PLM Global Collaboration Phase 1 Research Report

Taxonomy, Assessment and Improvement Priorities

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INTRODUCTION

Global Collaboration for the purposes of this research is defined to be comprised of data standards and work processes used for sharing and working with product data among A&D OEMs and their product design and manufacturing engineering partners and suppliers.

Within its 2014 research agenda, the A&D PLM Action Group identified PLM Global Collaboration as a high priority topic. The Group commissioned CIMdata to develop a taxonomy of product development collaboration, and prepare a survey to capture a generalized characterization of PLM global collaboration as currently practiced and experienced within the extended A&D product development ecosystem. The survey was tested in this Phase 1 project and, based on the findings, will be refined prior to broader distribution to a representative cross-section of industry companies in Phase 2.

CIMdata's Phase 1 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.

This report presents a taxonomy for product development collaboration, an initial assessment of the current state, characterization of high potential improvement opportunities, summary observations, 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.

Research Goals

The overall goal of this research is to improve understanding of the current state and future trends in capabilities and technologies for A&D global product development collaboration. More specifically the goals of the research are to:

- Define a taxonomy of global product development collaboration
- Characterize the current state and future trends in collaboration
- Identify the limits of current technologies
- Identify high potential improvement opportunities

- For the identified opportunities, provide insights on weaknesses, barriers, and problems in the current state and how these conditions will evolve over time
- Recommend how Action Group Members can improve collaboration with their design partners in the future

Specific goals for this Phase 1 project were to:

- Define a taxonomy of global product development collaboration
- Develop and test a survey strategy and tool
- Document an initial characterization and assessment of the current state and future trends in collaboration, including
    - Identification of high potential improvement opportunities
    - For the identified opportunities, insights on problems and their impacts in the current state
    - Recommendations for how Action Group Members can improve collaboration with their design partners in the future

Methodology

CIMdata conducted research on processes, data formats, and other collaboration aspects applicable to A&D global product development activities and development partner collaboration. The research was based on the taxonomy of global collaboration capabilities that was developed and agreed with the A&D PLM Action Group members.

CIMdata developed a survey tool based on the approved taxonomy and tested this tool using the A&D Action Group members as sources to be surveyed and interviewed. The members each appointed a contact person to coordinate with the CIMdata team.

Develop PLM Global Collaboration Taxonomy

CIMdata defined a high-level representation of PLM global collaboration in six primary dimensions as the framework for research and analysis. This taxonomy included relevant topics for collaboration (i.e. collaboration entities, environments, data formats, processes and technologies). A draft of the taxonomy was distributed for A&D PLM Action Group members' review. CIMdata made revisions and distributed the final taxonomy for member approval.

Gather PLM Global Collaboration Information

From the taxonomy template, the CIMdata team developed an on-line survey of approximately 60 questions to collect information from the A&D industry. This Phase 1 survey was approximately double the length of the survey intended for broader distribution in Phase 2.

CIMdata tested the survey with the A&D PLM Action Group members. Two of the A&D PLM Action Group members completed the on-line survey. After initial release of the on-line survey, the Members reviewed and revised the taxonomy. CIMdata then revised and reissued the survey, this time in Microsoft Word format. All four Members completed the revised survey.

CIMdata conducted telephone interview sessions (approximately 1 hour in length) with individuals from each of the A&D PLM Action Group member companies to discuss, elaborate, and clarify the survey topics and results.

Based on the survey and interview results, CIMdata characterized and assessed current state and trends in collaboration processes and technological capabilities, highlighting significant problems and impacts.

Prepare Report

CIMdata has prepared and is distributing this draft report for Member review. Revisions will be made in response to Member comments and the final report will be distributed to Members in both document and presentation format.

PLM GLOBAL COLLABORATION TAXONOMY

The taxonomy developed by CIMdata and approved after review and revision by the A&D PLM Action Group members sets forth a representation of PLM global collaboration in six primary dimensions:

- Program phase (When)
- Collaboration entity (Who)
- Collaboration purpose (Why)
- Collaboration environment (Where)
- Collaboration content (What)
- Collaboration process & technical capabilities (How)

This taxonomy, as presented in Table 1 below, provided the framework to capture a generalized characterization of PLM global collaboration as it is currently practiced and experienced within the extended A&D product development ecosystem.

Table 1 – PLM Global Collaboration Taxonomy

Collaboration Dimension		Description
1.	**Program Phase (When)**	Subset of product lifecycle stages that focus on product design
1.1	**Concept phase**	Front-end research, program KPIs, requirements analysis, partner selection, conceptual design
1.2	**Initial development phase**	Joint development, product structure definition, systems engineering and interface design
1.3	**Detailed development phase**	Design and tooling supplier selection, detailed 3D modeling, analysis, BOM creation & release
1.4	**Tests phase (partial)**	Requirements verification, issues resolution and changes implementation and monitoring through to certification of supplier parts
2.	**Collaboration Entity (Who)**	Party with whom the OEM is collaborating
2.1	**OEM remote site (internal)**	Party internal to OEM at geographically different site(s)
2.2	**Design & build partner**	Program partner responsible for system or major subsystem design and build; data certified within OEM process (e.g. wing)
2.3	**Equipment & system supplier**	Supplier under evaluation or contracted for component design and build; data certified through testing or TSO (e.g. engine)
2.4	**Design supplier**	Supplier under evaluation or contracted for subsystem or component design
2.5	**Build to print supplier**	Supplier under evaluation or contracted for subsystem or component build
2.6	**Tooling design supplier**	Supplier under evaluation or contracted for tooling or mold design or design and build

Table 1 – PLM Global Collaboration Taxonomy (continued)

3.	**Collaboration Purpose (Why)**	Business purpose for the collaboration
3.1	**Work assignment and design delivery**	Deliver requirements and technical information to and receive design solution from supplier
3.2	**Simultaneous design & evaluation**	Synchronous modeling, simulation and or analysis
3.3	**DMU baselining**	Digital mockup generation for validation and baseline context for concurrent design
3.4	**Design review & approval**	Review of requirements and evaluation of design solution, with response and sign-off
3.5	**Engineering change**	Deliver changed requirements to and process proposal revision from supplier
3.6	**Supplier selection – RFx and response**	Request for information, request for proposal to support supplier evaluation and selection
3.7	**Contractual discussions**	Claims and decisions register; technical analysis workflows regarding issues
4.	**Collaboration Environment (Where)**	Location of the data used in the collaboration
4.1	**Joint session (inside firewall)**	Shared dataset during a live joint session of an application running inside OEM firewall
4.2	**Joint project repository (inside firewall)**	Data files accessible by role within the OEM PDM project repository inside OEM firewall
4.3	**Joint sharing repository (outside firewall)**	Data files accessible in OEM established and managed PDM repository outside OEM firewall
4.4	**Send/receive files (outside firewall)**	Data files sent from and received to an OEM established address outside the OEM firewall

Table 1 – PLM Global Collaboration Taxonomy (continued)

