# REQUIREMENTS FOR A PRODUCT INFORMATION MANAGEMENT (PIM) INFRASTRUCTURE TO SUPPORT PARTNER PROGRAMS

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# REQUIREMENTS FOR A PRODUCT INFORMATION MANAGEMENT (PIM) INFRASTRUCTURE TO SUPPORT PARTNER PROGRAMS

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## ABSTRACT

Current Product Information Management (PIM) systems are architected to serve the product definition and development needs of a single company. For companies that exist in environments that are predominantly vertically integrated or that involve little or no collaborative product development, such systems may suffice. For globally distributed organizations or organizations that partner with other organizations to design, develop and deliver product to the market, such systems are inadequate at providing an infrastructure to facilitate true distributed, team based collaboration. This thesis uses the Distribution-Collaboration-Richness of Information space as a framework to propose a PIM architecture that will support inter-enterprise collaboration. It starts with an introduction and strategic analysis of the PIM industry. An automotive OEM Partner Program is used as a case study to examine the changing relationships with its business partners and their impact on the nature of interaction that is required to support it. A specific element of the interaction, CAD design, is used to derive the functional requirements for a PIM architecture that would facilitate such an interaction. A more generalized study involving several automotive OEM's and suppliers reinforces these requirements by projecting the degree of collaboration required based different design processes. A mapping of how PIM systems might meet these needs is discussed in the context of a generic and a specific Product Development process. Segmentation along vertical and horizontal dimensions is proposed as a means of decentralizing PIM architectures. The concepts of Organizational Domain, Enterprise and Extended Enterprise are introduced to aggregate PIM installations based on common business practice, business unit boundaries and product or program specific team membership respectively. The concept of a Collaborative Team Environment (CTE) is used to create a virtual foundation on which a distributed product team may collaborate and consolidate product development information across enterprises while retaining independent administration, processes and ownership of data. The recommended architecture is validated by showing how issues experienced by the Automotive OEM Partner Program may be resolved. The study concludes by identifying some of the limitations of the recommended architecture and future work that might carry this study further.

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# 1 INTRODUCTION

## 1.1 Problem Statement

A partner program is one that involves multiple organizations in the design, development and manufacture of a product. What makes product development in a large and complex partner program such as in the automobile industry specially challenging is not only the highly collaborative nature of design decisions and the large size of the teams, but also the possibility of distributed or dispersed product development teams. The coordination of related and dependent tasks poses a technical and organizational challenge from a PIM perspective.

The product development challenges of coupled and coordinated tasks [Patil], must be conducted across organizational and enterprise boundaries resulting in an even more complex process.

This thesis explores the possibility of improving partner program product development through a PIM architecture that emphasizes distributed team support across enterprises. It introduces the notion of segmenting PIM architectures along two dimensions - the Vertical Dimension and the Horizontal Dimension to provide a combination of formal and informal data sharing and collaboration patterns. Current capabilities in PIM functionality are extended by introducing the concepts of Distributed Teams, Distributed Team Instances and Collaborative Team Environments (CTE) that span installation and organizational boundaries. As an example, it is proposed that a CTE may be established to provide a single product development environment for partner programs such as one that might involve a joint venture to develop sport utilities for the global market. To keep the discussion as generic as possible, we will refer to the primary automotive company as Automotive OEM Company (AOC) and to the partner automotive company as Partner OEM Company (POC). The main goal of this thesis is to use the lessons learned from the XYZ Partner Program between AOC and POC as a case study to define the framework for a PIM architecture that would provide a scalable and collaborative environment for a distributed product development team.

The lessons learned from the XYZ Partner Program case study are reinforced by additional research conducted with participants from the automobile supplier and OEM communities through the Automotive Industries Action Group (AIAG). Both the case study and the AIAG research highlight a rapidly changing automotive business environment that is moving towards a greater number of partnerships or alliances. It is anticipated that by 2002 [Gartner], 40 - 60% of a vehicle will be designed by suppliers or partners. This will shift the nature of the automobile industry from being vertically integrated to being highly networked [D. H. Brown Associates][B. Enslow].

PIM systems are currently targeted at product development activities that occur late in the process such as Release, Formal Change Control and Life Cycle Definition. They are only just beginning to provide capabilities that would assist in rapid work-in-progress phases more upstream in the design process. Even so, current PIM systems function in a single enterprise. PIM functionality that spans multiple installations or Federated PIM functionality is in its infancy. It lacks any ability to provide a single collaborative environment, providing instead, multiple disconnected environments.

Current PIM systems are not architected for a globally distributed product development environment. In many cases, a centralized architecture is used to minimize the impact of a distributed team. However, this forced centralization can no longer be sustained. The volume of work being conducted in multiple distributed environments causes problems such as poor performance, lack of adequate support and administrative burden. The use of independent installations increases costs due to rework resulting from a lack of communication, version control, etc. PD may be viewed through three different lenses - as a search process, as a social process and as a creative process [Patil]. This thesis highlights that each of these is further complicated when one factors in partner programs (relationships between OEMs and suppliers or between OEMs themselves such as Ford and Mazda or General Motors (GM) and Toyota). Adding to this complexity is the fact that the direction of the relationship can vary from program to program. As an example, POC can be a supplier to AOC on one program and on another, AOC could be a supplier to POC.

## 1.2 Product Development across Extended Enterprises

Increased competition in the automotive industry has resulted in the need for higher efficiencies in product development (PD) and manufacturing, particularly in PD cycle times as well as in the need for innovative products developed with fewer resources. These drivers for productivity growth have resulted in a greater leveraging of supplier and partner expertise. Companies, in general, are being driven to tighten material, product and information links with their suppliers and partners. The result will be a new business model built on virtually shared resources and markets [Gormley et. al].

The new business model will be achieved in the following three stages [Gormley et. al]:

- Stage One - where the emphasis on the integration of existing systems that span the entire enterprise
- Stage Two - where the focus is on providing planning and execution capabilities with a few select partners and finally
- Stage Three - where the emphasis shifts to cascading practices across the entire supply/partner chain.

As an example, having implemented several initiatives within the company around Stage One and Stage Two type activities including integration with Mazda, Ford is now moving to Stage Three. This is not to say that Ford has solved all the problems in the previous stages, but that considering the dynamics in the automobile (and other) industries, Ford cannot afford to wait until all issues are resolved before moving to Stage Three.

Facilitating product development collaboration across extended enterprises will be vital to delivering the required efficiencies in the new business environment. Not only must enterprises shorten their product development lead times by changing their interaction between upstream design and downstream manufacturing activities, but they must also change their interaction to include sharing and collaboration on preliminary design information [Krishnan, Eppinger & Whitney] [Yassine, Falkenburg & Chelst]. There is a lot of work that has been done on business to business interaction but most of this work has focused on downstream manufacturing planning and execution. This thesis complements that work by focusing on business to business product development collaboration by proposing an information management framework on which this may be built particularly for the initial PD phases characterized by fast design evolution.

The challenges lie in the degree of distribution and collaboration required. These are best examined using the Distribution-Collaboration matrix shown in Figure 1.2-1.

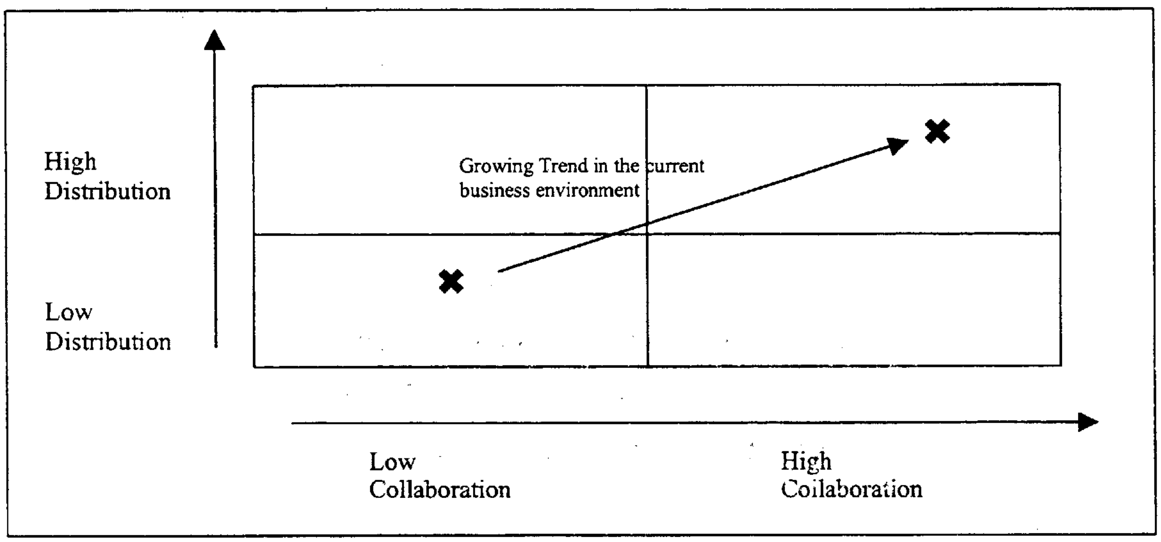



Figure 1.2-1 Distribution vs. Collaboration

Collaboration is made more difficult when accompanied by geographic distribution. The nature of an enterprise's business practices determines the level of distribution and/or collaboration. It is possible for a company to require very high collaboration without being geographically dispersed. Conversely, it is possible for an enterprise to be very widely dispersed without needing substantial collaboration, although this is a rapidly waning possibility. PD organizations must determine where they would be located on this matrix in terms of their business requirements for product development. There is a trend toward the top-right quadrant for work-in-progress collaboration. For example, based on their experiences with partner programs and relationships with their supplier community, Ford and GM are in the top-right quadrant, due in part to the growing number of acquisitions and partnerships.

Chrysler (before its merger with Daimler-Benz) was in the upper left quadrant where there was very little collaboration with most of the supplier relations being of the 'Black Box' variety. Toyota on the other hand seems to be in the lower right quadrant.

There are many forces that drive the position of an enterprise on the matrix one way or the other and in fact, the position is a balance of sorts. Communications infrastructure, technology, capital investment, global processes, engineering practice and knowledge management strategies are all examples of the forces that conflict with each other. As an example, Ford's relationships with Volvo, Mazda and other enterprises push Ford up the Distribution axis. However, Ford's current PIM architecture (a highly centralized implementation) has allowed Ford to move down along the distribution axis. However, this is now falling far short of meeting the enterprise's needs.

A potential third axis in the Distribution-Collaboration matrix would be the Richness of Information being decentralized and collaborated on. For example, it is trivial to provide the capability to share data files such as MS Excel, MS Word Files, simple CAD, CAM and CAE files or small volumes of Meta data. Enterprises needing to exchange such information would be spotted on the third axis closer to the origin. However, typical engineering environments require the sharing of complex product structures along with relationships to other data such as Product Direction Letters (PDL), Requirements, System and Subsystem Specifications, Tests, Analysis, etc. Only when there is a high degree of sharing of such information where changes in one area trigger potential changes in others, does one have a true collaborative environment. As an enterprise moves into this level of collaboration, the PIM emphasis shifts to managing complex relationships across multiple installations. Figure 1.2-2 below attempts to depict this.

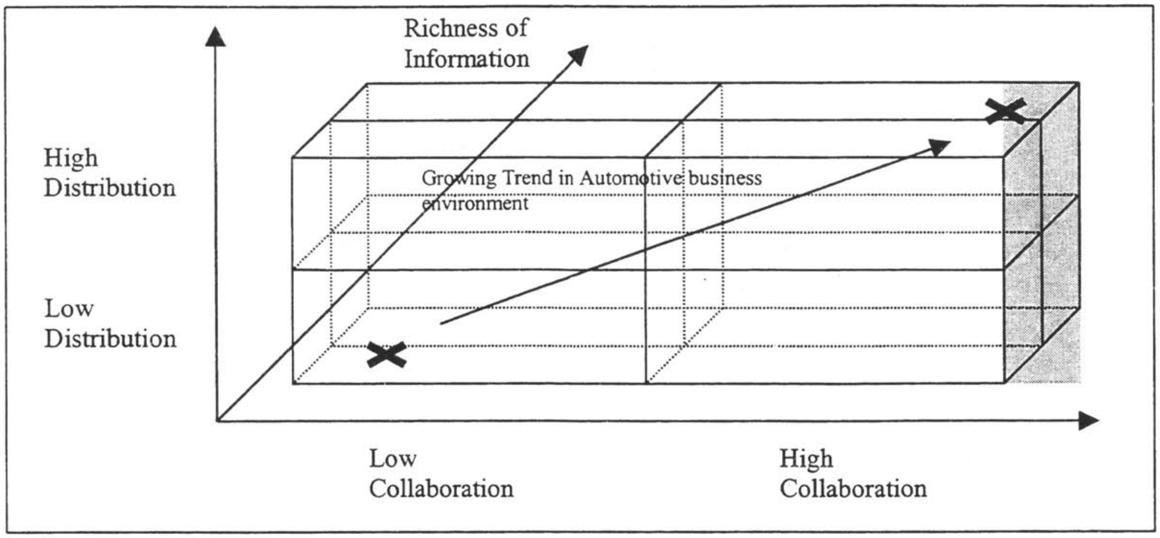



Figure 1.2-2: Distributive-Collaborative- Richness of Information Space

## 1.3 Information Technology Trends

Over the last decade, the use of information technology (IT) to derive greater efficiencies particularly in the product development arena has increased sharply. The evolution of IT application can be viewed based on five levels of capabilities [N. Venkataraman], summarized in Figure 1.3-1. IT application starts at Level 1 with a focus on local implementations to derive functional or activity based efficiencies. Progress then takes place up through multiple levels along the Business Transformation axis until the business is positioned to completely redefine itself if needed at Level 5. The focus of this thesis is on "Level 4" where the business starts to weave together implementations that span the extended enterprise (supply chain and partner communities). Very specifically, this thesis focuses on the ability to conduct collaborative product development across multiple enterprises in geographically distributed locations.

