the 22 downstream Discipline/Application combinations, 10 experience issues rated medium-high to high. Issues, realized or potential, are more severe in core product disciplines such as Engineering Analysis, Design, Manufacturing, Procurement, Quality and Service. These are also the disciplines with the highest volumes of CAD data usage.

Interestingly, and as might be expected, the downstream disciplines with highest volumes of CAD data usage and with potentially medium-high to high severity issues have a high occurrence of mitigation measures in place. These disciplines include:

- Electrical/electronic engineering
- Manufacturing engineering for tool paths (i.e. CAM)

- Quality engineering
- Service engineering technical publications

Other core product disciplines with medium-high to high volumes of CAD data usage and with potentially medium-high severity issues have a low occurrence of mitigation measures in place. These disciplines include:

- Engineering analysis
- Mechanical design collaboration
- Manufacturing engineering

The low occurrence of mitigation methods may be due to the high number and diversity of applications utilized within these disciplines. These business areas would benefit from future investment in development of effective mitigation methods.

Peripheral areas such as marketing and finance utilize CAD data, but, as the respondents report, the volume is low and the issues are not severe. These ratings should be validated as none of the respondents worked directly in these areas.

Systems Engineering utilization of CAD data was rated as low volume, with low severity of issues experienced. These results were surprising, given the high level of interest in the subject of systems engineering within the Members and Solution Provider organizations. It would appear that systems engineering, in current practice, is still very much a separate discipline and not well integrated into the aircraft program lifecycle processes.

Part D: Data Exchange Methods

In Part D of the survey, a list of downstream Discipline/Application combinations that commonly consume CAD models and or data from CAD models was presented once more. This time, respondents were requested to identify the data exchange methods (integration technology) used to exchange data for consumption by a downstream application. Multiple selections were allowed for each Discipline/Application pair. Choices for data exchange methods included:

- Synchronous integration with no translation
- Synchronous integration with standards based translation
- Asynchronous integration with no translation
- Asynchronous integration with standards based translation
- Manual with no integration and no translation

Member responses are summarized in Table 1Table 5. Solution Provider and System Integrator responses are summarized in Table 6.

Table 5 – Prevalence of Data Exchange Methods for CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence) from the Members' Perspective

Downstream User		Data Exchange Methods (% Occurrence)				
		Members Responses				
		Synchronous		Asynchronous		Manual
Business Discipline	**Application**	**Native**	**Standards-based**	**Native**	**Standards-based**	**Native**
Engineering Analysis	FEA (Finite Element Analysis)	17%	17%	50%	33%	33%
Engineering Analysis	CFD (Computational Fluid Dynamics)	17%	17%	50%	33%	33%
Engineering Analysis	Other CAE	17%	17%	50%	33%	33%
Systems Engineering	Linkage of RFLP (Requirement, Functional, Logical, Physical)	25%	25%	50%	25%	25%
Engineering Design	Digital mockup	80%	40%	20%	0%	0%
Engineering Design	Faceting/simplification	40%	40%	0%	20%	40%
Engineering Design	Interference Detection	33%	50%	0%	0%	17%
Electrical / Electronic Engineering	3D Geometry integration	40%	60%	0%	20%	0%
Mechanical Design Collaboration	Data Exchange for Collaboration	40%	20%	60%	60%	20%
Manufacturing Engineering	Animation	50%	25%	50%	25%	25%
Manufacturing Engineering	Toolpaths: milling, turning	33%	17%	33%	33%	17%
Manufacturing Engineering	Stamping	33%	33%	0%	0%	67%
Manufacturing Engineering	Molds & Dies	50%	50%	50%	50%	50%
Manufacturing Engineering	Manufacturing planning	20%	40%	40%	40%	0%
Manufacturing Engineering	Additive manufacturing	40%	20%	20%	40%	60%
Procurement	Collaboration	25%	50%	50%	50%	50%
Test Engineering	Data linkage to requirements	33%	0%	0%	0%	33%
Quality Engineering	Linkage of 3D geometry to quality applications e.g., inspection, FMEA, etc.	17%	17%	17%	17%	33%
Service Engineering	Maintenance Planning	20%	0%	0%	40%	40%
Service Engineering	Technical publications	17%	17%	33%	50%	33%
Marketing	Rendering for publications	25%	0%	0%	25%	100%
Finance	Costing	0%	0%	50%	50%	0%

Table 6 – Prevalence of Data Exchange Methods for CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence) from the Solution Providers' and System Integrators' Perspective

Downstream User		Data Exchange Methods (% Occurrence)				
		SPs & SIs Responses				
		Synchronous		Asynchronous		Manual
Business Discipline	Application	Native	Standards-based	Native	Standards-based	Native
Engineering Analysis	FEA (Finite Element Analysis)	40%	0%	20%	20%	0%
Engineering Analysis	CFD (Computational Fluid Dynamics)	25%	25%	25%	25%	0%
Engineering Analysis	Other CAE	50%	0%	0%	25%	0%
Systems Engineering	Linkage of RFLP (Requirement, Functional, Logical, Physical)	67%	0%	0%	0%	33%
Engineering Design	Digital mockup	80%	0%	20%	20%	0%
Engineering Design	Faceting/simplification	100%	0%	0%	0%	0%
Engineering Design	Interference Detection	100%	0%	0%	0%	0%
Electrical / Electronic Engineering	3D Geometry integration	100%	0%	0%	0%	0%
Mechanical Design Collaboration	Data Exchange for Collaboration	40%	20%	20%	20%	0%
Manufacturing Engineering	Animation	25%	0%	25%	25%	25%
Manufacturing Engineering	Toolpaths: milling, turning	40%	0%	20%	0%	20%
Manufacturing Engineering	Stamping	67%	0%	0%	0%	33%
Manufacturing Engineering	Molds & Dies	50%	0%	25%	0%	0%
Manufacturing Engineering	Manufacturing planning	67%	0%	33%	0%	0%
Manufacturing Engineering	Additive manufacturing	67%	0%	33%	0%	0%
Procurement	Collaboration	25%	25%	25%	25%	0%
Test Engineering	Data linkage to requirements	100%	0%	0%	0%	0%
Quality Engineering	Linkage of 3D geometry to quality applications e.g., inspection, FMEA, etc.	100%	0%	0%	0%	0%
Service Engineering	Maintenance Planning	67%	0%	33%	0%	0%
Service Engineering	Technical publications	25%	0%	25%	0%	50%
Marketing	Rendering for publications	33%	0%	0%	33%	33%
Finance	Costing	25%	0%	25%	0%	50%

While it would be helpful for comparison of SP & SI responses and member responses to display them side by side, there is simply too much data. Presenting the complete results in two tables was the only feasible option.