5.	**Collaboration Content (What)**	Data that is the focus of the collaboration
5.1	**Geometry**	Geometric model of the design subject, alone or within its geometric context
5.1.1	**Complete native 3D model**	CAD native format mechanical or electrical data including design intent
5.1.2	**Simplified native 3D model**	CAD native format mechanical or electrical data without design intent
5.1.3	**Standard format 3D model (STEP, IGES, other)**	CAD data converted to industry standard format
5.1.4	**Visualization model (JT, 3D PDF…)**	CAD data converted to lightweight format
5.1.5	**2D models (images, drawings…)**	CAD data that is not 3D
5.2	**Ancillary information**	Information in addition to the geometry that is relevant the design intent or design solution
5.2.1	**Requirements**	Specification of design form, fit, function and constraints (e.g. cost, weight, material)
5.2.2	**Interface control specification**	Boundary conditions between systems, subsystems and or components
5.2.3	**Technical standards**	Design standards and constraints, including prescribed design and manufacturing practices
5.2.4	**Simulation, analysis & test results**	Results from modeling behaviors and evaluating performance
5.2.5	**Bill of material**	Product structure, configurations, and attributes
5.2.6	**Planning information**	Main milestones, deliverables approvals and commercial information exchange

Table 1 – PLM Global Collaboration Taxonomy (continued)

6.	**Collaboration Process & Technical Capabilities (How)**	Actions performed to facilitate collaboration, and capabilities used during collaboration
6.1	**Processes**	Actions performed by the OEM to facilitate collaboration
6.1.1	**Collaboration environment set up**	Configure hardware and software environment
6.1.2	**Security administration**	Administer security permissions and invitations, assuring IP protection and export control
6.1.3	**Information preparation**	Locate, collect, modify and assemble geometry and ancillary data into a collaboration package
6.1.4	**Information send or post and notify**	Send collaboration package to recipient or load in repository and send notification to recipient
6.1.5	**Inquiry & response**	Resolve issues or questions raised by recipient; locate and provide additional data as required; maintain transaction log of each
6.1.6	**Information receive**	Receive information package or notification from sender and retrieve
6.1.7	**Information QA & remediation**	Examine and validate received data; raise issues and request additional data as required; maintain transaction log of each interaction
6.1.8	**Information post and notify internally**	Log final approved data, post to internal repository and issue internal notifications

Table 1 – PLM Global Collaboration Taxonomy (continued)

6.2	**Technical Capabilities**	Capabilities used during collaboration
6.2.1	**Shared views**	Live joint session of visualization application across multiple sites
6.2.2	**View manipulation**	Modify view of the visualized geometric model (e.g. zoom, rotate, page, section)
6.2.3	**Markup**	Highlight region of geometric model and add dimensions, labels, notes, etc.
6.2.4	**Metadata view & edit**	View and edit geometric model metadata (e.g. material, descriptions, tolerances)
6.2.5	**Evaluation**	Evaluate geometric model (e.g. dimensional measurement, center of gravity, weight)
6.2.6	**Simulation**	Fly through, motion simulation, post-analysis simulation, collision detection
6.2.7	**Geometry edit**	Modify geometric model (e.g.?)

Subsequent to final revision and approval by the Members CIMdata determined that a reordering of the Purpose elements would facilitate interpretation of the survey and interview results. That reordering has been done in the table above and is reflected in the results reported below.

CURRENT STATE ASSESSMENT

The *A&D PLM Global Collaboration Taxonomy* provides a representation of PLM global collaboration in six primary dimensions. Through evaluation of survey and interview responses CIMdata developed a general characterization of collaboration within the extended A&D product development ecosystem and was able to identify a set of nodes within this six-dimensional space that offer the greatest potential for business performance improvement. Then for those high potential nodes, CIMdata solicited and consolidated an initial generalized assessment of performance problems, impacts and improvement opportunities.

The reader must note that the characterization and assessment in this report are preliminary. The intent of this Phase 1 project was to test the taxonomy and survey strategy upon the Members. Consequently, the sample population was too small to provide confidence in the results. In Phase 2, the knowledge and insight gained in Phase 1 will contribute to a refined and focused survey suitable for distribution to an industry population of sufficient size to yield statistically reliable results.

Characterization

This section documents a preliminary and generalized characterization of collaboration within the extended A&D product development ecosystem in six dimensions:

- Program phase (When)
- Collaboration entity (Who)
- Collaboration purpose (Why)
- Collaboration environment (Where)
- Collaboration content (What)
- Collaboration process & technical capabilities (How)

In their survey responses, the Members characterized collaboration as experienced within their companies and extended collaboration ecosystems by indicating intensity on a scale from 1 to 5 of collaboration activity in a progression of two-dimensional combinations.

Each table below documents the average of values from the individual Member survey responses. Airbus returned one survey response from each division: Airbus (commercial), Defence & Space, and Eurocopter. For analysis, the three Airbus responses were averaged and then that Airbus average was used to compute the overall Group average. In addition, Airbus did not provide responses for the new elements that were added to the taxonomy subsequent to the first release of the survey. For those taxonomy elements, shown as rows or columns in the tables below, the average in the table is for responses from the other three Members.

Program Phases

Collaboration occurs during every aircraft program phase, from concept to series production. For this research project, scope is limited to the subset of product lifecycle stages that focus on product design. Those include Concept, Initial Development, Detailed Development, and a portion of the Test phase, as defined in the *PLM Global Taxonomy* presented in Table 1.

Collaboration Entities

Table 2 shows for each program phase how the volume of collaboration varies by collaboration entity.

Not surprisingly, collaboration volume is lower in the initial phases of an aircraft program and highest during Detailed Development. In addition, it should be noted that collaboration intensity is greatest with OEM Remote Sites and with Design & Build Partners.

Table 2 – Collaboration Entities and Volume of Collaboration during Various Program Phases

Program Phase	Collaboration Entity					
	OEM Remote Site (Internal)	Design & Build Partner	Equipment & System Supplier *	Design Supplier	Build to Print Supplier	Tooling Design Supplier *
Concept	2.5	1.5	1.3	1.1	0.5	0.2
Initial Development	3.5	3.2	2.3	2.5	1.0	1.6
Detailed Development	4.3	4.8	3.0	3.3	2.0	3.3
Test (partial) *	4.0	3.7	2.7	3.3	3.0	2.3

* - Only 3 responses

Legend
Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)

This pattern is common for most OEMs, who collocate their product development team, including partners, during the early phases. However, in the case where product development partners are geographically dispersed during initial program phases, the intensity of collaboration between OEM Remote Sites is high during all phases.

Collaboration Purpose

Table 3 shows for each collaboration entity, how the volume of collaboration varies by collaboration purpose.

Consistent with the pattern in Table 2, the highest volume of collaboration is with OEM Remote Sites and with Design & Build Partners. Table 3 reveals the additional information that the collaboration intensity with these entities is high for a wide range of purposes. In addition, Table 3 indicates that collaboration intensity with Design Suppliers is also high, a point that is only hinted at in Table 2.

Table 3 – Purpose and Volume of Collaboration with Various Collaboration Entities

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier selection – RFx and	Contractual Discuss'ns *
OEM Remote Site (Internal)	4.0	4.5	4.6	4.3	3.8	0.2	1.0
Design & Build Partner	4.0	4.4	3.8	4.3	3.8	1.6	2.3
Equip't & System Supplier *	2.3	2.7	2.3	2.7	2.3	2.3	2.0
Design Supplier	3.6	3.8	3.4	3.4	3.7	1.6	1.7
Build to Print Supplier *	2.3	1.7	1.7	1.3	2.0	2.3	1.3
Tooling Design Supplier	2.3	1.6	2.3	1.5	2.0	1.1	1.3

* - Only 3 responses

Legend
Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)
Very Low (<2.0)

Collaboration Environment

The columns in Table 4 represent four common environments within which collaboration occurs. The table shows for each collaboration purpose, which collaboration environments are used and with what intensity.