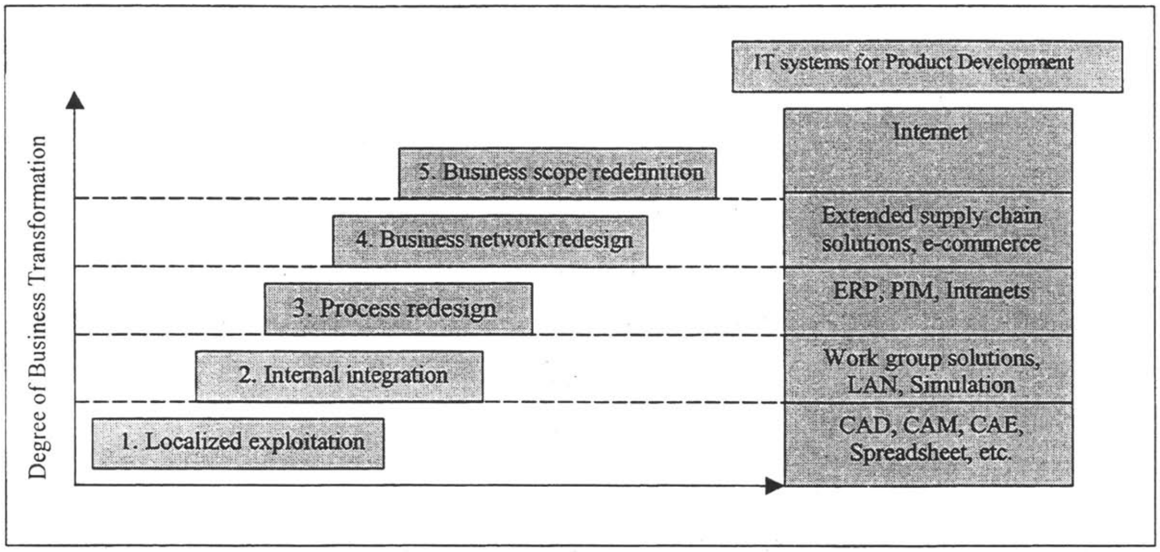



Figure 1.3-1: Five levels of IT-induced reconfigurations (Adopted from N. Venkatraman's framework)

Current product development systems such as CAD, CAE, CAM, PIM systems, enable single enterprises or functions to conduct their activities in a localized manner. Although technology to distribute data and facilitate communication exists in a fairly mature state, very little exists to facilitate complex product development across enterprises. Even less exists to ensure that such an infrastructure can be created such that it enables transient and opportunistic business relations. With the current business environment moving towards a networked rather than vertically integrated paradigm, there will be pressure on IT vendors to provide this functionality. This thesis proposes at a high level, a PIM infrastructure that can provide this functionality. The goal is to evolve to a zero-latency enterprise strategy wherein all parts of the enterprise can respond to design events as soon as they become known to any one part of the enterprise [Enslow & Schulte]. This may be achieved by reducing the number of design iterations across enterprise boundaries by increasing concurrent access [Yassine, Falkenburg & Chelst].

## 1.4 Overview of the thesis

This thesis is divided into eight chapters. Chapter 2 provides an introductory discussion on PIM in general and the industry forces that are pushing its domain upstream in the product development process. Readers familiar with the PIM industry may skip this chapter, although the analysis for its shift upstream in the PD process may prove interesting. Chapter 3 provides an insight into the changing business environment highlighting a shift towards increased outsourcing and partnering in the automobile industry. Chapter 4 summarizes the lessons learned from the AOC XYZ Partner Program case study. Chapter 5 reinforces the lessons learned by including feedback from multiple automobile OEM's and suppliers about their changing business environment and projected collaboration requirements. Chapter 6 proposes a PIM architecture to address some of the issues in supporting partner programs raised in the previous chapters and Chapter 7 exercises the recommended architecture. Chapter 8 summarizes the conclusions from this study and proposes from future work.

# 2 WHAT IS PIM?

## 2.1 Introduction to PIM

PIM is an acronym for Product Information Management. PIM is sometimes also referred to as PDM (Product Data Management).

PIM came into being in the late 1980's, originally as a means to manage engineering documentation. It offered a number of functions that were put together to answer questions like:

- What does the configuration of the current active revision of Product A look like?
- What did the prior revision look like?
- What changed between that prior revision and the current active one?
- What is being changed on the Bill of Material?

PIM systems manage product-related information including design geometry, engineering drawings, project plans, part files, assembly diagrams, product specifications, numerical control machine tool programs, analysis results, correspondence, bills of material, and many others. Such systems manage product data throughout the enterprise, ensuring that the right information is available for the right person at the right time and in the right form. PIM systems, therefore, improve communication and cooperation between diverse groups and form the basis for organizations to restructure their product development processes and institute initiatives such as concurrent engineering and collaborative product development.

PIM Systems now serve design engineers, engineering management, document control, change control board members, production planning, purchasing, manufacturing engineering, shop floor users, quality assurance and field service. As the list of users implies, PIM is focused on distributing product status information to a broad set of users. It therefore attempts to establish a broad information interface across the enterprise. By expanding PIM systems beyond engineering, people from other phases who were generally left out of design and development can now contribute to product development - a major objective of concurrent engineering. The result is faster work, fewer errors, less redundancy, greater cooperation, and smoother workflow translating into bottom-line money savings and time reductions.

Typical PIM systems support five basic functions:

- Data vault and document management provides for storage and retrieval of information.
- Workflow and process management controls procedures for handling product data and provides a mechanism to drive a business with information.
- Product structure management handles bills of material, product configurations and associated versions and design variations.
- Parts management provides information on standard components and facilitates re-use of designs.
- Program management provides work breakdown structures and allows coordination between product-related processes, resource scheduling and project tracking.

PIM systems themselves are enabled by a few core or underlying technologies:

- Communication capabilities such as links to e-mail provide for information transfer and events notification.
- Data transport functions that track data locations and move data from one location or to another.
- Data translation capabilities that allow the exchange of files in the proper format.
- Image Services that handle storage, access, viewing and mark-up of product information.
- Administration Utilities that control and monitor system operation and security.

As can be imagined, no single product can provide all the PIM capabilities. Instead, PIM systems are typically comprised of several software packages from different vendors integrated into a multi-level PIM product that balances enterprise controls with local functions.

It is critical to understand that technology is only one aspect of PIM systems. An equally important aspect is the suite of organizational issues surrounding the company's business strategy, evaluating workflow and processes in the organization, examining how information is and should be shared between groups and considering how people will react to the technology and process changes.

## 2.2 Benefits of PIM

PIM systems benefit the entire business - design and engineering, production operations, purchasing, marketing and sales.

Some of the key benefits are:

- Immediate Access to Product and Process Data - Increasingly, immediate access to product and process data is critical for responding to market changes. PIM provides this data at the desktop by managing the design process, controlling product description data, and acting as the design and information repository for each authorized user - including suppliers and customers.
- Security - PIM provides a flexible security mechanism by which data is protected and authorized global teamwork is facilitated by instant access to appropriate information.
- Support for Business Process - Business processes defined in PIM can be automatically system-driven to meet market demands. The PIM system's knowledge base supports business planning, and studies to help improve development and manufacturing processes.
- Product Structure Management - This is one of the most critical benefits provided by PIM. Designers and engineers obtain complete information via either leveraging part classification schemes or using advanced interfaces that enable direct manipulation of graphic representations of the product's structure.
- Workflow Management - Workflow support enables quick review and approvals of changes, resource monitoring and design alternatives. It allows rapid and flexible changes early in the design process while enforcing security and control during downstream phases.

- Reduced Scrap and Rework - Engineering change process cuts scrap and rework through tracking of versions.
- View and Mark-up Capabilities - Viewing of documents is facilitated at shop floor level thereby eliminating the need to distribute hard copy documents. Elaborate query filters enable flexible search options to retrieve related parts.
- Supplier Management - PIM can be extended to the supplier community thus facilitating the exchange of information with the extended enterprise.

Perhaps the greatest benefit that PIM offers is that of enabling change within a company - a change that stems from careful examination of existing work processes, a redesign and optimization of those processes if needed and their subsequent implementation with new technology. Many companies mistakenly assume that they can automatically achieve process improvements by simply putting in place a PIM System without re-thinking the organization's operations. Such an approach will yield only partial benefits if any. Process improvements require all aspects of an organization's operations to be carefully examined and optimized. Companies must consider the impact of PIM on routine tasks performed by users since this can completely change the way the company operates. Similarly, many process improvements can only be determined after PIM is used - its use will trigger process improvements that were previously unknown based on the presence of related information.

## 2.3 PIM Industry Analysis

The section provides an analysis of the PIM industry in an attempt to convey the state as of December 1998 as well as to set the groundwork for what may be expected in the near future (2 - 4 years).

### 2.3.1 Industry Competitors

The PIM industry has experienced a tremendous growth over the last 10 years. This growth has been in the number of PIM vendors as well as in the combined revenues from the sales and services of PIM systems worldwide. Figure 2.3.1-1: PIM Market Size shows the growth of the PIM market from 1989 to 1997 with a projected growth to the year 2002. The worldwide market for PIM software and services is expected to post a gain of 16% and exceed $1.2 billion in 1998.

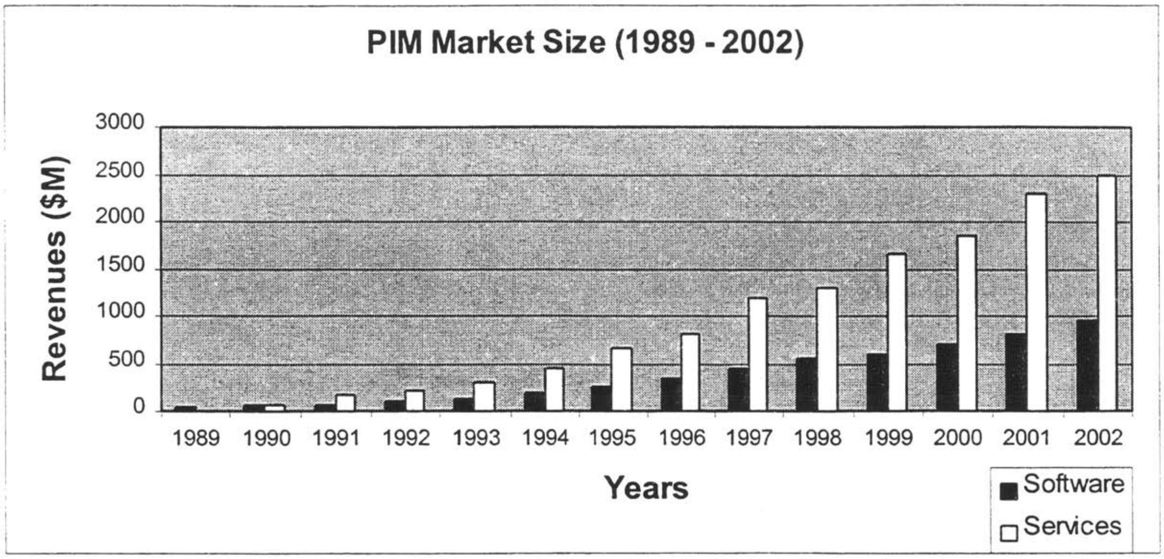



Figure 2.3.1-1: PIM Market Size (1989 - 2002)

Furthermore, the market is predicted to increase at a compounded annual growth rate of 16% through the year 2002, when the size is expected to reach over $2.5 billion (Data Source: CIMdata, November 1998). These figures do not reflect the required investments in complementary areas such as hardware, computing infrastructure, consulting, business process reengineering, planning and coordination.

With companies gradually positioning themselves in a global market, this market is truly global in nature with a broad geographic segmentation consisting of the N. American market comprising 45%, Europe comprising 39% followed by Asia Pacific with a size of 16%. This is reflected in Figure 2.3.1-2: Regional Distribution of PIM Revenues: 1997.