To provide comparisons between the perspectives of members and SP & SIs, results were summarized across all Discipline/Application combinations. Those results were further summarized to provide insight into two aspects of data exchange: the degree of automation, and the data exchange format. The two perspectives on the degree of data exchange automation are presented in Figure 2.

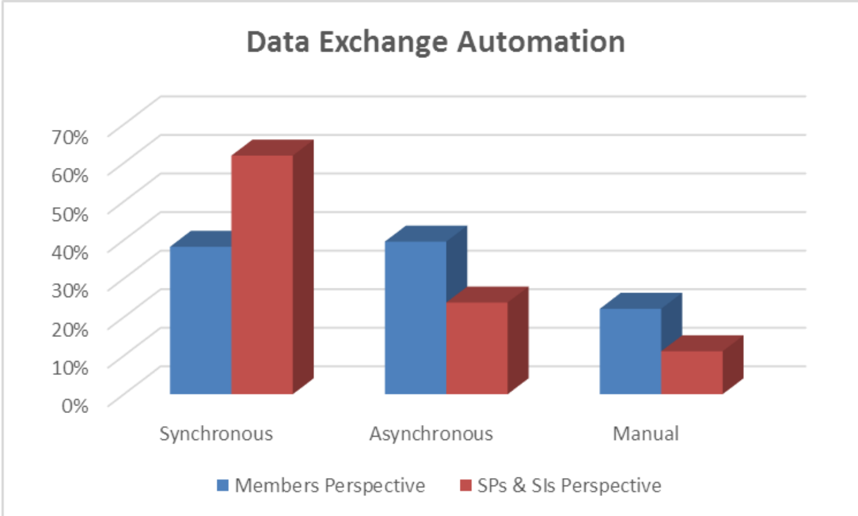


Figure 2 – Prevalence of Data Exchange Automation for CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

While the members responded that synchronous and asynchronous data exchange are equally prevalent, the SP & SIs responded that synchronous is twice as prevalent as asynchronous. Overall, manual data exchange is put at 10-20%.

The two perspectives on prevalence of data exchange formats are presented Figure 3.

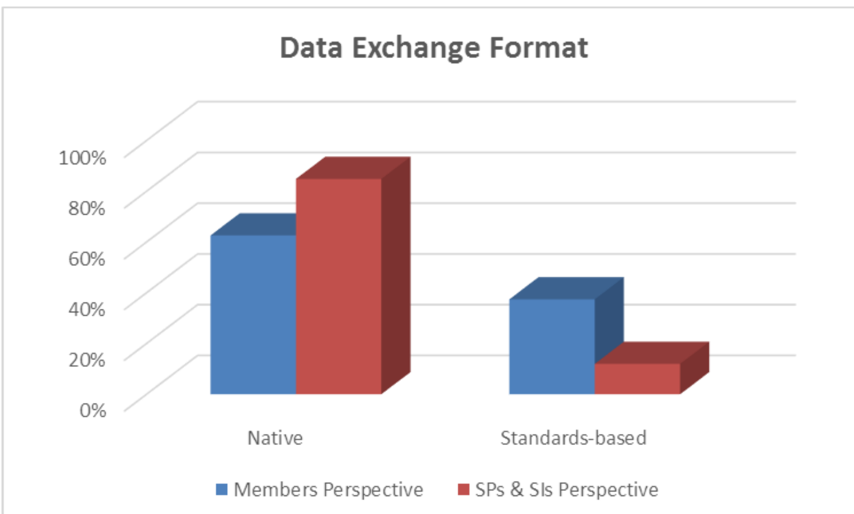


Figure 3 – Prevalence of Data Exchange Formats for CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

While members assess the split between native and standards-based formats for data exchange at 60-40, the SP & SI respondents assess this split at 80-20.

Observations

Data Exchange Automation

Analysis of the survey responses reveals that the vast majority (80-90%) of CAD data exchanges for consumption by downstream applications is automated.

The SP & SI assessment that a higher portion of CAD data exchanges are synchronous is significant, and not readily explained. It may be nothing more than a positive bias to the perspective of someone removed from daily execution of the process vs. someone immersed in the daily operation.

For the 10 to 20% of exchanges that are still manual, there is significant opportunity for error. Manual data extraction and reentry carries with it an inherent error rate. Manual data exchange is asynchronous by nature, which means the data in the consuming downstream application is always out of date, but what is worse is that the time discrepancy between source and consuming applications' versions of the data is variable and often unknown.

Data Exchange Format

The SP & SI assessment that a higher portion of CAD data exchanges are in native format may be because SP & SI respondents were typically CAD/CAE/Design experts and did not appear to have much experience with manufacturing and broader downstream process related issues.

Part E: Data Exchange Issues

In Part E of the survey, the same list of downstream Discipline/Application combinations that consume CAD models and or data from CAD models was presented. This time, the respondents were requested to identified the types of data exchange issues that occur while exchanging data for consumption by the downstream application. Multiple selections were allowed for each Discipline/Application pair. Choices for data exchange issues included:

- Data cannot be fully represented in target system
- Data cannot be accessed from source system
- Data cannot be bi-directionally updated
- Integration technology cannot support required data transformation
- Data is not clean or consistent in source system

Member and SP & SI responses are summarized in Table 7.