Consistent with the pattern in Table 3, the highest volume of collaboration is for the purpose of Simultaneous Design & Evaluation and for DMU Baselining. The greatest intensity of collaboration occurs within Joint Project Repositories that are located inside the OEM's firewall.

Table 4 – Collaboration Environments and Volume of Collaboration for Various Collaboration Purposes

Collaboration Purpose	Collaboration Environment			
	Joint session (inside firewall)	Joint project repository (inside firewall)	Joint sharing repository (outside firewall)	Send/receive files (outside firewall)
Work assignment & design delivery	1.6	2.6	1.4	4.1
Simultaneous design & eval'n	3.2	4.4	3.0	2.7
DMU Baselining	4.0	4.6	3.5	1.8
Design review & approval	2.8	3.1	1.5	1.4
Engineering change	1.8	3.3	2.4	1.9
Supplier selection – RFx and response	0.2	1.1	0.1	1.7
Contractual Discussions *	0.0	0.3	0.0	1.3

* - Only 3 responses

Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)
Very Low (<2.0)

Member responses differed significantly. Some members use multiple environments intensely for a wide range of purposes. Other members use only one or two environments intensely, not using at all an environment used heavily by others.

Collaboration Content

The content shared during collaboration falls into two general categories, geometric data and ancillary data. The types and volumes of geometric and ancillary data shared during collaboration vary depending on the purpose for collaboration.

Geometric Content

Table 5 shows for each collaboration purpose, which types of geometric data are shared and with what intensity.

By far, the Complete Native 3D Model is the most common type of geometric data shared for all major collaboration purposes. An exception is that Design Review & Approval utilizes Complete Native 3D Models, Simplified Native 3D Models and 2D Models in equal measure.

Table 5 – Types and Volume of Geometric Content Shared for Various Collaboration Purposes

Collaboration Purpose	Collaboration Content Type – Geometry				
	Complete native 3D model	Simplified native 3D model	Standard format 3D model (STEP, IGES, other)	Visualization model (JT, 3D PDF…)	2D models (images, drawings…)
Work Assignment & Design Delivery	4.2	2.8	2.2	1.1	2.3
Simultaneous design & eval'n	5.0	2.6	1.8	1.5	2.3
DMU Base Lining	4.3	2.8	1.0	1.6	1.5
Design review & approval	3.3	3.0	1.1	2.2	3.4
Engineering change	3.8	2.1	1.5	1.9	1.8
Supplier Selection – RFx and Response	3.2	1.8	1.1	1.0	2.2
Contractual Discussions *	0.0	1.0	1.0	0.0	2.0

* - Only 3 responses

Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)
Very Low (<2.0)

Some Members indicated higher use of 2D drawings and images because they included ongoing work being done on legacy aircraft programs.

Ancillary Content

Table 6 shows for each collaboration purpose, which types of ancillary data are shared and with what intensity.

Bill of Material is the most intensely and broadly shared type of ancillary data. Collaboration for the purpose of Design Review & Approval involves high volumes of several types of ancillary data.

Table 6 – Types and Volume of Ancillary Content Shared for Various Collaboration Purposes

Collaboration Purpose	Collaboration Content Type – Ancillary Information					
	Requirements	Interface control specification	Technical standards	Simulation, analysis & test results	Bill of material	Planning Information *
Work Assignment & Design Delivery	3.0	3.1	3.5	1.9	3.4	1.7
Simultaneous design & eval'n	2.9	3.1	2.8	2.5	4.0	0.7
DMU Baselining	1.8	3.4	2.3	2.8	2.8	1.0
Design Review & Approval	3.0	3.3	4.0	3.8	4.0	1.3
Engineering Change	2.9	2.8	2.9	2.4	3.3	1.3
Supplier Selection – RFx and Response	1.2	0.8	1.1	0.3	0.8	0.7
Contractual Discussions *	0.7	1.7	1.0	0.7	1.0	1.7

* - Only 3 responses

Legend
Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)
Very Low (<2.0)

Member responses differed significantly. One Member listed very high intensity of sharing Requirements, Technical Standards and Bill of Material content for a wide range of Collaboration Purposes due to the rigorous structure of their design methodology

Collaboration Process and Technical Capabilities

One lesson learned in execution of this Phase 1 test of survey strategy is that the survey structure of two-dimensional tables which provided good differentiation for characterization of the "who", "when", "why", "where" and "what" of collaboration was not so revealing regarding the "how" of collaboration. The survey did ask Members to indicate which process steps and which technologies they use for various collaboration purposes. However, since the response is affirmative for almost every condition, this approach yielded little differentiation.

That is not to say that no insight was gained from the survey regarding the "how" of collaboration. Later in the survey, Members were asked to indicate collaboration process steps and technologies with performance problems. Their responses to this line of inquiry yielded valuable insight. These results are presented and discussed in the appropriate section later in this report.

Process Steps

The applicability of collaboration process steps for various collaboration purposes is presented in Table 7. The value in each cell of the table is the percent of responses indicating that process step is executed for that collaboration purpose. With only a few exceptions, respondents are in complete agreement that all collaboration purposes require execution of all collaboration process steps.

Table 7 – Process Steps Executed for Various Collaboration Purposes

Collaboration Purpose	Collaboration Process Step							
	Collaboration environment set up	Security Administr'n *	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
Work Assignment & Design Delivery	67%	100%	92%	92%	92%	92%	83%	92%
Simultaneous Design & Eval'n	75%	100%	100%	100%	92%	100%	83%	100%
DMU Baselining	75%	100%	100%	100%	92%	100%	83%	100%
Design Review & Approval	75%	100%	100%	100%	67%	75%	58%	75%
Engineering Change	67%	100%	92%	92%	92%	92%	83%	92%
Supplier Selection – RFx and Response	58%	100%	83%	92%	92%	92%	83%	92%
Contractual Discussions *	67%	100%	100%	100%	100%	100%	100%	100%

* - Only 3 responses

Legend
Very High (91-100%)
High (81-90%)
Moderate (71-80%)
Low (61-70%)
Very Low (< 60%)

Technical Capabilities

The technical capabilities used for various collaboration purposes are presented in Table 8. As in the table above, the value in each cell is the percent of responses indicating that technical capability is utilized for that collaboration purpose. The table does reveal some significant differences in technical capabilities usage. All technical capabilities are broadly used for DMU Baselining, while only two of six technical capabilities are utilized for Work Assignment & Design Delivery by more than 60% of respondents.

Table 8 – Technical Capabilities Utilized for Various Collaboration Purposes

Collaboration Purpose	Collaboration Technical Capability					
	Shared Views	View Manipulation	Markup	Metadata View & Edit	Evaluation	Simulation
Work Assignment & Design Delivery	67%	33%	67%	42%	58%	33%
Simultaneous Design & Eval'n	67%	75%	67%	67%	75%	75%
DMU Baselining	92%	75%	100%	100%	100%	92%
Design Review & Approval	92%	67%	100%	75%	92%	75%
Engineering Change	92%	58%	75%	92%	83%	83%
Supplier Selection – RFx and Response	67%	50%	50%	67%	67%	25%
Contractual Discussions *	67%	67%	100%	67%	67%	33%

* - Only 3 responses

Legend
Very High (91-100%)
High (81-90%)
Moderate (71-80%)
Low (61-70%)
Very Low (< 60%)

Evaluation

Another lesson learned in execution of this Phase 1 test of survey strategy is that the researchers' intention and the respondents' interpretation of a line of questioning do not always align. In the matter of self-evaluation, the intention and the interpretation diverged on several key points. In response, the researchers modified their original methodology for interpreting the self-evaluation responses and rating the improvement priorities.