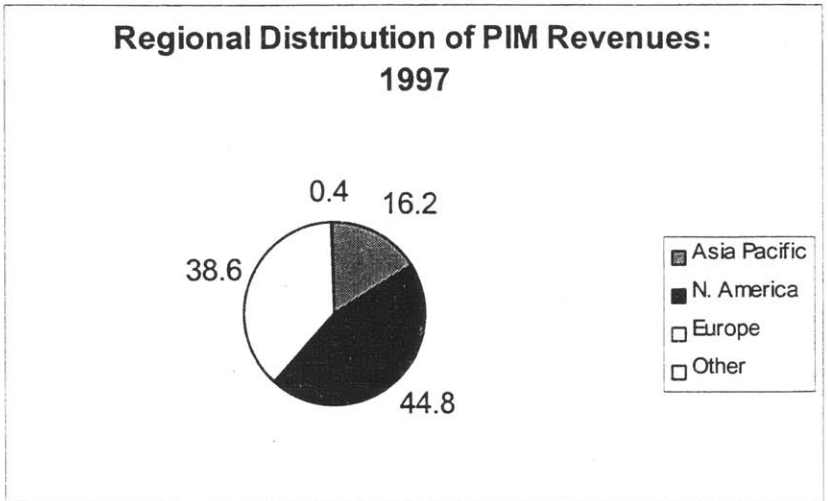
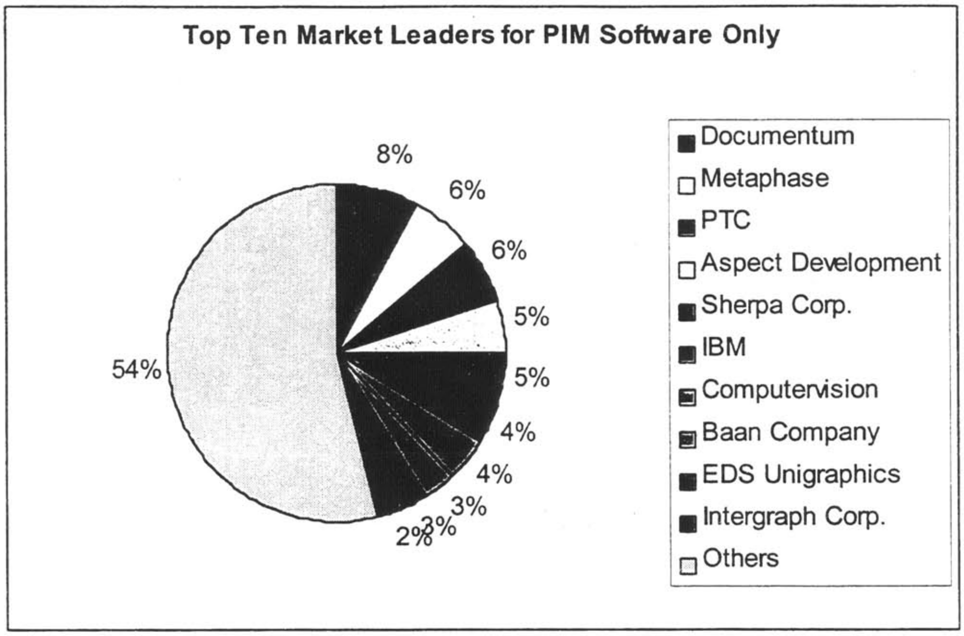



Figure 2.3.1-2: Regional Distribution of PIM Revenues: 1997

This worldwide market is being serviced by a fairly large number of PIM vendors reflecting a gradually maturing market in terms of the number of competitors. There are approximately 42 PIM vendors competing for a dominant position in the industry. As to be expected, the PIM vendor segment is highly fragmented with the market leader in software sales holding only about 8% and the top 10 vendors holding a combined share of only 46% of the market. The remaining 54% is shared by about 32 vendors! Since post-sales services are viewed as complementary assets, it is useful to view this data in terms of revenue from both software and services. There too the market is highly fragmented with the market leader holding just 7% and the top ten vendors combined holding only 43%. These two views are showing in Figures 2.3.1-3: Top Ten Market Leaders for PIM Software Only and Figure 2.3.1-4: Top Ten Market Leaders for PIM Software and Services respectively.




Figures 2.3.1-3: Top Ten Market Leaders for PIM Software Only

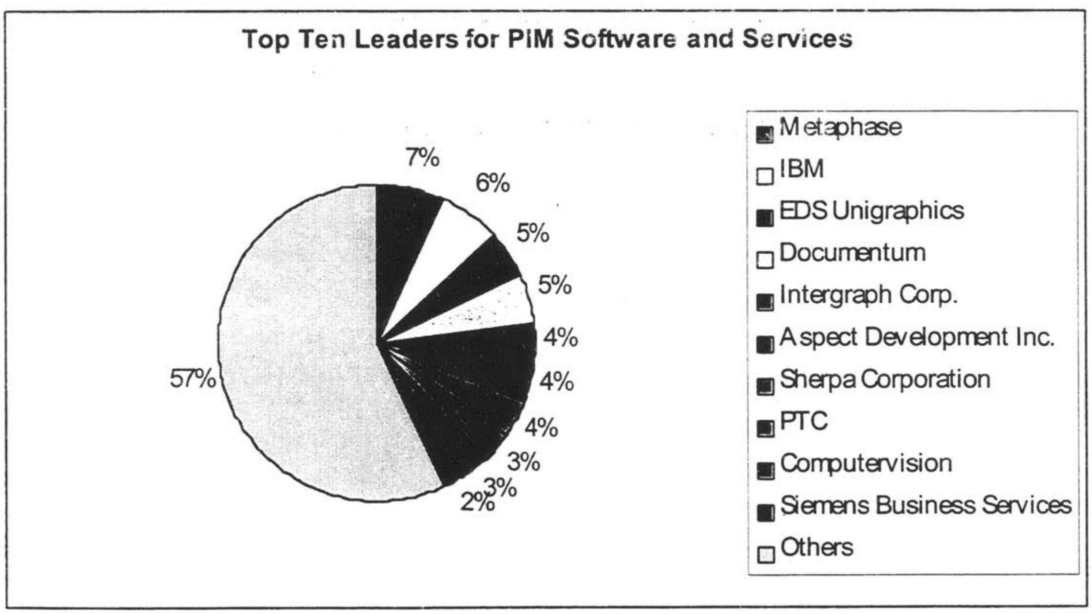



Figure 2.3.1-4: Top Ten Market Leaders for PIM Software and Services

The concentration ratio (percent of total sales accounted for by the 4 largest firms) of the PIM industry is 0.23 indicating a very low concentration. For ease of calculation, if we assume that the 57% portion of the software and services segment is shared equally by 32 vendors, the Herfindahl Index of the PIM industry is 280 indicating a very balanced size distribution.

Finally, due to the current state of PIM systems, value to the customer is created only after considerable post-sales customization. In order to facilitate that, a large percentage of a PIM vendor's assets consist of expertise in customizing its product - a very specific asset.

In summary,

- While there is a rapidly growing market in the PIM industry, there is also a very large number of competitors.
- There are market leaders, but no one vendor is the dominant player.
- Even though the firms are similar, the concentration ratio of the industry is low indicating the lack of opportunities for the players to coordinate and control the industry collectively.
- The Herfindahl Index is also very low indicating considerable rivalry stemming from a balanced market size distribution.
- Considering the percentage of revenues from post-sales PIM services as opposed to just software sales, holding such service-oriented assets is critical for success.

Clearly, we have a fragmented industry with no market dominance. Most requirements come from lead users who have predominantly been the automotive and aerospace industries. Since their operating environment is moving to a more collaborative one with suppliers and partners, so too must product offerings change to meet this need through support for collaboration, standards, interoperability and post installation configuration.

### 2.3.2 Presence of Substitute Products

As with most products, PIM systems face considerable competition not only from other PIM systems but from a growing number of substitute products as well. There are two products in particular that pose considerable threat to PIM Systems - Enterprise Resource Planning (ERP) systems and the Internet. In addition, PIM systems face minor competition from Component and Supplier Management (CSM) systems; however, it is becoming evident that there will be a gradual encapsulation of CSM functionality into the larger PIM domain to provide catalog type functionality eliminating CSM software as a competitor.

#### 2.3.2.1 ERP Systems

One of the greatest challenges facing manufacturing companies is the need to resolve the role of PIM and ERP in their organizations. ERP systems evolved from Manufacturing Resource Planning (MRP) systems that were geared for Inventory Control and subsequently for shop floor scheduling and coordination. ERP addresses the control and management of the entire manufacturing operation in areas that include purchasing, finance and engineering in addition to production. ERP systems coordinate manufacturing operations to ensure peak efficiency and have rapidly become indispensable to reduce manufacturing time and cost as well as to foster teamwork and collaboration.

PIM systems on the other hand manage product-related information throughout the enterprise including design geometry, engineering drawings, part files, etc. As noted previously, PIM systems are expanding to include other areas such as manufacturing, sales, marketing and finance.

The key area where the two systems come together is in maintaining product structure. ERP systems focus on defining parts and how they are *assembled* together on the shop floor. Included in this focus are views that drive manufacturing and assembly and therefore an orientation towards materials and production processes. PIM systems also focus on product structure but with a *functional* orientation towards the product's capabilities and how it may be configured. Since product structures are key to both ERP and PIM systems in defining the basic product definition for engineering and manufacturing, product structures are the primary link between the two systems. Integrating the two systems seems a natural next step. However, there is a constant battle between ERP and PIM vendors in terms of ownership of the ensuing processes, data and control.

The difficulties in integrating the two systems are enormous. Much of these difficulties arise from control and flow of information throughout the two types of systems, each of which has different ways of storing, accessing, exchanging and translating data. This is particularly difficult because ERP and PIM systems provide different views on the same information. As a result, ERP vendors are starting to offer PIM capabilities as part of their product offerings and PIM vendors are expanding their products to support downstream processes.

Figure 2.3.2.1-1: PIM and ERP Domains reflects this movement in the context of a generic product development process [adopted from Ulrich and Eppinger].

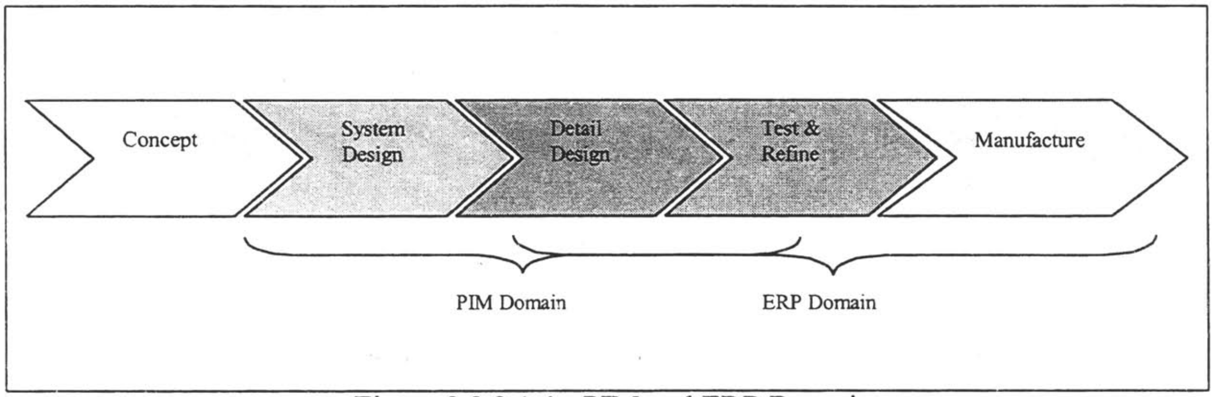



Figure 2.3.2.1-1.: PIM and ERP Domains

The impact of ERP Vendors will be discussed further in the section on Strategic Analysis of the PIM Industry.

### 2.3.2.2 The Internet

Over the past three years the Internet has introduced most to technologies and methodologies very similar to PIM. For example, one of the basic functions of PIM systems is to provide easy access to relevant data worldwide - this capability is just as easily provided through fairly simple applications developed for the Web. This has presented PIM vendors with an opportunity as well as an imperative. PIM systems can be positioned as a robust foundation for Web environments, but at the same time they need to provide the same capabilities, techniques and standards as the Web. So much so, that PIM and the Web now occupy the same positions in enterprise Information Technology (IT) architectures.

In summary,

- PIM systems face stiff competition from ERP systems (in 1997, for the first time an ERP vendor (Baan) became one of the top 10 PIM software vendors).
- PIM systems face competition from Web environments and applications.

PIM vendors need to focus on more upstream processes away from ERP turf, but provide a better integration with multiple ERP systems.

### 2.3.3 Buying Power

#### 2.3.3.1 Number of PIM System Buyers

The number of buyers continues to grow at a rough rate of about 10 - 12% each year. The majority of the buyers continue to be large manufacturing firms, particularly in the automotive, electronics and aerospace segments. The break up of the market for license revenues is approximately as provided in Figure 2.3.3.1-1: License Revenues by Industry. However, there is an increasing presence of non-manufacturing industries in the PIM customer market including the construction industry, complex facilities (such as airports and warehouses), process plants (such as oil refineries), power plants and distribution networks.