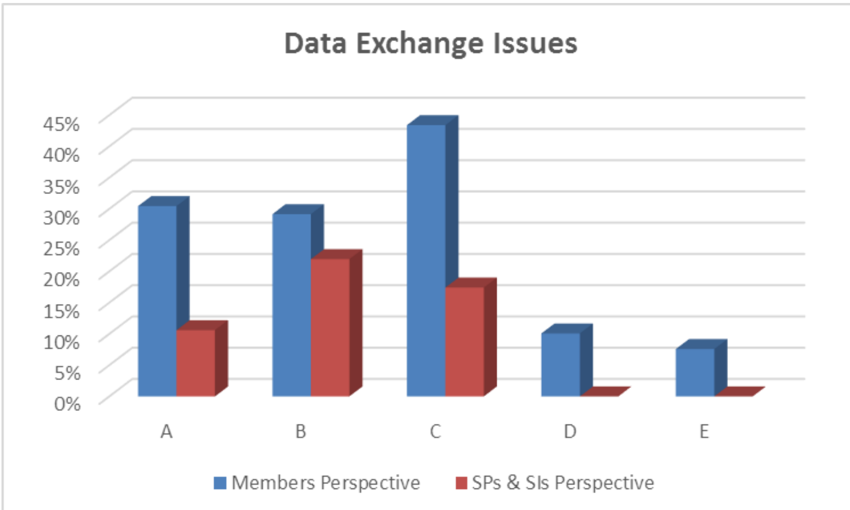
Table 7 – Prevalence of Data Exchange Issues that Impact CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

Downstream User		Data Exchange Issues (% Occurrence)									
		Members Responses					SPs & SIs Responses				
Business Discipline	Application	A	B	C	D	E	A	B	C	D	E
Engineering Analysis	FEA (Finite Element Analysis)	17%	33%	67%	0%	0%	0%	33%	33%	0%	0%
Engineering Analysis	CFD (Computational Fluid Dynamics)	17%	17%	67%	0%	0%	0%	33%	33%	0%	0%
Engineering Analysis	Other CAE	17%	17%	67%	17%	0%	0%	33%	0%	0%	0%
Systems Engineering	Linkage of RFLP (Requirement, Functional, Logical, Physical)	50%	50%	50%	0%	0%	0%	50%	0%	0%	0%
Engineering Design	Digital mockup	20%	20%	40%	0%	0%	0%	33%	0%	0%	0%
Engineering Design	Faceting/simplification	20%	60%	40%	20%	20%	0%	50%	0%	0%	0%
Engineering Design	Interference Detection	17%	33%	17%	0%	0%	0%	33%	0%	0%	0%
Electrical / Electronic Engineering	3D Geometry integration	40%	20%	40%	0%	0%	0%	33%	0%	0%	0%
Mechanical Design Collaboration	Data Exchange for Collaboration	40%	40%	40%	20%	40%	0%	33%	0%	0%	0%
Manufacturing Engineering	Animation	25%	25%	50%	0%	0%	0%	33%	33%	0%	0%
Manufacturing Engineering	Toolpaths: milling, turning	17%	17%	33%	0%	17%	0%	0%	33%	0%	0%
Manufacturing Engineering	Stamping	33%	33%	67%	0%	0%	0%	0%	33%	0%	0%
Manufacturing Engineering	Molds & Dies	50%	50%	100%	0%	0%	0%	0%	50%	0%	0%
Manufacturing Engineering	Manufacturing planning	20%	20%	40%	20%	20%	0%	0%	0%	0%	0%
Manufacturing Engineering	Additive manufacturing	40%	20%	40%	0%	0%	0%	0%	50%	0%	0%
Procurement	Collaboration	50%	25%	25%	25%	0%	33%	33%	0%	0%	0%
Test Engineering	Data linkage to requirements	33%	33%	33%	0%	0%	50%	0%	0%	0%	0%
Quality Engineering	Linkage of 3D geometry to quality applications e.g., inspection, FMEA, etc.	17%	17%	33%	33%	33%	0%	0%	0%	0%	0%
Service Engineering	Maintenance Planning	40%	20%	40%	20%	20%	50%	0%	50%	0%	0%
Service Engineering	Technical publications	33%	17%	17%	17%	17%	33%	33%	33%	0%	0%
Marketing	Rendering for publications	25%	25%	50%	0%	0%	0%	50%	0%	0%	0%
Finance	Costing	50%	50%	0%	50%	0%	67%	0%	33%	0%	0%

Data Exchange Issues: A-Data cannot be fully represented in target system
B-Data cannot be accessed from source system
C-Data cannot be bi-directionally updated
D-Integration technology cannot support required data transformation
E-Data is not clean or consistent in source system

The members and the SP & SIs respondents took different approaches when answering questions in this part of the survey. Members indicated which Discipline/Application pairs are prone to data exchange issues, and then for each indicated pair designated one or more issue of concern, sometimes associating multiple issues to a single Discipline/Application pair. As a result, the total of occurrences across all issues noted in the members' response is often greater than 100%. SP & SI respondents also indicated which Discipline/Application pairs are prone to data exchange issues, but then for each indicated pair might or might not designate an issue of concern. As a result, the total across all issues noted in the SP & SIs' response is often less than 100%. This difference in response approach makes comparison between the two perspectives difficult.

To provide visibility to trends in the data and comparisons between the perspectives of members and SP & SIs, results were summarized across all Discipline/Application combinations. The summary of data exchange issue occurrences from member vs. SP & SI perspectives is presented in Figure 4 below.



Data Exchange Issues: A-Data cannot be fully represented in target system
B-Data cannot be accessed from source system
C-Data cannot be bi-directionally updated
D-Integration technology cannot support required data transformation
E-Data is not clean or consistent in source system

Figure 4 – Prevalence of Data Exchange Issues that Impact CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

The difference between the two perspectives, manifest in the heights of the bars and the summation of occurrences of the various data exchange issues, has been explained above. Allowing for these distortion of the results, there are still other significant differences. The set of issues considered relevant by the SP & SI respondents is narrower. This group attributes concern only to those issues specific to the CAD application, whereas the member respondents consider integrations and operational factors to be significant.

Observations

Cannot Bi-directionally Update CAD Data

The highest ranking data exchange issue identified by members was inability to bi-directionally update data. While CAD application software has had associativity capability for many years, it is usually within an application rather than across different applications and is at a very granular data level. From a high level, this can be thought of as a complex master data problem. The level of detail that needs to be associative (e.g.

individual parameters or dimensions on a geometric feature across all solutions that can access the data) is daunting from an enterprise perspective. Another way to consider the issue is "should a downstream user be able to change data?" For example, NC programmers may want to change the product geometry to improve manufacturability, but do they really have the knowledge to fully assess the impact of the change? They certainly should be able to request the change, but in most cases should not be able to change data.

Cannot Fully Represent Data in the Target System

Inability to fully represented CAD data in the target system is a significant issue. This issue can have two manifestations. Either the target application cannot fully understand the data model from the source application, or the target application cannot reference the specific data it needs without being encumbered with extraneous data in the CAD model. For example, a cost modeling application may only need to extract the volume and material attributes of a 3D CAD model rather than the geometry and attributes.

The SP & SI rating of this issue was proportionately lower, likely due to the respondents' lack of experience outside CAD/CAM/CAE.