Importance

Table 9 shows for each collaboration entity, how the importance of collaboration varies by collaboration purpose, and, for each collaboration purpose, how the importance of collaboration varies by collaboration entity. The researchers assumed that importance would be directly related to collaboration volume and, therefore, Table 9 would be identical to Table 3 above. However, the respondents factored other considerations into their assigned ratings, such as the business impact of delay or error and, consequently, Table 9 is similar but different from Table 3. For comparison, values from Table 3 have been inserted below the assigned values in Table 9 in each cell where the values differ.

Consistent with the pattern in Table 3, the highest collaboration importance is assigned to OEM Remote Sites, to Design & Build Partners, and to Design Suppliers for a broad range of collaboration purposes.

Table 9 – Collaboration Importance Self-Assessment (Importance ~= Volume)

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier select'n – RFx & response	Contractual Discussions *
OEM Remote Site (Internal)	4.0	4.5	4.6	4.6 4.3	4.1 3.8	0.2	n.a.
Design & Build Partner	4.3 4.0	4.4	3.8	4.6 4.3	4.3 3.8	1.8 1.6	2.7 2.3
Equip't & System Supplier *	3.0 2.3	3.0 2.7	2.3	3.0 2.7	3.0 2.3	2.7 2.3	2.3 2.0
Design Supplier	3.8 3.6	3.8	3.4	3.7 3.4	4.2 3.7	1.8 1.6	2.0 1.7
Build to Print Supplier *	2.7 2.3	1.7	1.7	1.7 1.3	2.3 2.0	2.3	1.7 1.3
Tooling Design Supplier	2.5 2.3	1.6	2.3	1.8 1.5	2.3 2.0	1.6 1.1	2.0 1.3

Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Low (2.0-2.9)
Very Low (<2.0)

* - Only 3 responses

Performance

Table 10 shows for each collaboration entity, how the collaboration performance varies by collaboration purpose.

Collaboration performance is rated high for OEM Remote Sites. For all other collaboration entities, collaboration performance is rated fair to poor. Since collaboration importance was highly rated for Design & Build Partners, for Equipment & System Suppliers, and for Design Suppliers, it would seem logical that improvement priority would be high for these entities.

Table 10 – Collaboration Performance Self-Assessment

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier select'n – RFx & response	Contractual Discussions *
OEM Remote Site (Internal)	3.6	3.8	3.8	3.9	4.2	1.7	n.a.
Design & Build Partner	2.2	2.3	2.8	2.8	3.1	1.7	2.0
Equip't & System Supplier *	1.3	1.3	1.7	1.7	2.0	1.3	2.0
Design Supplier	2.4	2.5	2.6	2.8	3.3	1.7	2.0
Build to Print Supplier *	1.7	0.7	0.7	0.7	2.3	1.3	2.0
Tooling Design Supplier	1.6	1.4	1.8	2.3	2.3	1.3	2.0

* - Only 3 responses

Legend
Very High (4.4-5.0)
High (3.7-4.3)
Moderate (3.0-3.6)
Fair (2.0-2.9)
Poor (< 2.0)

Member responses were generally consistent. Interestingly, the Member that had indicated a distributed development team across multiple geographic sites during initial program phases also reported very good collaboration between the remote sites.

Improvement Priorities

The original method devised for rating improvement priorities was to request a self-assessment of collaboration importance and of collaboration performance, each on a scale of 1 to 5, and then subtract the performance rating from the importance rating. In that way, a collaboration condition with high importance and low performance would be assigned a high improvement priority rating. The results of this method are presented in Table 11.

Table 11 –Improvement Priorities, Method 1: Importance Minus Performance

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier select'n – RFx & response	Contractual Discussions *
OEM Remote Site (Internal)	0.4	0.8	0.8	0.7	-0.1	-1.5	n.a.
Design & Build Partner	2.1	2.2	0.9	1.8	1.3	0.2	0.7
Equip't & System Supplier *	1.7	1.7	0.7	1.3	1.0	1.3	0.3
Design Supplier	1.4	1.3	0.8	0.9	0.8	0.2	0.0
Build to Print Supplier *	1.0	1.0	1.0	1.0	0.0	1.0	-0.3
Tooling Design Supplier	0.9	0.2	0.4	-0.6	-0.1	0.3	0.0

* - Only 3 responses

Legend
Very High (2.1-3.0)
High (1.6-2.0)
Moderate (1.1-1.5)
Low (0.6-1.0)
Very Low (<0.6)

In the survey, the Members were asked to mark an "X" in each *Collaboration Entity-Collaboration Purpose* cell for which they believed the importance is high and the performance is low. Their responses were not consistent with the assessments they had provided in the previous tables.

In the final section of the survey, the Members were asked to provide write-ups elaborating on problems, impacts and suggested improvements for each *Collaboration Entity-Collaboration Purpose* cell that they had marked with an "X". Again, their responses were not consistent with the assessments they had provided in the previous tables. The two cells with the highest calculated improvement priority rating were marked with an "X" by multiple respondents and multiple write-ups were provided. However, some cells were marked by one or more respondent, but no write-ups were provided; while other cells were unmarked, write-ups were provided.

The researchers decided that marking cells and providing write-ups constituted a second legitimate method of indicating an improvement priority rating, and should be taken into account in the final rating determination. The ratings by this second method are presented in Table 12.

Table 12 –Improvement Priorities, Method 2: Member Assigned in Survey Response

Collaboration Entity	Collaboration Purpose						
	Work Assignment & Des'n Delivery	Simultaneous Design & Evaluation	DMU Baselining	Design Review & Approval	Engineering Change	Supplier Selection – RFx & Response	Contractual Discussions *
OEM Remote Site (Internal)		2 1 X, 1 Write-up	1 1 X, 0 Write-up	1 1 X, 0 Write-up			n.a.
Design & Build Partner	6 3 X, 3 Write-up	5 3 X, 2 Write-up	3 2 X, 1 Write-up	2 1 X, 1 Write-up	2 1 X, 1 Write-up	1 1 X, 0 Write-up	
Equip't & System Supplier *	2 2 X, 0 Write-up	2 2 X, 0 Writeup	1 1 X, 0 Write-up	1 1 X, 0 Write-up	1 1 X, 0 Write-up	1 1 X, 0 Write-up	
Design Supplier	3 2 X, 1 Write-up	2 ** 1 X, 1 Write-up	3 2 X, 1 Write-up	1 1 X, 0 Write-up		1 1 X, 0 Write-up	
Build to Print Supplier *	1 1 X, 0 Write-up	1 1 X, 0 Write-up	1 1 X, 0 Write-up	1 1 X, 0 Write-up		1 1 X, 0 Write-up	
Tooling Design Supplier	1 1 X, 0 Write-up	1 1 X, 0 Write-up	2 ** 1 X, 1 Write-up	1 ** 0 X, 1 Write-up		1 1 X, 0 Write-up	

Very High (5-6)
High (3-4)
Moderate (2)
Low (1)
Very Low (<1)

* - Only 3 responses ** - Write up, but no corresponding "X" in Table

The final improvement priority ratings, which are the simple summation of the results from method 1 (Table 11) and method 2 (Table 12), are presented in Table 13. The two methods individually and in summation clearly indicate the same two top priority improvement opportunities:

- *Work Assignment & Design Delivery* to/from *Design & Build Partners*
- *Simultaneous Design & Evaluation* with *Design & Build Partners*

The only significant difference in results from the two methods is the inclusion of DMU Baselining as an improvement opportunity of note.