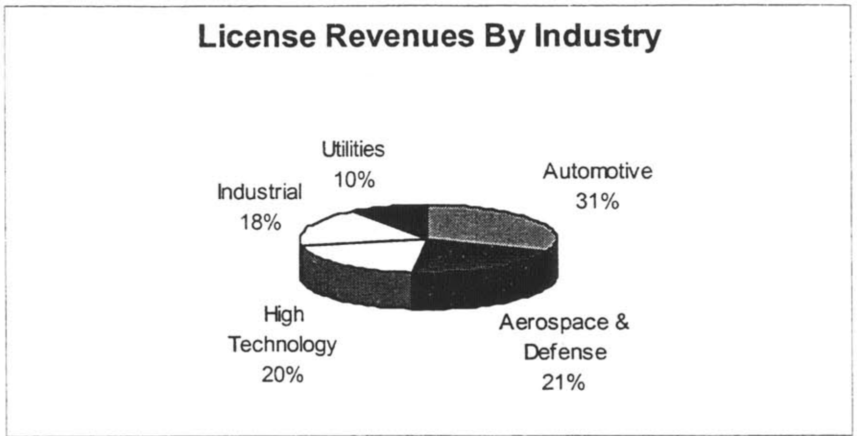



Figure 2.3.3.1-1: License Revenues by Industry

#### 2.3.3.2 Distribution of the Purchases

The distribution of purchases by buyers continues to be unbalanced. There are a few large customers that buy the majority share of the PIM software and service offerings. Once again these tend to be in the manufacturing industries. This clearly leads to a situation where the PIM vendors listen to their largest customers for the majority of their decisions on product direction. This is reinforced by the fact that the products' abilities are best determined through use with the large customer pushing the product to its limits. Figure 2.3.3.2-1: Influence by Customers reflects this.

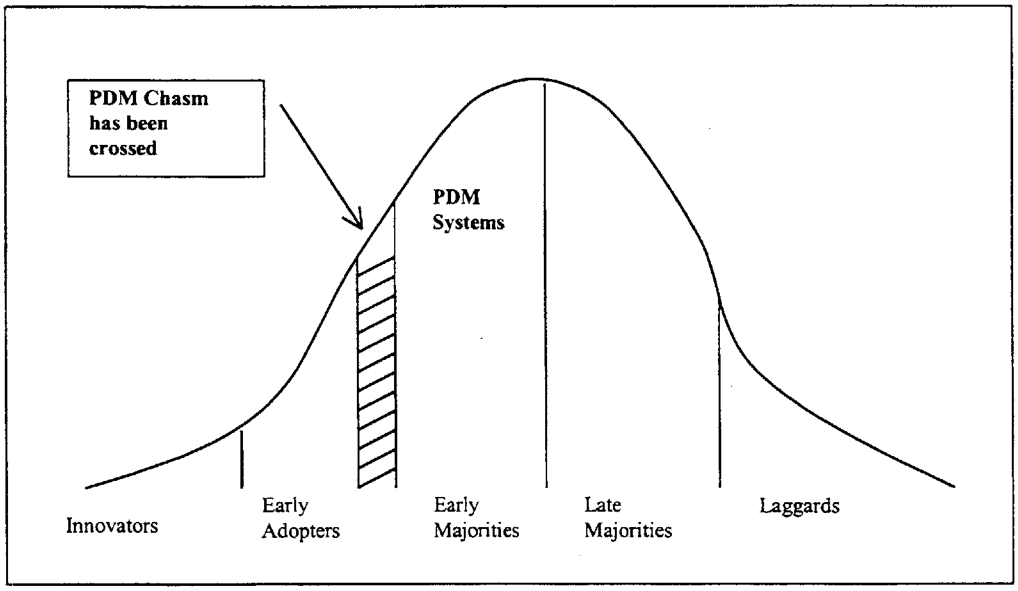



Figure 2.3.3.2-1: Influence by Customers

#### 2.3.3.3 Backward Integration

Finally, based on the current trend in most manufacturing organizations to buy rather than to make, there is a distinct move away from developing PIM capabilities in-house as opposed to purchasing the software. The rationale for this is that companies wish to invest only in core areas of their business, and typically, PIM development is not a core part of most engineering and manufacturing companies.

In summary,

- Buyer power is somewhat balanced by the lock-in or high switching costs due to massive customization and the lack of standardization.
- Product direction however, continues to be heavily influenced by a few large customers in the manufacturing industry.
- There is no driver for backward integration and therefore, the market will persist.

It is expected that automotive and aerospace customers will drive PIM tools towards collaboration since that is the nature of their business.

### 2.3.4 Power of Suppliers

There are no suppliers in the PIM industry. Most vendors are vertically integrated in that all aspects of the product - core technology, architectural foundations and existing functionality are developed in house. This may be contrasted with CAD, CAM and CAE vendors who do purchase certain key algorithms for various mathematical calculations.

Since PIM systems have had an architecture focus until now, there has been pressure to provide integration with various applications e.g. CAD software, view and markup software, etc. The vendors of these applications may be viewed as suppliers but since the relationships are typically win-win there is no net power either way.

In summary,

- Supplier power is non-existent.

### 2.3.5 Potential for Entrants

The PIM industry is a relatively new arena in IT. However, due to its rapid revenue growth and small capital investment, the industry seems attractive to new entrants. The large number of players in the PIM arena (42 in a span of 11 years) is evidence of the attractiveness of the market. Lastly, but perhaps the most important, is the legitimacy of the industry due to the entrance of the big ERP vendors into the PIM arena. Clearly, we have a new industry that, in spite of the large number of competitors, is still in its infancy with tremendous growth potential in profits and market size.

### 2.3.6 Size of Payoffs

The importance of PIM systems in product and process development is reflected in the revenue growth that the industry has seen since 1989 - almost a 20% year on year growth in revenues from both software sales as well as services. The new focus on smaller customers (to be discussed in the section on Strategic Analysis) is evidence of the acceptance of PIM in the mainstream IT industry. The payoffs are very large particularly because the technologies used by PIM systems are still relatively new leading to the potential for new entrants to leapfrog incumbents by applying the new technology in a better way.

However, entrants must realize that the payoffs although large, come from two distinct areas - sales of software and sales of services that include consulting, business process re-engineering, project planning, etc. As seen in Figure 1: PIM Market Size (1989 - 2002), the revenues from services far exceeds revenues from software sales. This requires investment in PIM expertise that may only be achieved over time or through the re-deployment of similar techniques from a related industry segment e.g. ERP.

### 2.3.7 Incumbent Reaction

The expertise in the PIM system that enables PIM vendors to offer services may be looked on as a very specific asset. While this expertise is not directly transferable to other industries, it may be applicable to other related industries e.g. ERP and CSM. This will result in the incumbent vendors protecting their market aggressively. The more a vendor invests in post-sales services i.e. customizations of the core product, the more the vendor is likely to react strongly. Almost all PIM vendors rely on services to augment their software sales.

### 2.3.8 Incumbent Reputation

While incumbent reputation is believed to be a minor factor in shaping company decisions on PIM system selection, it is not entirely absent. Most companies will team up with large and stable vendors to ensure that they will continue to have the support that they will need. Since companies tend to invest a large amount of money in PIM systems, vendor reputation is quite critical particularly with regard to the ability to deliver on the promised capabilities.

### 2.3.9 Economies of Scale

Once again this is viewed in the context of both software and services. Large companies are able to expand their operations globally and thereby reap the benefits of economies of scale. Smaller companies can not. An additional point to consider is the effort required for implementation e.g. ERP implementation is very labor-intensive, so economies of scale are hard to achieve.

### 2.3.10 Excess Capacity

Since this is a software product and the major portion of the revenue stream comes from post sales customization services, excess capacity relates to the availability of the appropriate expertise to realize value for the customer through customization and production use of the software. Current vendors are stretched to their limits to meet existing commitments indicating that there is room for additional capacity in the required expertise.

### 2.3.11 Sources of Incumbent Advantage

Contracts for software licenses and services form the predominant pre-commitment contracts. Most contracts are set up for extended periods of time resulting in a lock-in of the customers. Getting out of such contracts is difficult and time-consuming making this an important hurdle for new entrants. Very often the contract is for several years and includes evolution of the product in a certain direction on the part of vendors.

Learning-curve effects are not privately appropriable - they may be transferred between competitive products. No entry barriers exist since new entrants can learn considerably from the experience of incumbents. Spill-overs tend to be very high through key people switching companies and through third party consulting organizations. As an example, in 1997 the Chief Technical Officer and the visionary of a market leading PIM vendor left the company to join a competitor.

In summary, the barriers to new entrants are expected to be high and only surmountable by very large, well established companies because:

- Payoffs are large, but the payoffs will require a large investment in fairly specific assets i.e. expertise in product customization.
- Incumbent reaction will be strong since the investment in specific assets (expertise and customer relations) is very high.
- Incumbent reputation is expected to play a significant role in terms of having the ability to deliver on commitments.
- Economies of Scale are expected to be a barrier in light of the gradual move to a global position by most companies.
- Even though learning-curve effects are not very tightly appropriable and spill-over learning is high, building the required expertise takes a considerable amount of time.
- Pre-commitment contracts are likely to keep new entrants from a large portion of the market. PIM Products are "experience goods" resulting in high commitment and lock-in of customers.

Potential entrants must carefully analyze their capabilities along these dimensions and ensure that they are adequately equipped to enter this industry.

## 2.4 PIM Industry Analysis Conclusions

The PIM Industry is a very competitive arena with a large number of competitors resulting in intense rivalry and low coordination opportunities. While there is one market leader, there is no one dominant vendor. Substitute products provide stiff competition in the market with their vendors being large, well established firms. Buyer power is high due to an uneven distribution of sales; product direction is highly influenced by these few large customers.

Figure 2.4-1: Technology S-Curve and Diffusion Curve for PIM systems show where PIM systems are currently in terms of the technology and diffusion in industry respectively.

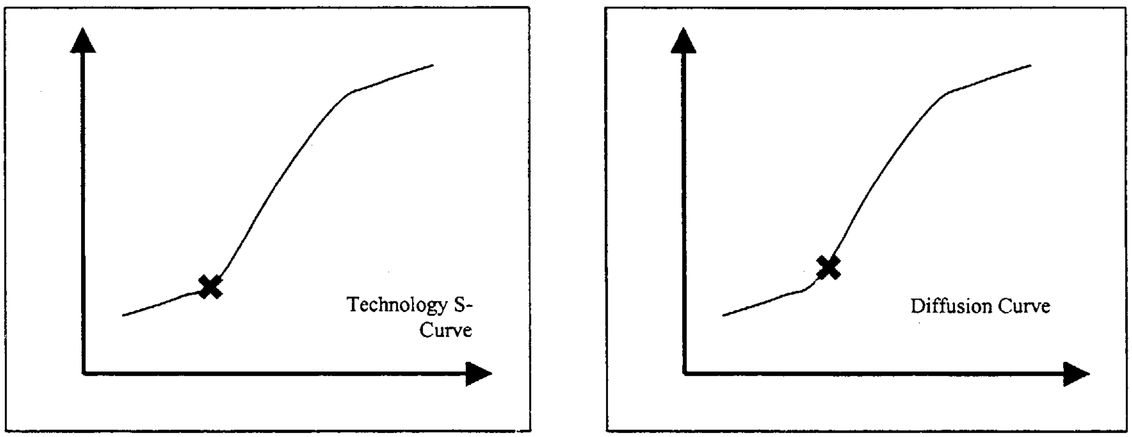



Figure 2.4-1: Technology S-Curve and Diffusion Curve for PIM systems

They are positioned at the threshold of the steep portion of the S-curve in both cases. The focus on architecture and core technology has prevented PIM systems from racing up the technology curve for end-user PIM applications. The focus on toolkits versus out-of-the-box PIM applications ready for use due to standard processes has prevented rapid implementation and thus, rapid adoption in industry. Due to the market fragmentation and as well as the supplier fragmentation it is difficult to get exact numbers of sales, licenses and services. This is further compounded by highly biased reports in the field.

To move up the S-curves, PIM vendors have to focus on collaboration across enterprises in support of the up-front PD phases.

## 2.5 Strategic Analysis

The PIM industry analysis conducted in the previous section helps in understanding the industry dynamics with regard to industry size, profitability, market segmentation and competition. This section provides an insight into the current state of the industry, the repercussions of past strategies, what the current strategies of the major players in the PIM industry are, and where it is likely to go in future.

### 2.5.1 Current State of the Industry (Customer Perspective)

The current state is analyzed in the context of the three biggest influences on the PIM industry - Are users realizing any value from the implementation of PIM systems, are PIM systems slightly off-target in terms of customer need and the influence of large, well established ERP vendors

#### 2.5.1.1 Is PIM delivering on its promises?

There is a general feeling in the customer community that PIM has not delivered on its promises. Even though PIM vendors have invested very heavily over the past two years in improving the core technologies of their products, this investment has not significantly improved the five important applications most often implemented by the customer community. There is no co-relation between investments in core PIM technology and improvements in end-user applications. In fact, vendors who have made minimal investments in core technology and architecture seem to be just as capable of developing and deploying meaningful PIM applications to end-users as those that have made very extensive investments in core technology [Source: D. H. Brown & Associates].