Cannot Access Data from the Source System

Inability to access data from the source CAD application has many possible causes. Security and infrastructure are common issues, but more complex data related issues can also be involved. Many of the causes of this issue can be addressed in a straightforward manner.

Part F: Mitigation Methods

In Part F of the survey, the same list of downstream Discipline/Application combinations that consume CAD models and or data from CAD models was presented again. This time, the respondents were requested to specify whether customizations or other mitigation measures have been put in place to address issues associated with exchange of data for consumption by the downstream Discipline/Application pairs. Choices for mitigation actions included:

- Manual procedures to correct data
- Custom automation to correct data
- Don't allow special capability to be used
- Don't have issue
- Don't address

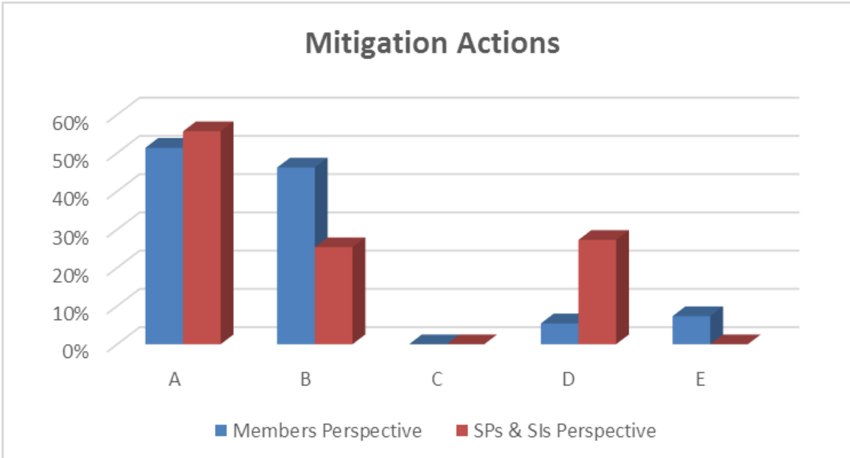
Summary results for each of the 22 downstream Discipline/Application combinations are presented in Table 8 below.

Table 8 – Prevalence of Mitigation Actions to Counter Data Exchange Issues that Impact CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

Downstream User		Mitigation Actions (% Occurance)									
		Members Responses					SPs & SIs Responses				
Business Discipline	Application	A	B	C	D	E	A	B	C	D	E
Engineering Analysis	FEA (Finite Element Analysis)	67%	50%	0%	0%	0%	75%	0%	0%	25%	0%
Engineering Analysis	CFD (Computational Fluid Dynamics)	67%	50%	0%	0%	0%	67%	0%	0%	33%	0%
Engineering Analysis	Other CAE	67%	50%	0%	0%	0%	33%	0%	0%	33%	0%
Systems Engineering	Linkage of RFLP (Requirement, Functional, Logical, Physical)	50%	25%	0%	0%	0%	50%	0%	0%	50%	0%
Engineering Design	Digital mockup	40%	40%	0%	20%	20%	75%	0%	0%	25%	0%
Engineering Design	Faceting/simplification	60%	60%	0%	0%	0%	100%	0%	0%	50%	0%
Engineering Design	Interference Detection	33%	50%	0%	0%	17%	67%	0%	0%	33%	0%
Electrical / Electronic Engineering	3D Geometry integration	80%	40%	0%	0%	0%	67%	0%	0%	33%	0%
Mechanical Design Collaboration	Data Exchange for Collaboration	60%	60%	0%	0%	0%	25%	50%	0%	25%	0%
Manufacturing Engineering	Animation	50%	25%	0%	25%	0%	67%	0%	0%	33%	0%
Manufacturing Engineering	Toolpaths: milling, turning	50%	33%	0%	17%	0%	50%	25%	0%	25%	0%
Manufacturing Engineering	Stamping	67%	33%	0%	33%	0%	50%	0%	0%	50%	0%
Manufacturing Engineering	Molds & Dies	100%	50%	0%	0%	0%	67%	33%	0%	33%	0%
Manufacturing Engineering	Manufacturing planning	60%	60%	0%	0%	0%	50%	0%	0%	50%	0%
Manufacturing Engineering	Additive manufacturing	80%	40%	0%	0%	0%	50%	50%	0%	50%	0%
Procurement	Collaboration	25%	50%	0%	0%	25%	67%	67%	0%	0%	0%
Test Engineering	Data linkage to requirements	25%	50%	0%	0%	25%	50%	50%	0%	0%	0%
Quality Engineering	Linkage of 3D geometry to quality applications e.g., inspection, FMEA, etc.	25%	50%	0%	0%	25%	50%	0%	0%	50%	0%
Service Engineering	Maintenance Planning	25%	50%	0%	0%	25%	0%	100%	0%	0%	0%
Service Engineering	Technical publications	25%	50%	0%	0%	25%	67%	33%	0%	0%	0%
Marketing	Rendering for publications	75%	50%	0%	25%	0%	50%	50%	0%	0%	0%
Finance	Costing	0%	50%	0%	0%	0%	50%	100%	0%	0%	0%

Mitigation Actions:
A-Manual procedures to correct data
B-Custom automation to correct data
C-Don't allow special capabilities to be used
D-Don't have an issue
E-Don't address

To provide visibility to trends in the data and comparisons between the perspectives of members and SP & SIs, results were summarized across all Discipline/Application combinations. The summary of mitigation action occurrences from member and SP&SI perspectives is presented in Figure 5 below.



Mitigation Actions: A-Manual procedures to correct data
B-Custom automation to correct data
C-Don't allow special capabilities to be used
D-Don't have an issue
E-Don't address

Figure 5 – Prevalence of Mitigation Actions to Counter Data Exchange Issues that Impact CAD Data Usage by Downstream Business Disciplines and Applications (% Occurrence)

Observations

The members' and the SP & SI respondents' align in their assessment that manual procedures are applied about half the time to mitigate data exchange issues.

From the members' perspective, custom automation is applied nearly half the time to mitigate data exchange issues.

It is interesting to note the both the members and SP & SI respondents indicated that disallowing use of special capabilities is never pursued as a remedy to data exchange issues. In contrast, this is a method frequently applied in the automotive and other industries.

Part G: Upgrades and Long-Term Archiving

In part G of the survey, practices and perceived impacts of technology obsolescence and managed upgrades were explored.