Table 13 – Improvement Priority Rating, Summation of Methods 1 and 2

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier select'n – RFx & response	Contractual Discussions *
OEM Remote Site (Internal)	0.4	2.8	1.8	1.7	-0.1	-1.5	n.a.
Design & Build Partner	**8.1**	**7.2**	**3.9**	**3.8**	**3.3**	1.2	0.7
Equip't & System Supplier *	**3.7**	**3.7**	1.7	2.3	2.0	2.3	0.3
Design Supplier	**4.4**	**3.3**	**3.8**	1.9	0.8	1.2	0.0
Build to Print Supplier *	2.0	2.0	2.0	2.0	0.0	2.0	-0.3
Tooling Design Supplier	1.9	1.2	2.4	0.4	-0.1	1.3	0.0

* - Only 3 responses

Legend
Very High (7.1-9.0)
High (5.1-7.0)
Moderate (3.1-5.0)
Low (1.1-3.0)
Very Low (<1.1)

HIGH PRIORITY IMPROVEMENT OPPORTUNITIES

A primary objective of this research was to identify high potential improvement opportunities, and then for those identified opportunities to provide insights on problems and their impacts in the current state and how these conditions will evolve over time. The ten cells with moderate to very high improvement priority ratings, as shown in Table 13, have been organized into a set of Top Five Collaboration Improvement Opportunities in Table 14. Collectively, Group Members identified collaboration with *Design & Build Partners* as their primary concern across the five collaboration purposes from *Work Assignment & Design Delivery* through *Engineering Change*. The green arrows in Table 14 point out variants across other collaboration entities with somewhat lower, but still compelling, ratings.

Table 14 – Top Five Collaboration Improvement Opportunities

Collaboration Entity	Collaboration Purpose						
	Work assignment & des'n delivery	Simultaneous design & evaluation	DMU Baselining	Design review & approval	Engineering Change	Supplier select'n – RFx & response	Contractual Discussions *
OEM Remote Site (Internal)							n.a.
Design & Build Partner	1 8.1	2 7.2	3 3.9	4 3.8	5 3.3		
Equip't & System Supplier *							
Design Supplier	4.4	3.3	3.8				
Build to Print Supplier *							
Tooling Design Supplier							

Very High (7.1-9.0)
High (5.1-7.0)
Moderate (3.1-5.0)
Low (1.1-3.0)
Very Low (<1.1)

Each of the Top Five Collaboration Improvement Opportunities is described and discussed below. Each Opportunity includes summary descriptions of the problems, their impacts, and suggested methods for improvement that have been extracted from the Group Member survey responses and interviews. Relevant CIMdata observations are included as well.

The material presented focuses on the primary opportunity, but the discussion will also highlight similarities and differences with the variant opportunities.

1 Work Assignment & Design Delivery

Collaboration for the purpose of *Work Assignment & Design Delivery* to/from *Design & Build Partners* is the highest rated collaboration improvement opportunity. In addition to rating importance as moderate-to-high and current performance as fair-to-poor, three Members contributed extensive descriptions of problems, impacts, and suggestions for improvement in their survey responses.

Work Assignment & Design Delivery to/from *Equipment & System Suppliers* and to/from *Design Suppliers* are variants with lower priority ratings that still offer significant improvement opportunities. One Group Member contributed a description of problems, impacts, and suggestions for improvement in their survey response.

Problems

Table 15 shows collaboration process steps and technical capabilities that demonstrate performance problems during *Work Assignment & Design Delivery* to/from *Design & Build Partners*. Each "X" represents one Member's designation of a performance problem in their survey response.

Table 15 – Collaboration Process Steps and Technical Capabilities that Demonstrate Performance Problems during Work Assignment & Design Delivery to/from Design & Build Partners

Collaboration process steps with performance problems (put an "X" under each step that applies):							
Collaboration environment set up	Security Administration	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
XX	X	XX	XXX	XXX		X	X
Technical capabilities with performance problems (put an "X" under each capability that applies):							
Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation		
X			X	X	X		

One Group Member notes that while they as the OEM have control over the relationship with their Design & Build Partners, they do not control the setup on the Partners' development machines. They indicate that technical limitations of the approved tool set and collaboration between the supplier and OEM technology staffs can result in significant performance losses and system instability when collaborating with highly integrated suppliers. Because supplier users are responsible for managing their own hardware and network, system variations generate novel issues that are difficult to troubleshoot without hands–on collaboration with the affected users. Additionally, they report that supplier users are resistant to providing detailed descriptions of issues until design deadlines reach critical junctures resulting in significant acrimony between the OEM and the supplier organization.

A second Group Member continues with this theme of IT incompatibilities but also ties it together with process differences between the OEM and Partners. They report that they do not have a complete environment for the design across the OEM, Design Partners, and Equipment Suppliers. OEM designers create their own CAD representations of the design of an engine or a piece of equipment in order to complete DMU baselining. In addition, they do not manage analysis data centrally. They rely upon individual groups to manage their own analysis data. No prescribed standards are enforced for the creation, management and communication of analysis results. Each group is allowed to pick what works for them with little exposure of that data to external groups.

A third Group Member states that there is a lack of effective control over project milestones linked to real deliverables from Design Suppliers. "The way that we share information it is more exchanging or viewing files than sharing and collaboration on the same file."

Impacts

The Group Member who reported issues of IT infrastructure where the operating system and tools of the OEM and Partners may vary, explains that the differences sometimes cause a conflict with PLM tools, forcing schedule delays to resolve the issues that arise. They note that in general, program objectives and timetables slide to the right in response to system issues. In worst-case scenarios, litigation is required to resolve issues. With

Design and Build Partners, delays in engineering directly translate to production delays which can in turn generate even more litigation and costs to both the OEM and the Partners.

The Group Member that linked independent processes with IT differences notes the impact is a number of escapes in the design process leading to engineering error and rework. With the lack of access to the design, they rely upon their own representation of the design that may not be accurate. Further, their ability to conduct simulation is hampered by the quality of the representation coupled with the lack of centralized data management.

The third Group Member reports development impact due to schedule misalignment with Design Partners. Loss of time for document changes markup, approval and updates occur when using only view manipulation instead of shared views.

Suggestions for Improvement

To resolve IT difference issues, the Group Member most affected recommends a solution that would establish a buffer between the OEM and the Design & Build Partner—a DMZ in effect. Partners would interface between their local data repositories and a webserver controlled by the OEM, who would then manage data movement across the firewall into their OEM data vault. With the OEM having more control over the entire design environment, it is suggested there would be significantly fewer issues. Individual suppliers would be assigned to separate blade pools in the OEM DMZ that are collocated with the Supplier's instance of the vault. Users would then use a remote desktop service such as Citrix to remote into OEM hardware outfitted in approved hardware and a standard software configuration. Performance would be greatly improved between the Partner's database and the OEM's vault, security would be controlled by a single policy managed by the OEM, and user support would be improved by removing novel issues that are created by individual Supplier configurations.