Interestingly, PIM vendors have fallen short of delivering effective applications because they have focused very heavily on developing architectures and toolkits as opposed to end-user applications. This is reflected in Figure 2.5.1.1-1: Strategic Focus of PIM Vendors below.

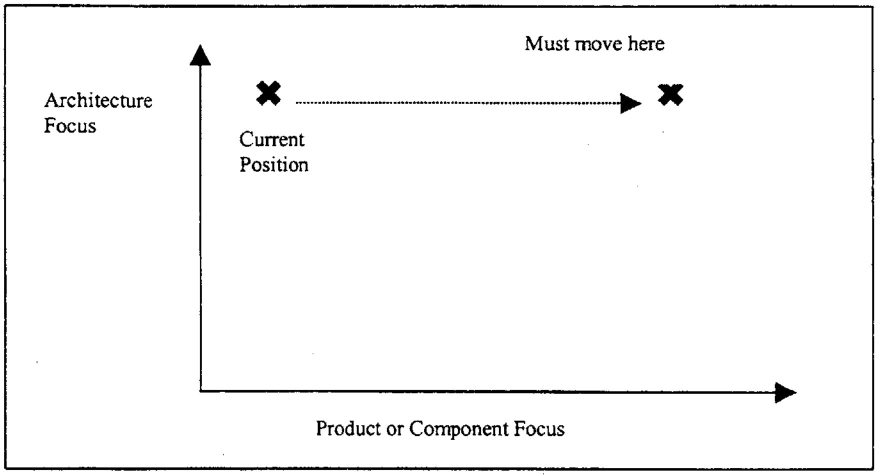



Figure 2.5.1.1-1: Strategic Focus of PIM Vendors

Users need and expect end applications to simplify and enhance their business processes. Such applications require a completely different focus and emphasis than the existing effort to design, develop and deploy PIM architectures and toolkits.

Two influences that have caused PIM vendors to continue to invest in core technologies are:

- PIM has entered the mainstream in large manufacturing organizations - this has resulted in greater pressure from these companies for such core issues as greater database distribution, communication facilities, middleware support, etc. These are systems issues that don't enhance usability.
- World Wide Web - as mentioned before in the section on substitute products, the Internet incorporates methodologies and techniques that are similar to PIM. This has put pressure on PIM vendors to bring their technologies in line with that of the Internet as well as to position their products as a foundation for Web environments.

As a result of these two influences, PIM vendors have focused more on core technology at the expense of user level applications. While building applications on a strong architecture with a robust toolkit does result in longer lasting applications, this may not have been the right strategy in the PIM industry. From the user perspective, applications that do not deliver significant end-user functionality are not worth developing and using. This is one of the reasons that directly affects customer's value proposition in investing in PIM systems. *The outcome is that customers have to not only invest in expensive PIM software but also in extensive customizations to get the software to do what they want.* These customizations tend to be a very expensive proposition due to the lack of PIM expertise in the market. Furthermore, in existing industrial environments where "change is constant", customizations developed one year are likely to be obsolete the next. Due to such incremental evolution, customers are saddled with very complex systems with high maintenance costs. Figure 2.5.1.1-2: Product - Process Application Focus reflects where PIM vendors have focused and where customers are focusing.

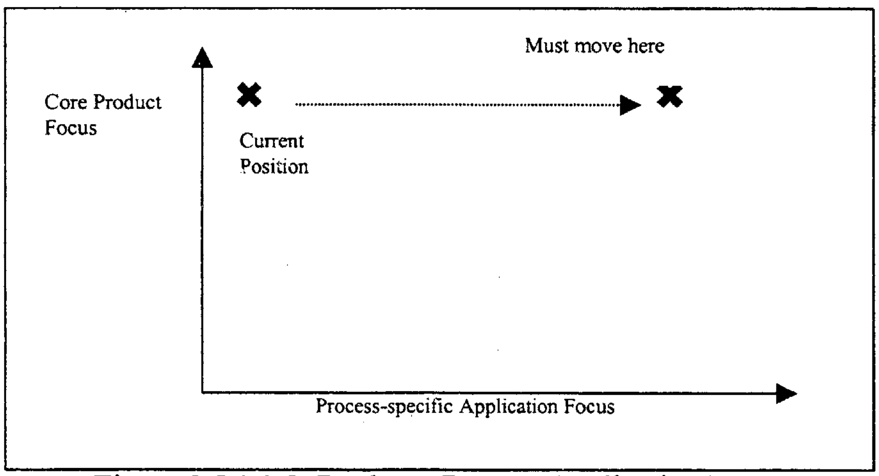



Figure 2.5.1.1-2: Product - Process Application Focus

***Example:*** One Automotive OEM currently has over 60 people involved in design, development and deployment of PIM solutions using Metaphase. This is a large percentage of the number of developers at Metaphase Technology Inc., one of the market leaders! The solutions still don't do what the users want, resulting in continued investment in on-going Metaphase development.

PIM vendors must shift from being product focused with a concentration of core technology and toolkits to being customer focused with process specific applications. Figure 2.5.1.1-3: Product - Customer Focus reflects the current status and where PIM vendors must move to.

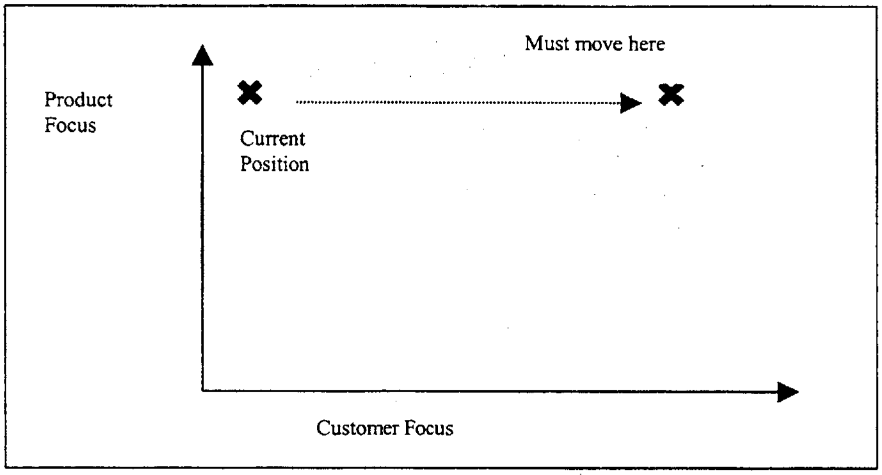



Figure 2.5.1.1-3: Product - Customer Focus

### 2.5.1.2 Have PIM Systems Missed the Mark?

Organizations are investing very heavily in PIM software customization. The example provided above is only one of many. If one views a generic product development process as being broadly divided into the Concept and Early Design, Detail Design/Re-Design and Production phases, PIM Systems have targeted the Detail Design/Re-Design phase since that phase is more defined and less dynamic. However, customers realize the most value when these systems are used during the Concept and Early Design phases. This is the other reason why they have invested and are continuing to invest very heavily to customize the product to use it where it is most beneficial. Figure 2.5.1.2-1: Product Development Stages reflects this [adopted from D. Burdick]. VPDM stands for Virtual Product Data Management (or VPIM for "Information"), that focuses on the upstream concept development phase.

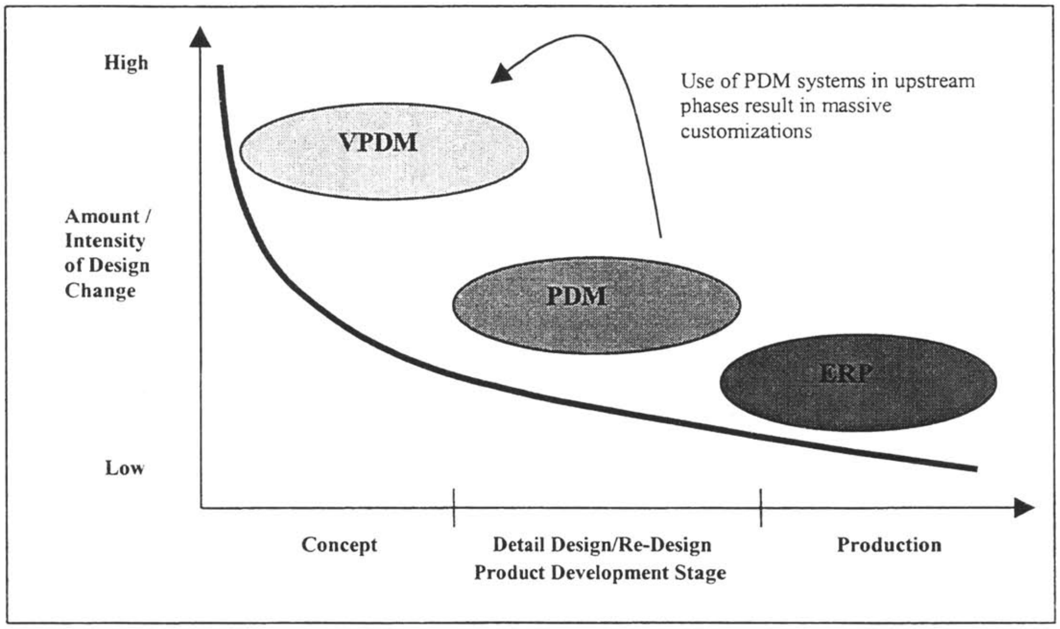



Figure 2.5.1.2-1: Product Development Stages and Role of PIM Systems [Adopted from Burdick]

Clearly PIM vendors must start to focus on the upstream phases of product development where the real need for data access and control is one of the most critical functions being that of collaborative product development. The processes, tasks and data remain highly dynamic, less constrained and more exploratory in nature during the early phases of PD, resulting in different functionality expected from a PIM system. For example, search capabilities during the early phases require the ability to scope multiple databases; during the later phases however, the data is more likely to be in one or two "Release Vaults" resulting in less need for multiple and remote database access. PIM systems are not geared towards multiple database access - the performance penalties are high. Users are forced to accept workarounds because PIM systems cannot handle the scoping of multiple databases. ERP systems would not be any better considering the very well defined state of the data that they process.

As a result of this analysis, PIM systems must move towards process specific applications that are focused more upstream where the true PIM value proposition lies. Given the current and future state of the customer environment (increased outsourcing and partnering), the most critical functionality that is needed is that of global, distributed collaboration - the ability to define, design, analyze, test, verify and manufacture products across an extended enterprise.

# 3 THE CURRENT BUSINESS ENVIRONMENT

## 3.1 Introduction to the Current Business Environment

This chapter discusses how requirements to support the current automotive business environment are pushing PIM software vendors upstream in the PD process.

The automotive industry is a very competitive one marked by very little growth and over-capacity. The automobile is gradually approaching a commodity with very little margins or product differentiation. The latter, which used to be achieved along multiple dimensions such as Quality, Design, Performance, Luxury, etc., is now very difficult to come by. On-going consolidation of independent companies into larger conglomerates is one attempt at surviving in a fiercely competitive industry where customer loyalty must be earned over several years. This has resulted in a need to reduce time to market substantially without compromising on Quality or other vehicle characteristics. The market is driving companies to increased innovation and killer products. Product Development continues to be one key area in which companies continue to derive competitive advantage.

## 3.2 Characteristics of the Changing Environment

The changing automotive business landscape is typified by the following characteristics:

- <u>Increased outsourcing of entire systems and subsystems</u> - Competitive pressures, as well as stockholder pressures for better returns, are forcing automotive companies to re-engineer themselves to focus on what they excel at. This is resulting in companies retaining those activities that give them a competitive edge and outsourcing the remaining to more competent suppliers or partners. Products are collaboratively developed across multiple organizations and enterprises. Roughly 40 to 70% of automotive content is designed and developed by suppliers and partners. The Original Equipment Manufacturers (OEMs) such as Ford Motor Company, General Motors Corporation, Toyota, Honda and Daimler-Benz are starting to focus at the system level and retaining ownership of vehicle level attributes. Each OEM as well as each of the enterprises in its supplier network has its own unique business processes and systems that support them. With the growing emphasis on outsourcing and market pressures for shorter time to market and innovation, there is an increased need for product development collaboration and coordination across the supply chain.