Members and SP & SI respondents were asked to indicate the severity of their companies' experience with data loss during a range of technology refresh scenarios. Results are shown in Figure 6 below.

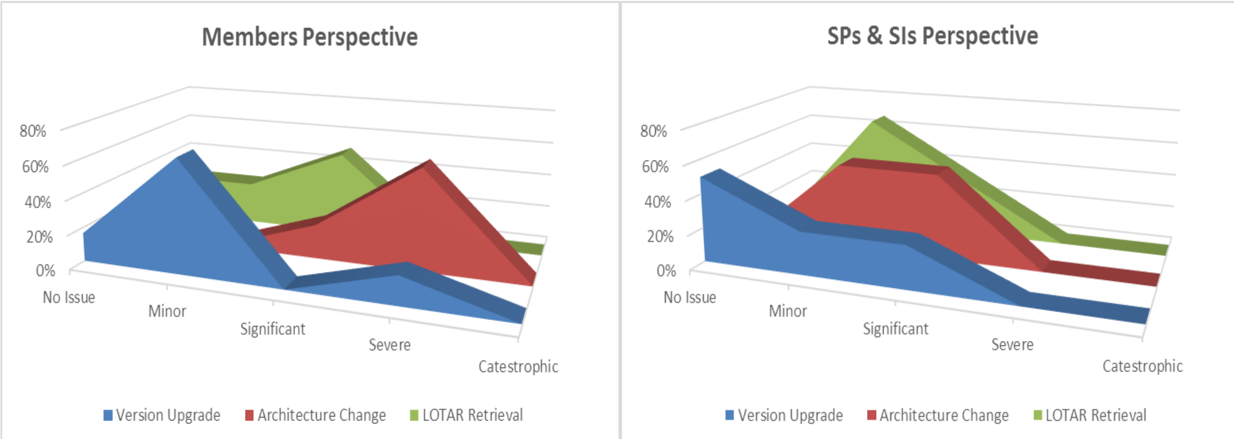


Figure 6 – Severity of Data Loss Experienced During Various Technology Refresh Events (% Occurrence)

Perceptions of the members and of the SP & SI respondents vary significantly. Whereas some of the members assessed their experience in certain scenarios as severe. The SP & SI respondents assessed the issues to be minor and sometimes significant, but never severe.

Members were also asked whether their company has defined a long-term data archival and retrieval (LOTAR) strategy, and whether that strategy has been implemented and tested. SP & SI respondents were asked the same questions with respect to their A&D customers. The summary results are presented in Figure 7.

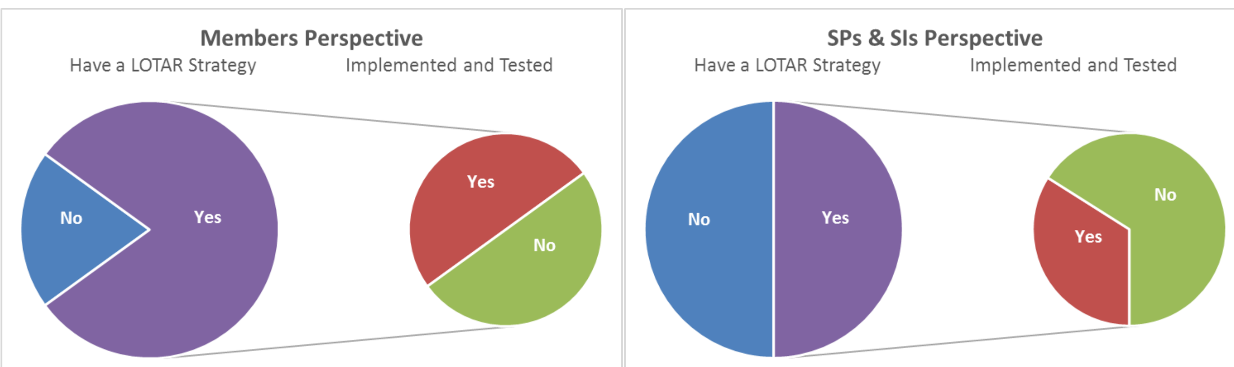


Figure 7– Prevalence of LOTAR Strategies and Implementations within Industry (% Occurrence)

The members' and the SP & SI respondents' assessments regarding status of LOTAR within A&D are fairly well aligned. Interestingly, the SP & SI respondents' assessment is slightly more negative than the members' assessment.

Observations

Technology Refresh

Figure 6 shows the difference in perspective between the members and the SP & SI respondents on various technology refresh events. Version upgrades (the equivalent of moving from CATIA V5R2013 to CATIA V5R2014) were generally uneventful for both groups of respondents.

The effect of an Architecture change event (the equivalent of moving from CATIA V4 to V5) was quite different. Members' rated issues as Severe, while SP & SI respondents rated issues between Minor and Significant. Finally, members experienced Significant issues when accessing LOTAR data, while SP & SI respondents rated issues for this scenario as Minor. Some of this difference may be due to respondents' professional experience.

LOTAR

The results of questions regarding LOTAR strategy and implementation status are presented in Figure 7. In general, the members feel they are further along in implementing and testing LOTAR strategies than the SP & SI respondents' assessment of the state of the A&D industry.

Within the interviews, it was confirmed that classic drawing or PDF based archives work well. None of those interviewed was comfortable that 3D model based LOTAR has been fully achieved. Gulfstream is one company on a very short list to have spoken publicly about their successful implementation of Type data to support LOTAR and certification.

A major consideration in defining and implementing a LOTAR strategy is establishing the use cases for LOTAR data. Validation requirements are much easier to support that design modification.

Use of Standards

During the interview process, respondents were questioned regarding Standards usage, their strength and shortcomings, the organization attitude toward standards, the rate of progress, and prognosis. Responses collected from members, solution providers and systems integrators reflect a range of experiences.

Current Practices

Almost all internal data exchange is in proprietary (i.e. native) format processed through direct translators. A notable exception is one member's use of STEP and IGES for exchange of CAD geometry into Simulation applications.

Most external data exchange is in native format, but the volume of standards-based data exchange between OEMs and their supply chains is significant and growing. One member regularly exchanges CAD data externally using 3D PDF and a basic subset of STEP AP242; results are satisfactory but fall short of a complete model based definition (MBD).

It was noted that STEP based translations often fail on very large assemblies. Other issues were noted regarding metadata quality. It was stated that process refinements and training could effectively address most of these issues.