Exploring this issue revealed an opportunity for our second Group Member. As they completed the collaboration survey, they remarked that they were struck by the observation that they do not currently host their design (nor the designs of their Partners) external to their firewall. Either they bring the person inside the firewall to a physical site or the Partner VPN's into their system. The only other method they support is data exchange whether it is by file transfer or some fashion of database connection. They do not currently use cloud or any third party hosting of their data. Therefore, designs exist complete for analysis only to the extent that they can approximate those elements that they don't design internally.

CIMdata Observations

A review of the issues noted by each of the Group Member OEMs for *Work Assignment & Design Delivery* to/from *Design & Build Partners* indicates that all the Group Members are working in design environments that are outdated with regard to advantages available from current technology for network (including cloud) and workstation platforms. This is understandable given that aerospace OEMs in general choose a hardware/software platform and related development processes at the start of each new aircraft program development cycle and maintain it for the duration of the program, which lasts for many years.

Further, it appears that approved data exchange formats and data transfer mechanisms are not officially defined in detail prior to the start of a development cycle other than native data formats used by the OEM. Many of the reported data exchange mechanisms seem to have evolved naturally over time.

In addition, no Member OEM indicated that they supply their Partners with any form of data validation tool that must be run and passed prior to submission of data to the OEM. This is seen as a best practice in other industries.

2 Simultaneous Design & Evaluation

Collaboration for the purpose of *Simultaneous Design & Evaluation* with *Design & Build Partners* is the second highest rated collaboration improvement opportunity. In addition to rating importance as moderate-to-high and current performance as fair-to-poor, two Members contributed descriptions of problems, impacts, and suggestions for improvement in their survey responses.

Simultaneous Design & Evaluation with *Equipment & System Suppliers* and with *Design Suppliers* are variants with lower priority ratings that still offer significant improvement opportunity. A third Member contributed a description of problems, impacts, and suggestions for improvement in their survey response.

Problems

Table 16 shows collaboration process steps and technical capabilities that demonstrate performance problems during *Simultaneous Design & Evaluation* with *Design & Build Partners*. Each "X" represents a Member's designation of a performance problem in their survey response.

Table 16 – Collaboration Process Steps and Technical Capabilities that Demonstrate Performance Problems during Simultaneous Design & Evaluation with Design & Build Partners

Collaboration process steps with performance problems:							
Collaboration environment set up	Security Administration	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
XX		XX		X			
Technical capabilities with performance problems:							
Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation		
XX				X	X		

One Group Member indicates that a major issue is the relative speed of design teams, one to another. Technical skill levels and mastery varies across teams creating different rates of progress on simultaneous design. This rate difference creates relative delays in schedule due to evaluation delays. With the data in flux, multitasking on other priorities can create further delays.

A second Group Member voiced a similar concern. Information misalignment causes rework. Teams are working on different model revisions. A lot of clash detection problems could be avoided if up-to-date models are used. Ultimately the decision making process regarding technical subjects is slow and doesn't achieve current needs.

A third Group Member notes that especially for simulation large amounts of data are exchanged. The workaround today is moveable hard disks, which leads to lead time delays.

Impacts

Group Members described three major impacts:

- Joint definition and integration tasks throughout the design are negatively affected. The disconnect accounts for a significant number of engineering releases and is especially troublesome where the design is shared across two design teams.
- Impacts range from extra rework, claims and problems with suppliers, higher development costs, and projects delays
- Forces long lead times

Suggestions for Improvement

Across the range of these problems, Group Member recommended solutions including:

- Improvements to both process and technology. The process requires training and consistency of skill application. In the technology domain, one idea is to attach attributes to the design designating the maturity and the ownership of the design. The maturity of the design is often unknown except through interaction with the engineer, usually via a meeting (or email) or spreadsheet.
- Having a system that would allow on-line collaboration
- Establishing sharing techniques for simulation

CIMdata Observations

A review of the issues noted by each of the Group Member OEMs for *Simultaneous Design & Evaluation* with *Design & Build Partners* indicates that Group Members are tracking development schedules with milestones set too far apart. Shorter durations between milestone may highlight potential delays sooner and allow for quicker corrective action.

With regard to on-line collaboration, its absence may be due again to the use of older software solutions. CIMdata sees dramatically increased use of the social media technologies for collaboration in product development across numerous industries. These technologies are often embedded within the current PLM solutions.

Further, in the last five years much more attention has been paid to CAE data, its storage, reuse, and collaborative sharing within the automotive and large machinery industries. New aerospace projects should investigate and update their future design and simulation environments as appropriate based on these developments.

3 DMU Baselining

Collaboration for the purpose of *DMU (digital mockup) Baselining* with *Design & Build Partners* is the third highest rated collaboration improvement opportunity. In addition to rating importance as moderate-to-high and current performance as fair-to-poor, one Member contributed a description of problems, impacts, and suggestions for improvement in their survey response.

DMU Baselining with *Design Suppliers* is a variant with lower priority ratings that still offers a significant improvement opportunity. One Member contributed a description of problems, impacts, and suggestions for improvement in their survey response.

Problems

Table 17 shows collaboration process steps and technical capabilities that demonstrate performance problems during *DMU Baselining* with *Design & Build Partners*. Each "X" represents a Member's designation of a performance problem in their survey response.

Table 17 – Collaboration Process Steps and Collaboration Technical Capabilities that Demonstrate Performance Problems during DMU Baselining with Design & Build Partners

Collaboration process steps with performance problems:							
Collaboration environment set up	Security Administration	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
X		X	X		X		
Technical capabilities with performance problems:							
Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation		
X	X	X		X	X		

One Group member cautions that for Design & Build Partners, manufacturing data is required as well as design data. Another Group Member laments that due to the volume of data and the distances involved, online collaboration is not possible.

Impacts

Group Members report that impacts include incorrect data or references being used for manufacturing, and design being done with out-of-date models leading to interference clashes.

Suggestions for Improvement

Group Members suggest possible solutions including:

- Using open standards including feedback for synchronization
- Using lightweight data and synchronous exchange, instead of heavy CAD models to share information

CIMdata Observations

A review of the issues noted by each of the Group Member OEMs for *DMU (digital mockup) Baselining* with *Design & Build Partners* indicates that Group Members for the most part are not taking full advantage of the latest technology for design collaboration using lightweight model formats. Over the recent past, the major PLM vendors and a wealth of independent third party solution providers have implemented very robust DMU applications based on lightweight models, such as ISO standard JT from Siemens PLM Software, and 3D PDFs. In addition, no Group Member mentioned the use of cloud technologies (even private cloud) for data sharing.

4 Design Review & Approval

Collaboration for the purpose of *Design Review & Approval* with *Design & Build Partners* is the fourth highest rated collaboration improvement opportunity. In addition to rating importance as moderate-to-high and current performance as fair-to-poor, one Member contributed a description of problems, impacts and suggestions for improvement in their survey response.

Problems

Table 18 shows collaboration process steps and technical capabilities that demonstrate performance problems during *Design Review & Approval* with *Design & Build Partners*. Each "X" represents a Member's designation of a performance problem in their survey response.

Table 18 – Collaboration Process Steps and Collaboration Technical Capabilities that Demonstrate Performance Problems during Design Review & Approval with Design & Build Partners

Collaboration process steps with performance problems:							
Collaboration environment set up	Security Administration	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
X		X	X	X	X	X	X
Technical capabilities with performance problems:							
Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation		
X				X	X		

One Group Member voices the concern that today they do not have a system that enforces discipline and schedule alignment. They note infrastructure problems and performance issues affect some design reviews, depending on information volume and type of files.