- Bi-directional Nature of Business Relationships - The very nature of the business relationship between OEMs and suppliers is evolving from static to dynamic, global and opportunistic. Enterprises are suppliers in some vehicle programs and are OEMs in others. An example of this is the Ford Motor Company - Mazda relationship where Mazda is a supplier on one program and Ford Motor Company is the supplier to Mazda on another. The implications of such bi-directional relationships are enormous when one considers the complexity of releasing sub-systems, systems and components via the OEM's business systems. To take the Ford - Mazda example further, the vehicle program wherein Ford is the OEM requires all systems, sub-systems and components to be released through Ford's complex network of business systems starting with WERS. Conversely, the vehicle program wherein Mazda is the OEM, requires systems, sub-systems and components to be released via Mazda's business systems starting with MIDAS. The existing processes and technology to support this are very complex and expensive to maintain. Such a relationship is discussed in Chapter 4 with regard to the AOC and POC joint venture. With such a growing diversity in the OEM - Supplier relationships, there is a need for rapid establishment and dis-establishment in the inter-enterprise connectivity of Product Development and Business Systems [B. Enslow and R. Schulte][D. H. Brown Associates][Jeffery F. Rayport and John J. Sviokla][Sherbenou and Vedapudi].
- Temporary and Permanent Partnerships - The on-going consolidation in the automotive industry will continue to result in partnerships across multiple organizations and systems. Ford partnered with Mahindra & Mahindra of India for a period before getting a foothold in the subcontinent and then dissolving the partnership to establish an independent presence. Ford's relationship with Nissan to develop the Mercury Villager is another example of a partnership for convenience. With the new relationship between Renault and Nissan, this relationship will no doubt be re-examined. Furthermore, Ford, Mazda and Volvo have plans to participate in a vehicle program with product differences being based

on the their respective brands. Increased returns on investment will only be possible if there is a substantial degree of commonality in vehicle content as well as in the technology and processes that develop the vehicle. As an example, Ford and Mazda use I-DEAS Master Series and Metaphase as their CAD, CAM and PIM tools. On the other hand, Volvo uses CATIA and ENOVIA. Similarly, GM uses Unigraphics and IMAN while Toyota uses an internally developed tool set. Lastly, each of the brand specific vehicle lines will be released through the company's business systems. Such partnerships and diversity in partner infrastructure requires a higher degree of collaboration and commonality across the partner organizations.

- Supplier and Partner Data Independence - The dynamic nature of the OEM and supplier relationships as well as the suppliers' relationships with multiple OEMs, requires a higher degree of data and process independence for the OEMs and suppliers to be as efficient and nimble as is desired. Suppliers who are partners on one vehicle program are competitors on the outsourcing decisions of another. For example, in AOC's current PIM implementation, all supplier data resides in the AOC PIM system. This has required the implementation of complex security mechanisms to prevent unauthorized access by competing suppliers. In addition to increased complexity in the data architecture, this has resulted in an increased volume of work-in-process data in AOC's systems. This requires a more distributed PIM architecture capable of supporting collaboration across the supply chain without being dragged down by expensive security and other connectivity and legal measures.
- Globalization - The increasing global nature of the automotive business fueled by global partnering is creating the need to support globally distributed product development teams that require data and process support close to them. As an example, AOC now has product design centers in North America, England, Europe, Australia and Asia. Competitive pressures have resulted in higher and more aggressive reusability targets even across vehicle platforms. The implications of such geographically distant design centers and increased partnering across these design centers is requiring a greater degree of connectivity and collaboration particularly as local suppliers are being sourced for global partner programs. The lack of appropriate collaboration infrastructure to facilitate fast product development will result in costly workarounds that will only inhibit the company's

ability to establish a leadership position. An example is the just replaced AOC - POC CAD Data Exchange that required a complex and expensive process that was expensive to maintain.

- Technology Enablers - Technology advances such as the Internet are changing the nature of business relationships [Mike Gilpin]. The paradigm of being able to access data anywhere in the world without requiring knowledge about where it is located, and yet being subjected to the local security measures is starting to spill over into the product development arena. The implications of such a paradigm lie in a more distributed PIM architecture with local controls, making a more centralized architecture outdated and highly inadequate to support the business environment.

The changing automotive business environment can be examined in terms of the automotive business paradigm, technological evolution and automotive business relationships [adopted from Dave Burdick, Gartner Group]. Clearly there is an emerging change in the business model as we move into the next millenium. "Single Domains" characterized PIM architectures through the '80s and up to the mid-90's with a "Reactive" paradigm to product development. The rest of the '90's have been characterized by the incorporation of Supply Chain Management with a more "Proactive Inter-enterprise Notification" paradigm. It is expected that the future starting from the year 2000 will be characterized by an emphasis on Supply Chain Collaboration rather than mere "Management" with a more "Collaborative" paradigm. These shifts in PIM architectures are summarized in Table 3.2-1 below.

| | 80's - mid-90's | 1995 - 2000 | 2000+ |
|---|---|---|---|
| **PIM Characteristic** | Single Domains | Supply Chain Mgmt. | Supply Chain Collaboration |
| **Operating Paradigm** | Reaction within a single enterprise | Proactive Inter-Enterprise Notification | Collaboration across the supplier and partner network |

Table 3.2-1: Business Environment Paradigm Shifts

The Reactive paradigm is one in which users must seek out the activities that pertain to them, while in a Proactive Inter-Enterprise Notification paradigm, users are informed of certain activities that are of interest to them. The paradigm shift in the automotive business environments described above, has required a corresponding shift in technology requirements. The technology shifts corresponding to these business environment shifts may be analyzed along data architecture, interaction mechanism and application integration dimensions.

The Single Domain PIM architecture was characterized by the data structures being completely contained and "owned" within the applications. The application owner designed the data structures for operation within the execution space of the application. The interaction mechanisms by users of such PIM systems involved standard e-mail. The applications were integrated using point-to-point translators, an inefficiency highlighted by [Jolliffe, Vedapudi, Devlin and Louch].

The Supply Chain Management PIM architectures, on the other hand, are characterized by the data structures being created in the context of a single (possibly) Federated PIM system with the same data model. While multiple systems may exist in the federation, all the systems have the same data model, as in the AOC. The interaction mechanism involves a combination of process steps and subscription to changes. The applications are integrated into a pre-defined integrated data model [Bsharah]. In some cases the data model is the union of the individual application data structures and in others, the data model contains only common data elements augmented by elements required for the integration. The AOC's existing PIM implementation incorporates a consolidated data model that has common elements of applications that have been integrated e.g. the mechanical CAD assembly structure from the CAD authoring tool and the data types and attributes needed to support Manufacturing and other custom PIM applications. The interaction between various design teams is based on process steps where required data is shared at process milestones i.e. not very often.

It is expected that the Supply Chain Collaboration PIM architecture will require data to exist across multiple installations or enterprises such as the entire supplier and partner communities in AOC's extended enterprise. The typical interaction mechanism is expected to be one of Publish-and-Subscribe and through federated processes - independent processes that are integrated in a higher level process that spans organizational boundaries [D. H. Brown

Associates, Inc.]. Users will subscribe to a variety of PIM events for specific types of data. This subscription will trigger a notification every time that event occurs. For example, a CAD designer may subscribe to new versions of a specific part. When a new version is created, the CAD designer is immediately notified. The applications will be integrated using XML/EAI adapters or PIM Enabler layers. Table 3.2-2 below summarizes this discussion on the supporting technology evolution.

| | Single Domain | Supply Chain Mgmt. | Supply Chain Collaboration |
|---|---|---|---|
| **Data Architecture** | Data exists within the application | Data exists within a single Federation of common data models | Data Exists across multiple enterprises |
| **Interaction Mechanism** | E-Mail and Phone | Process Steps and Subscription to Changes | Publish-and-Subscribe |
| **Application Integration** | Point-to-Point Translation | Pre-defined consolidated data model | XML/EAI |

Table 3.2-2: Summary of Technology Evolutions

As discussed above, the nature of automotive business interactions has changed substantially. These may be examined based on the Organizational Relationship, Interaction Mechanism and Business Integration Models and are further discussed in Chapter 5.

The Single Enterprise model was characterized by a disconnected and static organizational relationship between automotive OEMs and suppliers. Long term relationships were set up with suppliers but even so, these relationships were intentionally kept at a distance [B. Enslow]. There were very few relationships between the suppliers themselves resulting in a one-to-one interaction mechanism between the OEM and each of its suppliers and the business integration model involved manual mechanisms [B. Enslow]. As an example, Electronic Data Interchange (EDI) was restricted to the production and manufacturing planning domains.

The Supply Chain Management model, as is currently in place, continues to be static involving long term relationships albeit with a more strategic flavor i.e. unified strategic plans, accountability and joint ownership characterize these organizational relationships. The interaction mechanism is one-to-many [D. H. Brown Associates] with the requirements for a single OEM and multiple suppliers being defined in the same PIM architecture [Jerre Sherbenou and Manu Vedapudi]. AOC's current implementation has all its PIM capability provided in its one enterprise PIM system. Suppliers are granted access to the AOC PIM system with each of them storing their data and conducting their product development via the single system. The business integration model may be characterized as being a single Hub-and-Spoke [Jeffery F. Rayport and John J. Sviokla].

The Supply Chain Collaboration model will involve multiple dynamic and sometimes transient relationships with suppliers that will be driven by innovation and competitive pressures. The number of long-term partnerships between OEMs and will gradually reduce to be replaced by more opportunistically driven ones [Bill Gates and Collins Hemmingway]. Partnerships between OEMs will increase as the automotive industry moves towards greater consolidation to relieve the competitive pressures. The interaction model will be one of many-to-many as is characterized, for example, by Ford's new relationships with Mazda and Volvo. The business integration model will be one of being loosely coupled (with each relationship being directionally aligned but not necessarily requiring the same tools and processes). To carry Ford's example further, it is quite conceivable that Ford, Mazda and Volvo may continue down a path of a single PIM solution paradigm, but each may retain its own processes. The emphasis will be on the loose integration of processes and systems rather than on use of the <u>same</u> processes and systems [Jolliffe, Vedapudi, Devlin, Louch]. These are summarized in the Table 3.2-3 below.

| | **Single Domain** | **Supply Chain Mgmt.** | **Supply Chain Collaboration** |
|---|---|---|---|
| **Organizational Relationship** | Separate and Static | Strategic and Static | Dynamic |
| **Integration Mechanism** | One-to-One | One-to-Many | Many-to-Many |
| **Business Integration Model** | Manual | Hub-and-Spoke driven by unified data model | Loosely Coupled |

Table 3.2-3: Summary of the Automotive Business Interactions

## 3.3 Summary of Business Environment

The emphasis in the automotive industry, exemplified by AOC's business environment evolution, is moving from Supply Chain Management to Supply Chain Collaboration. Automotive product development competitiveness is shifting from market share to market size as demonstrated by AOC's financial goals for 1999 and 2000 (i.e. higher returns due to top line growth). The product development strategy itself will shift from shorter time-to-market to more innovative products that engage the consumer's senses. The use of IT will shift from data sharing to knowledge based, collaborative product design and the product development processes themselves will shift from concurrent engineering within an enterprise to collaborative engineering across the extended enterprise. Finally, organizational focus will shift from purely cross- functional teams within an enterprise to inter-enterprise, distributed teams collaborating in a single, common environment. AOC currently has a vehicle program that is being developed in four separate design centers located in Europe, England and Asia. Members of the vehicle program team (including suppliers) are distributed across these centers. Ford, too, indicated that the majority of its programs in the future will be conducted through such collaboration across enterprises [Bill Wilkins].

Agility and flexibility will be derived from speed of adding not whole products, but innovative features to products through the leverage of new supplier capabilities and flexible processes across supply chain. Successful automotive companies will be ones that will have developed a core competency in collaborating across the supply chain [B. Enslow and R. Schulte].

Supplier and Partner relationships will be established based on innovative suppliers, increased component function and the ability to collaborate rather than simply work in a 'Black Box' mode. Chrysler is known to have the lead in such a competency, although the collaboration is more of the "black box" variety than true collaboration with joint design ownership. The polarization or "flattening of the supply chain hierarchy" between OEM and suppliers will reduce much more as suppliers and OEM take on more joint responsibility and accountability.

A critical enabler for such a shift in business models and operating modes will be ability to put in place successful collaborative environments. There is a need for a PIM architecture and supporting functionality to support this shift from a vertically oriented PIM architecture to a more horizontally oriented PIM architecture that is more aligned with business processes.