A practice that is common to many OEMs is storage of CAD files in native and STEP formats within the OEM's design repository. One member maintains an internal Type Design Repository with STEP and native versions of all CAD models.

It was reported that several OEMs collaborate and exchange CAD data with their supply chains using JT format.

Future Trends

The general attitude toward the use of standards for data exchange is very positive. Some members have a few years' experience in production use of STEP. Others have adopted STEP as a direction and are piloting use cases.

JT is still not universally accepted. One member who currently relies on direct translation is evaluating JT as a lower cost higher performance alternative.

Members are very interested in moving to full model based definition (MBD) and consider standards to be essential to this strategy.

Another area of interest and investment is standards for MBD to support long term archive and retrieval (LOTAR) strategies. Several respondents stated that standard formats for data storage are the only option for a viable LOTAR strategy.

SUMMARY OF FINDINGS

Quality of Participation

It was intended to validate the perspectives of the members on the subject of this research by obtaining perspectives of the three major PLM software providers, at least three major systems integrators, two A&D thought leaders, and two automotive companies. CIMdata and several members individually made multiple contacts to encourage outside participants. The greatest surprise and disappointment was that after several contacts and several promises to participate, neither Dassault Systèmes nor Siemens PLM completed the survey. In the end, the combined responses from PTC, Accenture, IBM and TCS provided the researchers with an external perspective of value for the analysis.

A second important dimension of participation was the breadth of subject matter expertise of the respondents. In general, the members provided access to SMEs with backgrounds in CAD methods, data exchange and downstream use of CAD data, and LOTAR. In contrast, the solution providers and system integrator respondents had narrower backgrounds, heavily focused on CAD and CAE.

Special CAD Capabilities Benefits and Issues

The first line of inquiry was to identify CAD capabilities that cause the most severe issues for downstream consumers of the CAD data. The next was to assess the level of benefit received by the design team from utilizing these capabilities. In addition to the level of benefit, respondents were asked to note whether these capabilities enable the creation of design content that is practically impossible by other means. The result is a ranked list of CAD capabilities of greatest concern, or conversely offering the greatest opportunity for business improvement, based on a qualitative cost-benefit assessment of each. The top 5 special CAD capabilities are as follows:

- Product Manufacturing Information (PMI)
- Assembly Level Features
- Surface Types
- Routed Systems
- Assembly Configurations

Each of these five exhibits a profile that suggests a tailored strategy for business performance improvement.

PMI

Product Manufacturing Information (PMI), the representation of annotation and tolerances directly on the 3D model, was identified as the top capability in both benefits and severity of issue.

PMI data is primarily use for viewing information in place of formal drawings. In the interviews it was noted that significant effort is still expended to generate PMI views that are readable. It was also noted that some machine to machine automation is occurring by leveraging PMI data for manufacturing planning and CNC programming.

The major issue with PMI also occurs with paper-based geometric dimensioning and tolerancing (GD&T). Certain annotation and tolerance feature representations can be interpreted in more than one way, leading to ambiguity, confusion and rework. PMI authoring modules have functions to validate data, but they are not 100% accurate.

PMI was characterized as a CAD capability that provides high value to the design team while causing high severity issues downstream, and a capability for which no practical alternative exists. A potentially profitable strategy would be for members to impose design standards to eliminate ambiguity in interpretation of annotation and tolerance feature representations.

Assembly Level Features

Management of assembly level features is necessary to get a complete digital representation of a configuration over the lifecycle, but the physical implementation of the assembly level feature is managed reasonably well within manufacturing process documentation.

Assembly Level Features was characterized as a CAD capability that provides relatively low value to the design team while causing high severity issues downstream, and a capability for which practical alternatives do exist. A potentially profitable strategy would be for members to impose a prohibition on the use of this feature.

Routed Systems

Routed Systems capability typically supports wiring and hydraulic system data and is critical to generating a complete digital representation of a product. Routed Systems was characterized as a CAD capability that provides high value to the design team while causing medium-high severity issues downstream, and a capability for which no practical alternative exists. A potentially profitable strategy would be for members to establish design standard, ensure modeling tools can support FAA guidelines for CFR part 25 EWIS (Electrical Wiring Interconnect Systems)[2], as well as Step AP 212 and VDA 4968 VEC KBL to support harness exchange for manufacturing.

Surface Types

Surface Types capability is important as shape is so critical in aerospace due its impact on simulation and manufacturing. Surface Types was characterized as a CAD capability that provides high value to the design team but causes medium-high severity issues downstream, and a capability for which alternatives do exist. A potentially profitable strategy would be for members to accelerate the migration from proprietary algorithms that create non-standard surface types to modern algorithms based on NURBS.

Assembly Configurations

Assembly Configurations provides the capability to represent alternative component configurations or alternative component positioning. The alternate component may be the same item in a different state, such as a hose in its free state or installed state.

Assembly Configurations was characterized as a CAD capability that provides high value to the design team but causes medium-high severity issues downstream, and a capability for which alternatives do not exist. A potentially profitable strategy would be for members to develop standard procedures and ensure the supply chain uses these same procedures. In the longer term, work with Standards Organizations to ensure that a standard data format is defined, and work with solution providers to ensure that their CAD assembly modelers and viewers can interact bi-directionally with EBOM management solutions.

Downstream Use of CAD Data

Respondents were presented with a list of 22 downstream Discipline/Application combinations that commonly consume CAD models and or data from CAD models, and asked to indicate the volume of CAD data consumed, rate the severity of issues associated with the data, and indicate whether measures have been put in place to mitigate these issue. They reported that issues, realized or potential, are more severe in core product disciplines such as Engineering Analysis, Design, Manufacturing, Procurement, Quality and Service. These are also the disciplines with the highest volumes of CAD data usage.

In general, downstream disciplines with highest volumes of CAD data usage and with potentially medium-high to high severity issues have a high occurrence of mitigation measures in place. Three exceptions are Engineering Analysis, Mechanical Design Collaboration, and Manufacturing Engineering. This may be due to the high number and

[2] http://www.faa.gov/training_testing/training/air_training_program/job_aids/media/EWIS_job-aid_2.0_Printable.pdf

diversity of applications utilized within these disciplines. Clearly these are business areas that should be a focus for future investment in development of effective mitigation methods.

Systems Engineering utilization of CAD data was rated as low volume, with low severity of issues experienced. These results suggest that systems engineering, in current practice, is still very much a separate discipline and not well integrated into the aircraft program lifecycle processes.