Impacts

The Group Members list a number of impacts:

- The problem causes information misalignment due to file updates in different revision levels. Outdated information is being used. The need to setup replica environments.
- Lose of time in execution of design reviews with information misalignment, and failure to have all required resources during reviews. These conditions force rework and resource rescheduling.
- All these factors add risks for the program delivery timeline, in addition to costs effects. They also affect relationships with suppliers, raising the number of claims and discussions with contract administrators.

Suggestions for Improvement

The Action Group Members were at a loss to recommend improvements in this area.

CIMdata Observations

A review of the issues noted by each of the Group Member OEMs for *Design Review & Approval* with *Design & Build Partners* indicates that Group Members are not taking full advantage of the latest technology for design validation. As previously noted, no OEM indicated that they supply their Partners with any form of data validation tool. Over the recent past both PLM vendors and third party solution providers have developed tools that allow user companies to select from a set of prepackaged checks and to implement their own custom checks on data being submitted by an outside developer.

5 Engineering Change

Collaboration for the purpose of *Engineering Change* processing with *Design & Build Partners* is the fifth highest rated collaboration improvement opportunity. In addition to rating importance as moderate-to-high and current performance as fair-to-poor, one Member contributed a description of problems, impacts and suggestions for improvement in their survey response.

Problems

Table 19 shows collaboration process steps and technical capabilities that demonstrate performance problems during *Engineering Change* processing with *Design & Build Partners*. Each “X” represents a Member’s designation of a performance problem in their survey response.

Table 19 – Collaboration Process Steps and Technical Capabilities that Demonstrate Performance Problems during Engineering Change Processing with Design & Build Partners

Collaboration process steps with performance problems:							
Collaboration environment set up	Security Administration	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
		X	X	X	X		
Technical capabilities with performance problems:							
Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation		
		X	X	X			

A Group Member reports that collaboration for change management exists largely outside their PLM system and is performed by screen captures of CAD models annotated with text and documented in a textual system. The process is built around the exchange of documents and is not architected to use 3D data beyond representative models. Communication with outside parties is difficult with change intent not fully evaluated nor planned.

Impacts

That Group Member goes on to indicate that the flow time to assess, plan and execute a change is a major impact. They have examples on development programs where the ability to manage high volumes of changes was critical to program success. They have seen flow times double and triple due to difficulty in capturing and planning a good change package.

Suggestions for Improvement

This Member's recommendation is that change attributes need to be architected against both the business attributes and the configuration of the product. They note that there is a boundary between change authorization and change execution. The boundary prevents a full utilization of the model-based definition.

CIMdata Observations

Once again, a review of the issues noted by each of the Group Member OEMs for *Engineering Change* processing with *Design & Build Partners* indicates that Group Members are not taking full advantage of the latest technology for design collaboration. The latest capabilities in change management solutions provided by the PLM vendors should be explored.

SUMMARY OBSERVATIONS AND FINDINGS

This section documents summary observations and findings from this research project in three categories:

- Taxonomy and survey strategy effectiveness
- Phase 1 lessons learned
- Phase 2 scope

Taxonomy and Survey Strategy Effectiveness

After a 4 week open review period, the Members provided no comments back on the first draft of the taxonomy, so the researchers issued a survey based on this first draft taxonomy. During the process of completing the survey, several Members found issues and provided comments back on the taxonomy. At a Group meeting seven weeks after first release, the taxonomy underwent a substantial open review by the Members. At the end of that process, the Members seemed well satisfied and approved the taxonomy, and the researchers issued a revised survey based on the newly approved taxonomy. Through the subsequent survey response and interview process, no respondents expressed confusion or suggested additional changes to the taxonomy or the survey, although a number of Group Members noted that there was a potential for survey respondents to interpret survey terms and definitions differently.

Phase 1 Lessons Learned

This Phase 1 project provided a test of the taxonomy and survey strategy. This test revealed several lessons that could improve the efficiency and quality of results for a follow-on (Phase 2) research project.

Respondents' Knowledge is Limited

During the interviews, several respondents noted that their individual knowledge and experience did not span the full scope of the survey questions. This condition of limited individual knowledge was common to all Members, but the Members' responses to this condition varied. One Member collected input from several individuals and held meetings to reconcile inconsistencies in their response. Other Members collected and consolidated input from a few or several individuals, leaving gaps and inconsistencies unresolved.

A potential means for dealing with this discrepancy of method and result would be to solicit responses from several individuals with a variety of backgrounds within a company and request that each individual only answer questions in areas that they know well. Then the researchers can combine the responses to obtain a complete profile.

Respondents' Interpretations Vary

A key line of inquiry during the follow up interviews with survey respondents was to explore significant deviations between an individual Member's response and the average response for the Group. This strategy revealed several significant differences in collaboration practices and resulting problems between Members. This process also revealed that respondents were interpreting the survey questions in ways that varied from each other and from the intent of the survey authors.

A potential means for dealing with this inconsistency of interpretation would be to make the taxonomy definitions and survey questions more precise.

Survey Must Be Much Shorter

Since only the four Members were the intended targets for this Phase 1 survey, the researchers were not constrained by usual the survey completion time conventions, and developed a comprehensive survey of approximately 60 questions. Preparation of Member responses involved between two and six individuals, and response preparation time varied from four to eight hours. Even though the Members were the sponsors and would be the direct beneficiaries of the research, the Member representatives and research coordinators struggled to secure participation of the appropriate individuals within their companies.

This experience confirms the need for any follow-on research survey to be more focused, shorter, and easier to complete and analyze.

Participation Incentives Will Be Needed

Even if a follow-on survey can be designed to be far less burdensome and less time consuming than the Phase 1 survey, it may still exceed the bounds of normal convention. In addition, it may be determined that a specific list of companies should be targeted for the survey in order to achieve most meaningful results. Consequently, extraordinary means of recruiting and incentivizing survey participation may be required, such as individual targeting and personal invitation and follow-up by CIMdata and Group Members, and providing a gift or other incentive.

Phase 2 Focus

Analysis of the survey responses and follow up interviews produced a set of ten areas with moderate to very high improvement priority ratings, as shown in Table 13 and in Table 20 below. These were organized into a set of Top Five Collaboration Improvement Opportunities with variants, and each of these has been described and discussed in this report. The Top Five Collaboration Improvement Opportunities would be the logical focus for follow-on research.

Companies to Survey

As shown by the arrows and highlighting in Table 20, the Top Five Collaboration Improvement Opportunities encompass three classes of collaboration entities: *Design & Build Partners*, *Equipment & System Suppliers*, and *Design Suppliers*. Follow-on research should be focused on A&D companies within these categories.