## 3.4 Extended Enterprise Collaboration

Given the discussion above, the Figure 3.4-1 below is an attempt at showing what product development collaboration is across the extended enterprise [adopted from "Collaborative Product Commerce", D. H. Brown]

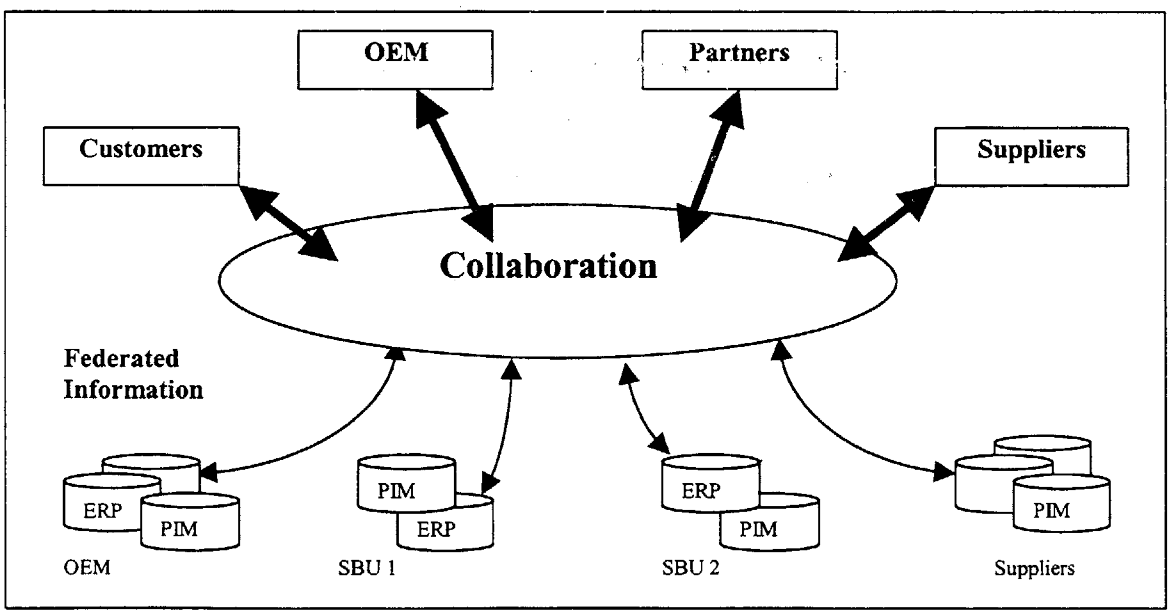



Figure 3.4-1: Collaboration across the Extended Enterprise [adopted from D. H. Brown]

As the figure and discussions above show, the data architecture in the current automotive business environment is rapidly moving away from a centrally oriented architecture to a more distributed and 'Federated' architecture. Federated architecture is one in which the individual installations (e.g. supplier PIM installations), while being valid on their own, also combine to form the environment for a higher level organization (the OEM Extended Enterprise). From a business process standpoint, the move to Federated Data Architecture is driven by a move to a Federated Process Model to support the collaborative business interaction.

### 3.4.1 Levels of Federation to Support Extended Enterprise Collaboration

There are different levels of federation in the automotive industry [adopted from Collaborative Product Commerce, D. H. Brown Conference] which collectively provide the case for a move to composite technology.

- Federated Information - This involves several PIM installations considered to be in the same enterprise. The data in external PIM systems is brought into the local installation through a "Proxy Object" and presented as if it were a local object. Very simplistically, this is a pointer to the "real master object" in the external system. A Federated Product Structure is an example of how this might be used. AOC has prototyped the use of Federated Product Structure between PIM systems in the U.S. and Europe.
- Federated Application - This includes the use of various application software that are capable of operating on external proxy objects. The PIM system would establish communication with the external system and bring back data in a proxy object. This would be inadequate without application logic to process these proxies. AOC uses this concept of proxy objects obtained from external systems in its distributed database architecture - when some of the databases are not in the current scope of operation, the PIM system uses proxy objects to indicate external data. There are guidelines that must be adopted in ensuring that applications successfully process proxies - applications need to be designed up-front for proxy processing, the source application or PIM system provides the access control rules and stipulates which data subset must be public, the applications must be able to communicate the creation of additional relationships to the proxy objects, etc.

- Composite Application - Information from multiple systems is integrated into a single view and operated on by an application. This requires a data model that allows the integration of data from disparate systems before processing can occur. The difference between this level and the Federated Application Level is that in this level the actual data is brought over without the use of proxy objects. As an example, the Federated Application Level is adequate when viewing different configurations of a vehicle at the Meta data level; the actual integration of supporting CAD data for viewing in a CAD authoring tool would require a Composite Application Level of federation.
- Composite Business Object - This involves the use of transient objects composed of data from multiple systems and methods that act on that data. Very typically, business objects are defined in terms of business processes. AOC is currently defining some composite business objects with a view to piloting them in the near future [Bsharah]
- Federated Business Process - These are business processes from multiple business organizations that are interwoven into a single extended enterprise process. This level of federation allows individual suppliers and partners in a collaborative activity to follow their business process with support from their underlying PIM architecture.

In conclusion, the automotive business is moving quickly towards collaborative product development across multiple, rapidly changing departments, organizations and systems. Product information will become increasingly federated across the supply chain requiring PIM support for federated business processes. Automotive business relationships (OEM - supplier, OEM - OEM and supplier - supplier) will be much more dynamic and opportunistic. The relationships will evolve from a "supply chain" to a "collaborative chain" for product development. There will be need for a PIM architecture that enables such a business environment.

# 4 XYZ Case Study - PIM Lessons Learned from the XYZ Partner Program between Automotive OEM Company and Partner OEM Company

This chapter summarizes the lessons learned from use of the previous and existing PIM infrastructure to support Partner Programs (joint venture between two automotive OEMs). The introduction summarizes the evolution of the XYZ Joint Venture Program between Automotive OEM Company (AOC) and Partner OEM Company (POC) by discussing the original program intent, how the automotive business dynamics influenced a change in the program intent and how this change has resulted in new requirements for a PIM infrastructure. The major issues experienced by the 2000 model year XYZ Partner Program are captured in the table that follows the discussions. The information provided below is summarized from interviews with members on the XYZ Partner Program.

## 4.1 Introduction

In the early nineties, AOC's strategy for the Asia - Pacific market was based on acquiring a controlling share in the then ailing POC in Asia and using its assets to penetrate the Asia Pacific markets. POC's assets included its manufacturing facilities, distribution channels, supplier infrastructure, a large presence in Asia and a vehicle engineering process that had very short product development cycles. Having established such a relationship, AOC was determined to bring the two companies closer together as quickly as possibly.

By the mid-nineties, the Sport Utility Vehicle (SUV) market segment had grown rapidly with AOC dominating the light SUV segment. Customer feedback highlighted the fact that interest in SUV's would spread to other vehicle classes such as the large and compact vehicles. In order to continue to dominate the SUV market, AOC had to expand its SUV lineup to include large and compact sizes. Since AOC already had a large vehicle platform, it had no hurdles in introducing large SUV's. However, with no similar platform to build on, AOC was seriously behind in the compact SUV segment. Competitors were already establishing several vehicle programs directed at this segment e.g. Toyota RAV and Honda CRV. POC too had commenced on development of a compact SUV but had not committed to taking it to production.

## 4.2 Chronicle of the XYZ Partner Program

The following is a chronicle of how the XYZ partner program was established and evolved to meet the needs of the market. The intent is to highlight the dynamic nature and complexity of partner programs:

- To leverage its business relationship with POC and respond to the SUV market, AOC established a joint venture program with POC called the XYZ JV program. The JV was a typical "one-dimensional" joint venture (one entity being the supplier and the other being the OEM), with POC being the Lead Vehicle Engineering Activity (LVEA) and AOC the Lead Vehicle Manufacturing Activity (LVMA) i.e. POC would engineer the vehicle, while AOC would assemble and manufacture it.

- The target market was North America with AOC's plant being the manufacturing facility.

- Sourcing would be done to AOC's US suppliers since AOC was the LVMA and the manufacturing facility was in the US.

- Since the program's suppliers would be US based, sourcing would be done using AOC's business systems only. After considerable negotiation, POC agreed and had its engineers trained in AOC's business systems. This caused a change in POC's engineering process since data now had to be released in a non-legacy format and to non-legacy systems. This decision added time and cost to the original engineering budget.

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- The program was further complicated by the attempt to use a single development process. Both POC and AOC had vastly different processes and had to arrive at a middle ground on several issues in order to use the common design and analysis tools. Examples include:

1. AOC vehicle programs freeze designs early to support prototype builds while POC does not believe in freezing designs early. They continue to iterate well beyond the prototype stage. There was considerable resistance on both sides to changing their approaches due to timing and resource targets as well as a lack of the PIM infrastructure to support such changes. This is predominantly because of differences in the supplier relationships at POC and AOC. POC has a smaller supplier base although choices are numerous. POC has much stronger control and power over its suppliers. They will accept late changes and increased iterations in design specifications. POC's suppliers can respond in a timely manner - they have to otherwise POC will change the supplier. AOC, on the other hand, has a large supplier base with less power over them. AOC's US suppliers demand more time and advance notice and will not accept late changes without substantial increase in costs. AOC's US suppliers cannot respond as nimbly as POC's suppliers and don't really have to. Due to capacity constraints and business requirements, it is not easy to find well-qualified suppliers in the US.

2. The program experienced a very large number of change notices. Changes were driven by different and changing market requirements for both programs. AOC vehicle programs prefer change management processes that involve vehicle level updates at program milestones while POC prefers rolling or incremental builds.

3. At the time the XYZ program was kicked off, POC had a paper based release process for its supply base, while AOC had an electronic releasing process.

4. Organizational interaction was complicated because typical PD functions resided in different organizations within POC and AOC. POC prefers a single point of contact for all issues related to the program, while AOC was comfortable with multiple points of contact with different organizations. Therefore, the XYZ Consolidation Center was

set up to be the sole point of contact for all XYZ joint venture issues. US suppliers and AOC would send data and parts to the XYZ Consolidation Center; the XYZ Consolidation Center would then forward it on to POC; POC in turn would interact with the XYZ Consolidation Center. The impact was a 14-day addition to all interactions.

5. The Joint Venture process had to be re-designed to account for the move away from a single-dimension program.

6. Cultural differences forced decisions and workarounds one way or the other. As an example, POC's tendency to avoid dispute caused them to agree to several AOC requirements e.g. learning the AOC business systems. The use of US based suppliers for POC's Asian Assembly Plant forced US suppliers to use dual language processing.

The result of such a relationship and infrastructure was that the program had dual design and engineering systems and dual release systems to support the sourcing activities in the US and Asia.

## 4.3 Key PIM Issues Experienced

Table 4.3-1 summarizes the key PIM issues experienced:

| # | Issues |
|---|---|
| 1 | Different design, engineering and business systems that required complex data manipulation and conversion |
| 2 | Separate design, engineering and business communities that operated in different environments. Consolidation of the data always requires re-assembly and is an additional and explicit step |
| 3 | Inadequate change control and communication of changes causing designers and engineers at different sites to work on incorrect versions of the data |
| 4 | Increased time to communicate and transfer design changes (conducted only at milestones) |
| 5 | Different supply bases on different systems |
| 6 | Interaction between suppliers and OEM's was very difficult due to different and inadequate infrastructure |
| 7 | IT infrastructure did not support the use of different processes |
| 8 | Poor system performance to transfer bulk data |
| 9 | Difficult to implement single administrative guidelines and cooperation for infrastructure |
| 10 | Poor IT support for data security |
| 11 | No support for requirements tracking (relations to the designs) and cascade |
| 12 | Very high volume of data transfer/exchange for each interaction |
| 13 | Lack of efficient access to carryover data from other vehicle programs |
| 14 | Changing nature of the business relationship i.e. gradual move from "Black Box" development (one-dimensional joint venture) to "Collaboration" (multi-dimensional joint venture) product development |
| 15 | Suppliers operated in silos with consolidation only occurring at milestones causing incorrect versions and designs to propagate |
| 16 | Lack of centralized control of the design and engineering environment allowing ad hoc relationships to data |
| 17 | CAD and CAE conducted in different environments |
| 18 | Partner interaction was never consistent - the same interaction was sometimes conducted at the work-in-progress level (FTP) and sometimes at the more formal enterprise level (PIM System) |
| 19 | Inadequate support for global collaboration particularly between US based suppliers and their counterparts in Asia |
| 20 | Hub and Spoke architecture that required the POC or AOC to manage supplier data |
| 21 | Lack of support for Manufacturing tools in the CAD environments |
| 22 | Different part numbering formats |
| 23 | Different security models |
| 24 | Strong manufacturing/supply technology tie-in to legacy systems e.g. AOC's suppliers know to deal with AOC part numbers; with POC being the LVEA, POC engineers used POC part numbers; since sourcing was done through AOC's systems which could not handle POC's part numbers, the program was forced to use workarounds. |

Table 4.3-2: Summary of Issues

## 4.4 CAD Data Exchange Between AOC and POC

This section uses the complex issues around CAD Data Sharing as a framework to highlight the increasing need for deeper collaboration. The XYZ CAD data sharing process underwent a substantial evolution through 3 stages.

- **Stage 1 -** The XYZ program started with AOC and POC using two completely different CAD systems. During the preliminary stages of the program, drawings were scanned and sent to each other via mail.

- **Stage 2** - This progressed to Data Conversion where the CAD data was shared on demand by sending the CAD files to the recipient via FTP using AOC's custom data sharing system. As with all translations, there was loss of data that had to be redrawn using hard copies of the part drawings that were mailed to the XYZ Consolidation Center as the master. The following steps are examples of the data exchange process.