Data Exchange Methods

Respondents were again presented with a list of downstream Discipline/Application combinations that commonly consume CAD models and or data from CAD models, and this time asked to indicate the data exchange methods (e.g. integration technology) used to exchange data for consumption by the downstream application. Results were summarized to provide insight into two aspects of data exchange: the degree of automation, and the data exchange format.

Analysis of the survey responses reveals that the vast majority (80-90%) of CAD data exchanges for consumption by downstream applications is automated. For the 10 to 20% of exchanges that are still manual, there is significant opportunity for error. Manual data extraction and reentry is asynchronous by nature and carries with it an inherent error rate.

Members assess the split between native and standards-based formats for data exchange at 60-40, while the SP & SI respondents assess this split at 80-20. By either assessment, the use of standards for data exchange is still only an emerging practice, despite heavy investment over decades. During follow on interviews, respondents expressed the view that direct translators work better, but standards-based solutions are desirable and their use is growing.

Data Exchange Issues

Once more, respondents were presented with a list of downstream Discipline/Application combinations that commonly consume CAD models and or data from CAD models, and this time asked to indicate which of 5 types of data exchange issues occur while exchanging data for consumption by the downstream application. To provide visibility to trends in the data and comparisons between the perspectives of members and SP & SIs, results were summarized across all Discipline/Application combinations.

Cannot Bi-directionally Update CAD Data

The highest ranking data exchange issue identified by members was inability to bi-directionally update data. This issue is most applicable to parametric 3D modeling and metadata updates. While in a WIP environment bi-directional update capability would provide some value, in a broader life cycle context, it is questionable whether a downstream user should be able to change the CAD data. A manufacturing engineer should be able to initiate a change or problem report, but should not be able to change a product model.

Cannot Fully Represent Data in the Target System

Granular access to data via a robust API will limit the need to fully represent data in target systems. Source data should be referenced. Modern standards such as Open Services for Lifecycle Collaboration (OSLC) take this approach.

Cannot Access Data from the Source System

Access to source systems should be investigated in more detail to determine root causes. Interviews indicated that some of the issue was due to administrative overhead and management of access rights.

Mitigation Methods

The same list of downstream Discipline/Application combinations that consume CAD models and or data from CAD models was presented again, and respondents were requested to specify whether customizations or other mitigation measures have been put in place to address issues associated with exchange of data. To provide visibility to trends in the data and comparisons between the perspectives of members and SP & SIs, results were summarized across all Discipline/Application combinations.

More than 90% of data exchanges need some sort of mitigation whether manual procedures or custom automation. Granular access to CAD data and PDM metadata via well-defined protocols, ideally standards-based, offers the potential to dramatically reduce the complexity of these mitigations. However, enterprise architecture will need significant enhancements in philosophy, technology and implementation for these advances to deliver a real impact.

It is of note that members and SP & SI respondents indicated that disallowing use of special capabilities is never pursued as a remedy to data exchange issues. This is in sharp contrast to the automotive industry, where it is common practice for CAD UIs to be tailored to eliminate access to functions, and for data checkers to disallow certain data types. This type of remedy should be seriously considered by the members.

Software Upgrades and Long Term Archiving

Technology Refresh

Respondents were asked to indicate the severity of their companies' experience with data loss during a range of technology refresh scenarios. Version upgrades (the equivalent of moving from CATIA V5R2013 to CATIA V5R2014) were generally assessed as uneventful. However, issues associated with architecture change (the equivalent of moving from CATIA V4 to V5) and with access to LOTAR data after a technology change were rated as Significant or Severe by the Members. In contrast, SP & SI respondents rated issues in all scenarios as only Minor or Significant, indicating a disconnect between solution providers and their user base.

LOTAR

Respondents were also asked whether their company has defined a long-term data archival and retrieval (LOTAR) strategy, and whether that strategy has been implemented and tested.

Historically, LOTAR has focused on management of 2D paper or PDF archives. The vision to implement MBD, and eventually MBSE, will require significant improvement in LOTAR strategies.

Today's reality is that many A&D companies keep legacy environments running, thereby avoiding LOTAR issues to some extent. Maintaining virtual environment based archives is possible, but it is not certain that links between data will be stable given the environment complexity. A concern beyond whether the environment will be stable and operational over time is whether, over the long-term, personnel will be available who know how to operate the applications and interpret the data. All of these environments contain custom code that is not well understood or documented. In many cases, the original author is the only repository of such knowledge and has left the company or is close to retirement. This situation will become unsustainable over the next 10 to 20 years.

Use of Standards

Standards for CAD data exchange such as STEP are rarely used internally by members. They use native data and direct translators for most internal exchanges. In many cases, the data exchange is automated within the member's PDM or PLM solution. When exchanging CAD data with suppliers, it is more common to use STEP, and sometimes IGES. JT is used for visual collaboration at some member sites.

The strength of standards-based exchange is ubiquity. The main shortcomings are in the realms of reliability and quality. Translators sometimes fail, especially on very large datasets. The quality impacts are dependent on whether a particular object type is supported and what happens when it is unsupported or only partially supported.

All respondents who were interviewed felt strongly that standards-based exchange is desirable and needed. The general sentiment expressed by the interviewees was that as long as the quality and speed of the standards-based exchange is good enough, then standards-based exchange can be used.

Standards-based exchange is commonly used within the supply chain and appears to be good enough to support most use cases. For use cases where this practice is not acceptable, staying within a solution provider's tool suite is a reasonable mitigation.

CONCLUSIONS

The intent of this project was to explore the relationships between special CAD capabilities and the integrations that enable downstream use of the data they create, and how data standards impact these integrations. The ultimate goal is to provide a base of information and insights from which the A&D Action Group can develop direction statements to guide the efforts of solution providers and standards bodies to produce more sustainable solutions. The intent has been fulfilled. Member assessment will determine to what degree the ultimate goal has been achieved.

Participation

Neither CIMdata acting on behalf of the A&D PLM Action Group, nor the members themselves acting directly, have found an effective method for securing the participation of PLM solution providers, or aerospace and automotive OEM thought leaders in the Group's research projects. For a second year, less than half of the PLM solution providers and systems integrators who were invited actually participated in the research; and this result was with many repeated invitations and encouragements.

Special CAD Capabilities Benefits and Issues

There is a relatively short list of advanced CAD capabilities that cause notable issues with downstream consumption of CAD data. These 12-15 capabilities are known and well understood by experts in the field. Each of these exhibits a profile that suggests a tailored strategy for business performance improvement.