Table 20 – Three Collaboration Entities with Highest Improvement Priority Ratings

Collaboration Entity	Collaboration Purpose: Work Assignment & Des'n Delivery	Simultaneous Design & Evaluation	DMU Baselining	Design Review & Approval	Engineering Change	Supplier Selection – RFx & Response	Contractual Discussions *
OEM Remote Site (Internal)	0.4	2.8	1.8	1.7	-0.1	-1.5	n.a.
Design & Build Partner	**8.1**	**7.2**	**3.9**	**3.8**	**3.3**	1.2	0.7
Equip't & System Supplier *	**3.7**	**3.7**	1.7	2.3	2.0	2.3	0.3
Design Supplier	**4.4**	**3.3**	**3.8**	1.9	0.8	1.2	0.0
Build to Print Supplier *	2.0	2.0	2.0	2.0	0.0	2.0	-0.3
Tooling Design Supplier	1.9	1.2	2.4	0.4	-0.1	1.3	0.0

Legend
Very High (7.1-9.0)
High (5.1-7.0)
Moderate (3.1-5.0)
Low (1.1-3.0)
Very Low (<1.1)

Topics to Probe

In follow-on research, it is intended not only to narrow the scope but also to deepen the level of inquiry selectively.

Collaboration Purpose

Phase 1 research has provided insights for deeper inquiry in two areas.

- *Work Assignment & Design Delivery* to/from *Design & Build Partners*
- *Simultaneous Design & Evaluation* with *Design & Build Partners*

Collaboration Process Steps and Technical Capabilities

Members provided write-ups with details on all five of the high priority opportunities and several of the variants. In the survey, respondents were asked to indicate collaboration process steps and technical capabilities with performance problems. Tables 21 and 22 show the combined results from all respondents.

Table 21 – Four Collaboration Process Steps Most Frequently Cited for Collaboration Performance Problems

Collaboration process steps with performance problems:								
Opp'y #	Collaboration environment set up	Security Admin'n	Information Preparation	Information Send or Post & Notify	Inquiry & Response	Information Receive	Information QA & Remediation	Information Post & Notify Internally
1	XX	X	XX	XXX	XXX		X	X
1c	X		X	X	X		X	
2	XX		XX		X			
2c	X		X					
3	X		X	X		X		
3c	X		X	X		X		
4	X		X	X	X	X	X	X
5			X	X	X	X		
Total	10	1	10	8	7	4	3	2

Table 21 shows four out of eight collaboration process steps (red arrows) were indicated as problematic more than twice as often as the others. Table 22 shows three out of six collaboration technical capabilities (red arrows) were indicated more than twice as often as the others. These would be topics to investigate more deeply in follow-on research.

Table 22 – Three Collaboration Technical Capabilities Most Frequently Cited for Collaboration Performance Problems

Technical capabilities with performance problems:						
Opp'y #	Shared views	View manipulation	Markup	Metadata view & edit	Evaluation	Simulation
1	X			X	X	X
1c				X		
2	XX				X	X
2c						X
3	X	X	X		X	X
3c	X	X	X		X	X
4	X				X	X
5			X	X	X	
Total	6	2	3	3	6	6

CONCLUSIONS

The results of this Phase 1 project support two main conclusions:

- The specific goals of the Phase 1 research were achieved
- A solid foundation for Phase 2 research was established

Specific goals of the Phase 1 research were achieved

A taxonomy for global product development collaboration was defined, reviewed and approved by the Members, and successfully tested through the survey process.

A survey and interview strategy was developed for capturing a generalized characterization of PLM global collaboration as it is currently practiced and experienced within A&D OEMs. A survey tool was designed based on the approved taxonomy and successfully tested on the Members.

An initial characterization and assessment of the current state and future trends in collaboration was documented, including:

- Identification of high potential improvement opportunities
- For the identified opportunities, insights on problems and their impacts in the current state
- Recommendations for how Action Group Members can improve collaboration with their design partners in the future

Solid foundation for Phase 2 research was established

The outcome of the Phase 1 project provides a clear indication of a reduced and focused scope for a follow-on research project. In addition, Phase 1 results indicate a specific set of topics for in-depth investigation.

The Phase 1 test yielded several significant lessons learned that would improve the efficiency and quality of results from a follow-on research project.

RECOMMENDATIONS

Recommendations include actions that Members can take in the near term, as well as details for planning follow-on research.

Potential Short Term Improvements

Some observations and suggestions developed in the course of this Phase 1 project indicate certain actions that Members could take in the near term to improve collaboration performance:

Assist Partners in building IT infrastructure

Help primary Partners build an appropriate IT infrastructure to support your business. Some automotive companies provide an excellent example of how to do this well. Possibilities include providing software collaboration licenses for the OEM approved collaboration tool.

Improve shared data management

Allow suppliers to access data from a PDM vault outside the OEM's firewall, and assure that is appropriately protected. Rationalize security policies to support the business as opposed to enforcing unconditional IP protection. Manage work and milestones in PDM, linked to actual project deliverables and schedules expected from suppliers. Add issue tracking to PDM workflow tasks, and assure that suppliers know that issues must be tracked from the point when they arise.

Use PDM workflows

Use PDM workflows to drive the product development processes (e.g., approvals, engineering changes, issue resolutions, validation analyses) directly linked to the affected product definition information and entities involved in the process to reveal issues, delays, and bottlenecks. Include automated status reporting to management and project leaders.

Standardize data exchange

A finite set of data exchange format and transfer mechanisms should be offered to Partners. By contract, any divergence from one of the approved exchange scenarios should be disallowed. OEMS should explore the use of lightweight CAD models, 3D PDFs, and data standards such as STEP as part of the solution. Transfer mechanisms should be limited to approved IT infrastructure solutions.

Conduct design reviews using current lightweight model technology

Use lightweight data for DMU and real-time collaboration. This will allow suppliers to protect their IP, and improve speed of on-line collaboration sessions. For this to work, participants must have appropriate access to see the data . That is, the data needs to be in a common collaboration repository such as PDM.

Own the data

Make sure suppliers are contractually obligated to provide appropriate levels of their IP, such as 3D CAD data or neutral model formats, to support the product development collaboration processes, such as DMU. Provide on-line collaboration capabilities in which suppliers can participate based on a reasonable security model.

Invest in validation tools

Explore and deploy data exchange validation tools that each Partner must execute and pass before transferring any data to the OEM. The capabilities in such tools can be implemented incrementally over time.

Follow-On Phase 2 Research Project

Direct CIMdata to prepare a project plan for Phase 2 research involving a sample size of 40 to 50 respondents so that:

- Results will be statistically reliable
- Derived requirements and/or policy positions will be broadly representative of the A&D industry

The research plan would address the following goals:

- Characterize the current state and future trends in collaboration
- Identify the limits of current technologies
- Identify high potential improvement opportunities
- For the identified opportunities, provide insights on weaknesses, barriers, and problems in the current state and how these conditions will evolve over time
- Recommend how Action Group Members can improve collaboration with their design partners in the future

The research would focus on 12 to 15 companies in each of the following collaboration roles:

- *Design & Build Partners*
- *Equipment & System Suppliers*
- *Design Suppliers*

The research would explore all of the following collaboration purposes, but explore the first two more deeply:

- *Work Assignment & Design Delivery*
- *Simultaneous Design & Evaluation*
- *DMU Baselining*
- *Design Review & Approval*
- *Engineering Change*

The research would explore in depth the following collaboration process steps:

- Collaboration environment set up
- Information preparation
- Information send or post and notify
- Inquiry & response

and the following collaboration technical capabilities:

- Shared views

- Evaluation
- Simulation

The research plan would include specific features that address lessons learned during this Phase 1 project:

- Respondents' knowledge is limited, so incomplete surveys need to be accommodated
- Respondents' interpretations vary, so survey has to be unambiguous
- Survey must be much shorter
- Participation incentives will be needed

The project plan for Phase 2 research would be included in the list of research projects under consideration by the Group for funding in 2015.

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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