As would be expected, there are advanced CAD capabilities that provide high value to the design team while causing high severity issues downstream, and for which there are no practical alternatives. However, there are only 2 of these:

- Product Manufacturing Information (PMI) and
- Routed Systems

With both capabilities, the data is authored within CAD applications but is used in many downstream systems providing significant benefits to the design team and also to the downstream consumer. As aircraft shapes, structures, and the manufacturing techniques to produce them advance over time, both of these advanced CAD capabilities will be even more important to support advances in product development. In addition, as in the electronics and software content of the aircraft continues to grow, wire harness engineering and design will become ever more important.

Downstream Use of CAD Data

Issues, realized or potential, are more severe in core product disciplines such as

- Engineering Analysis,
- Design,
- Manufacturing,
- Procurement,
- Quality and
- Service

These are also the downstream disciplines with the highest volumes of CAD data usage.

In general, core product disciplines have a high occurrence of mitigation measures in place. Three exceptions are Engineering Analysis, Mechanical Design Collaboration, and

Manufacturing Engineering. This may be due to the high number and diversity of applications utilized within these disciplines. These are business areas that should be a focus for future investment in development of effective mitigation methods.

Systems Engineering, these results suggest, is still very much a separate discipline and not well integrated into the aircraft program lifecycle processes.

Data Exchange Methods

The majority of integrations are at risk, and will require updating and retesting, with a technology update or an architectural change. This is because the vast majority (80-90%) of CAD data exchanges for consumption by downstream applications is automated, and the majority of data exchanges (60-80%) are in native format. Solution provider application suites are commonly made up of acquisitions and use integration technology within the provider's product line. These integrations are often incomplete and unstable release to release. Also, the customer's use cases may not align with solution provider's release validation processes.

The use of standards for data exchange is still only an emerging practice (10-20%), despite heavy investment over decades. Results of follow up interviews suggest that direct translators work better, but standards-based solutions are desirable and their use is growing.

Data Exchange Issues

There are policy issues to be resolved by the members that will impact data exchange requirements and assessment of issues associated with CAD data exchange to downstream consumers. A case in point is the member assessment of bi-directional update of CAD data as an issue of high severity. In a broader life cycle context, it is questionable whether a downstream user should be able to change the CAD data. Depending on Member policy, this may not be an issue at all.

Modern standards such as OSLC will address and diminish the issue of full representation of data from the CAD model in the target system.

Administrative overhead and management of access rights may be significant contributors to downstream data exchange issues.

Mitigation Methods

More than 90% of data exchanges need some sort of mitigation whether manual procedures or custom automation.

Granular access to CAD data and metadata including electrical/wire harness data via well-defined protocols, ideally standards-based, offers the potential to dramatically reduce the complexity of these mitigations. However, enterprise architecture will need significant enhancements in philosophy, technology and implementation for these advances to deliver a real impact.

These research results indicate that within the member companies disallowing use of special capabilities is never pursued as a remedy to data exchange issues.

Software Upgrades and Long Term Archiving

Data loss issue associated with an architecture change (the equivalent of moving from CATIA V4 to V5) and or access to legacy data stored in original native format after a technology upgrade can be severe.

The LOTAR standards community is two generations behind current industry needs. Drawing based LOTAR is well understood and supported. Model-based LOTAR is in early stages of development. LOTAR for integrating systems engineering data, especially embedded software, is in early stages of discussion.

Use of Standards

Standards-based data exchange is working in production today within the A&D supply chain and could be used to facilitate data exchange for consumption by downstream users within the OEMs. The only impediment is that direct translators are already built into the process so there is little immediate business value in changing one set of technology for another.

Direction Statements

The results of this research are sufficient to support development of a direction statement for solution providers and standards bodies regarding Product Manufacturing Information (PMI) CAD capability.

The results of this research provide strong indication but are not sufficient to support development of a direction statement for solution providers and standards bodies regarding Routed Systems CAD capability.

RECOMMENDATIONS

Direction Statements

Publish a direction statement for solution providers and standards bodies regarding Product Manufacturing Information (PMI) CAD capability, with expanded description and supporting evidence derived from this research.

Conduct additional research to achieve additional insight and evidence necessary to support a direction statement for solution providers and standards bodies regarding Routed Systems CAD capability.

Internal Improvement

Establish internal teams to review the assessment profiles of the 12-15 advanced CAD capabilities determined by this research to offer the greatest potential for business performance improvement, and define a tailored strategy for each, following the examples presented in this report.

Give special consideration, and investment, to developing mitigation methods for issues that arise with downstream use of CAD data within the Engineering Analysis, Mechanical Design Collaboration, and Manufacturing Engineering business disciplines.

Accelerate the migration of data from legacy CAD, simulation, and manufacturing applications that use proprietary algorithms for creation of non-standard surface types to modern applications that use algorithms based on NURBS.

Seriously evaluate the automotive industry practice of tailoring CAD UIs to eliminate access to some functions, and for data checkers to disallow certain data types. This type of remediation would be a powerful tool to address the issues raised by some advanced CAD capabilities.

Seriously evaluate life cycle collaboration policy and design and, in particular whether bi-direction update of CAD data is appropriate.

Drive adoption of standards internally, such as OSLC for synchronization and STEP AP242 for CAD data exchange. In cases where the standards are incomplete or lack capability, extend and flavor existing standards-based technology to meet business needs, drive vendors and standards organizations to fill gaps, and remove extensions and flavorings over time.

Engagement with Solution Providers

Drive compliance with A&D PLM Action Group direction statement regarding PMI.

Drive adoption of STEP and LOTAR standards that define machine to machine (or software application to software application) communication of semantic PMI data.

Promote support of granular access to CAD data and metadata including wire harness data based on standards.

Promote supplier support of OSLC.

Aggressively promote support of LOTAR by suppliers to accelerate development and adoption of standards that address MBD and MBSE.

Engagement with Standards Organizations and Projects

Promote incorporation of A&D PLM Action Group direction statement regarding PMI.

Promote development of standards for granular access to CAD metadata.

Promote aggressive development of OSLC standard.

Engage aggressively with LOTAR to accelerate development of standards that address MBD and MBSE, and ensure the LOTAR working groups release standards on schedule.

Research Methods

Develop new incentives for increasing participation of solution providers and aerospace and automotive industry thought leaders.

About CIMdata

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

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

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

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