**a) CAD File from POC to AOC**

- ♦ Communicate with POC Vehicle Program Leader via collocated counterpart (or XYZ specific Communication Form)
- ♦ Vehicle Program Leader completes CAD File Transfer Form: From POC to AOC/Supplier
- ♦ Systems Administrator informs Supplier upon file's arrival to custom data management system
- ♦ Recipient retrieves CAD file from custom data management system to local workstation

**b) CAD File from Shared CAD Library on Custom Data Management System**

- ♦ Communicate with POC Vehicle Program Leader via collocated counterpart
- ♦ Reference Shared CAD Data List (Tracking Log)
- ♦ Recipient retrieves appropriate files from custom data management system

**c) CAD File to POC**

- Communicate with POC Vehicle Program Leader via collocated counterpart
- (or XYZ specific Communication Form)
- Supplier completes CAD File Transfer Form: From AOC/Supplier to POC
- Store CAD file in custom data management system using 'External supplier' or "I" (AOC internal) status
- Inform custom data management system Administrator of file name, status, and intended recipient
- Fax CAD File Transfer Form to XYZ Data Administrator and Vehicle Program Leader

- **Stage 3** - This involved the switch to common CAD, CAE, CAM and PIM tools. Both POC and AOC adopted the same tool suite for CAD, CAM, CAE and PIM, providing the ability for AOC and POC to exchange CAD data through a combination of FTP and the PIM system

The following discussion serves to highlight a complex process that stems from limitations in the underlying tool set. The CAD tool selected is I-DEAS Master Series and the PIM tool selected is Metaphase. I-DEAS has its own local data management system called Team Data Manager (TDM). The TDMs were configured to include a template that reflected the company's logical breakdown of the vehicle (AOC's structure). AOC ran TDMs with the AOC templates while POC ran their TDMs with POC templates. Due to technology limitations, TDMs had to run the same template to import data i.e. a TDM can only import data that has been exported from another TDM using the same template. This caused a complex data exchange process. As an example, sending data between AOC and POC during the three phases (Development, Design Review and Release) involved the following steps:

- **Development Phase** - During the development phase, it is assumed that only complete assemblies would be required for exchange with POC.

**POC Requires AOC Data**

1. If the POC Engineer does not know part numbers then he sends e-mail to the AOC counterpart. (If the POC Engineer knows what parts are required then he fills out the Transfer Form.)
2. If AOC Engineer receives e-mail request, AOC Engineer interprets POC request and enters relevant information onto Transfer Form. If AOC Engineer receives Transfer Form notification, the Transfer form is opened.
3. When AOC Engineer is finished, the Transfer Form is saved. Before concluding, the AOC Engineer sends e-mail to the AOC Data Administrator selected on Form.
4. AOC Data Administrator opens Transfer Form and does one of the following :
   - If the data exists only on TDM's, export data and stores into FTP-PAH. The filename is then entered onto the Transfer Form and the form saved.
   - If data exists in the PIM system, then the word 'PIM' is entered in the Project/Library field. When all entries are done, the form is saved.
5. E-mail is sent to the POC Engineer selected on Form.
6. POC Engineer opens Transfer Form and adds storage locations etc and saves the Transfer Form and selects 'Send Mail' before closing the form.
7. E-mail is sent to the POC CAD Dept.
8. POC CAD Dept. opens Transfer form uses the information supplied to pull the data from the PIM system and/or FTP/PAH. The data is stored/imported into the POC TDM and the POC Engineer informed.

**AOC requires POC Data**

1. The Initial contact is made via e-mail from AOC Engineer to POC counterpart.
2. POC Engineer interprets AOC request and enters relevant information onto CAD File Transfer Form, saves it and sends e-mail to POC CAD Dept.
3. POC CAD Dept. opens Transfer Form, exports the requested data and stores it into FTP-PAH. The filename is entered onto the Transfer form and saved. Prior to closing the form and e-mail is sent to the AOC Data Administrator.

4. AOC Data Administrator opens Transfer Form and uses the information supplied by POC to import the data from FTP-PAH. The data is stored onto the AOC TDM and the Data Administrator fills in the Transfer form with part numbers and locations and saves the form. Before closing the form, e-mail is sent. After the POC data has been imported into the AOC TDM and placed into valid projects and libraries, it can be checked into the PIM system by using a PIM system interfacing software tool. The POC part numbers need to pass the AOC Part Number Standard in order for the check-in to be successful
7. E-mail is sent to the AOC Engineer.
8. AOC Engineer opens Transfer form to find part numbers and location of the data.

- **Design Review Phase (One Way Only - AOC to POC)** - If a concern is raised on a part used by AOC and POC (common parts & almost common parts) and the design is changed by AOC, the revised design must be sent to POC for their concurrence.

1. AOC Engineer enters POC counterpart and relevant information onto CAD File Transfer Form.
2. When AOC Engineer is finished, the Transfer Form is saved. Before concluding, the AOC Engineer sends e-mail to AOC Data Administrator selected on Form.
3. AOC Data Administrator opens Transfer Form and does one of the following :
    - If the data exists only on TDM's, export data and stores into FTP-PAH. The filename is then entered onto the Transfer Form and the form saved.
    - If data exists in the PIM system, then the word 'PIM' is entered in the Project/Library field. When all entries are done, the form is saved.
4. E-mail is sent to the POC Engineer selected on Form.
5. POC Engineer opens Transfer Form and adds storage locations etc, saves the Transfer Form and sends e-mail to the POC CAD Dept.
6. POC CAD Dept. opens Transfer Form and using the information supplied, pulls the data from AOC's PIM system and/or FTP-PAH. The data is stored/imported into the POC TDM and the POC Engineer informed.

If the POC engineer has any issues with the new design, he should convey them via e-mail to the AOC engineer.

- **<u>Release Phase (One Way Only - AOC to POC)</u>** - When a concern is closed and a part is released in the PIM system (Life Cycle process), POC has to be automatically notified for all 'common parts' & 'almost common parts'.

  1. AOC Engineer enters POC counterpart and part numbers onto CAD File Transfer Form.
  2. When AOC Engineer is finished, the Transfer Form is saved. Before concluding, the AOC Engineer sends e-mail to AOC Data Administrator selected by on Form.
  3. AOC Data Administrator opens Transfer Form and checks that the parts specified on the Transfer Form are at 'Released' state in the PIM system. If everything is OK, sends e-mail to the POC Engineer selected on Form.
  4. POC Engineer opens Transfer Form and adds storage locations etc, saves the Transfer Form and to the POC CAD Dept.
  5. POC CAD Dept. opens Transfer Form and using the information supplied, pulls the data from AOC's PIM system. The data is stored/imported into the POC TDM and the POC Engineer informed.

  The above process is a time consuming and complex exchange process. Very often this process was bypassed and CAD files were sent to the recipient via FTP. This workaround caused considerable problems because the integrity of having a single master was lost.

The evolution in the XYZ program was due to market requirements that changed rapidly on both sides with the consequence that very soon the program was designing two <u>similar</u> vehicles rather than the same vehicle. This is reflected in the subsequent categorization of XYZ parts:

- Asian Unique Parts (supplied from US based suppliers) meeting AOC Quality Standards
- Asian Unique Parts (POC sourced) meeting POC Quality Standards

- Common North American and Asian Parts (Majority AOC suppliers) meeting AOC Quality Standards
- North American Unique Parts (AOC suppliers) meeting AOC Quality Standards
- Almost Common Parts (Same part with very slight variation for each product)

## 4.5 Summary

What started as a typical "Black Box" relationship rapidly morphed into a "Grey Box" relationship with collaborative design and manufacturing. With other joint ventures following the same trend, partner programs have taken on a new flavor. Design and engineering activities take place in multiple places, suppliers are located in multiple sites, suppliers are sourced from multiple systems to deliver parts to multiple facilities and lastly, there is the need to support multiple processes.

# 5 THE NEED FOR COLLABORATIVE PRODUCT DEVELOPMENT

## 5.1 Introduction

While Chapter 4 reported on the analysis of a Automotive OEM Company Partner Program with POC, this chapter reports on additional research conducted with independent companies as part of an effort to derive requirements to support AOC's extended enterprise. Specifically, this work was initiated as part of sub-team working on the generic requirements for a workgroup level collaborative PIM system. It was recognized that in spite of its size and diversity, AOC could not develop these requirements in isolation and had to solicit the assistance of suppliers and other organizations. Initial plans to add specific supplier organizations to the team met with stiff resistance from the supplier interfacing organizations who highlighted the risk of broad litigation from the supplier community on grounds of favoritism. Non participating supplier organizations would view any closer ties with the OEMs such as this effort to define the next generation PIM system as preferential treatment of the selected organizations by the OEM. In order to circumvent legal issues around perceived favoritism AOC initiated this effort through the Automotive Industries Action Group (AIAG), which sponsored this work on information exchange as part of the Vehicle Product Data Project Team. [Note: The themes and conclusions from this activity and included in this chapter will be reported as part of the PDES & AIAG Vehicle Product Data Project Team PDM Information Exchange Workgroup Report sponsored by the AIAG. In addition, an internal Automotive OEM Company technical report will also contain this information.

This chapter starts with the motivation for the study and a list of the participants. It then provides the framework on which surveys were conducted and conclusions reached. A summary of these conclusions is presented in two tables that capture the current and projected characteristics of PIM interaction between enterprises. The chapter then concludes with an attempt to map the collaboration requirements and required infrastructure into a generic Product Development Process [Ulrich and Eppinger] and a specific automotive product development process example.

## 5.2 Motivation for the Study

As outlined in Chapter 3 on the current Automotive business environment and reflected in the Automotive OEM Company Partner Program discussed in Chapter 4, the automotive industry is undergoing substantial change from a process and technology viewpoint. Increased globalization as well as partnerships at the OEM and supplier levels is changing the nature of business to business product development interaction, which in turn is driving requirements for greater efficiencies in inter-enterprise collaboration. The increasing trend to leverage the supplier communities for system, sub-system and component design and manufacturing further increases this requirement for efficiencies in information sharing. In addition to such structural changes in the automotive business environment, new IT technologies such as the Internet are now available that do enable efficiencies in information exchange.

Current limitations in the business and technology environments do not allow a consistent and robust exchange of data for product development to enable collaboration. Current technology emphasizes the need to exchange large volumes of bulk data including CAD, CAM and CAE files; however, the infrastructure cannot sustain the volumes required for a deeper level of information exchange between development teams needed for collaboration. This is true not only between automotive OEMs and Tier 1 Suppliers (suppliers contracted to directly by the OEMs), but also between Tier 1 and Tier 2 Suppliers (suppliers contracted to the Tier 1 Suppliers or sub-contractors). The relatively small volumes of data being shared precipitate a number of problems such as outdated information and lack of timely change notification [Bsharah]. Since these issues tend to be replicated across the enterprises, they force the corresponding replication in product data, and with that, the non-value added work to manage its change across the enterprises [Bsharah].

Clearly, there is a need to develop the requirements for a next generation collaborative PIM system and for these requirements to tie in to the next generation business interaction. This study surveyed a number of external companies for expected changes in their product development business environment. Examples of the deliverables expected included the current business interaction, kind of information being shared and the mode of sharing.

The study included fourteen companies who are listed in Figure 5.2-1 below.

- Allied Signal
- Delphi Automotive
- ERIM
- General Dynamics Land Systems
- Lockheed Martin
- Northrop Grumman
- Structural Dynamics Research Corporation (SDRC)
- Daimler Chrysler
- Electronic Data Systems (EDS)
- Ford Motor Company
- General Motors Corporation
- Modine
- Rockwell International
- Visteon Automotive Systems

Figure 5.2-1 List of Participating Companies

## 5.3 Framework of the study

This section discusses the framework around which the conclusions were derived. It provides a useful means of analyzing the PIM needs of an enterprise in the context of the nature of the business relationships with its partners. The information exchange needs between enterprises was examined along two dimensions:

- <u>Characteristic of the Business Relationship</u> - This dimension examined the nature of the business relationship between the partners. This relationship in some sense is a reflection of the design process used in the specific relationship and could be one of five possibilities [Bsharah]:

  1. <u>Commodity Design</u> - Purchase of commodity components from existing catalogs for direct use in the product design
  2. <u>Black Box Design</u> - High level requirements are specified by the customer with the partner doing the design

3. Grey Box Design - High level requirements as well as specific design constraints are specified by the customer with the partner doing the design
4. Collaborative Design - Design by joint customer-partner team to meet high level requirements specified by the customer and jointly refined.
5. Customer Design - Item is designed by the customer and out-sourced to a partner for manufacture.

Enterprises wising to conduct similar studies may choose a different classification of their business relationships

- Characteristic of the Information Exchange - This dimension captures the scope of interaction in terms of whether it is within an enterprise or across enterprises, and if across enterprises, whether the exchange is formal or informal [Bsharah]. There are summarized as:

  1. Intra-company - This includes workgroup to workgroup interaction as well as workgroup to enterprise level interaction.
  2. Customer to Partner - This captures the customer - partner interchange with the exchange being initiated by the Customer and the information being sent to the partner.
  3. Partner to Customer - This captures the partner - customer interchange with the exchange being initiated by the partner and the information being sent to the customer.

The direction of information exchange was called out explicitly due to the current common supplier position of not wishing to allow external enterprise access to their data.
Participants were asked to characterize the volume of data currently being exchanged for each business interaction and Information exchange combination as well as projections for the future. Participants were also asked to differentiate between the volume of information exchange at the Meta Data and bulk data levels. The raw data is summarized into a High, Medium and Low generalization and are presented below. The Grey Box and Collaborative Design processes show an increase in usage.

| | Commodity Design | | Black Box Design | | Grey Box Design | | Collaborative Design | | Customer Design | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Current | To-Be | Current | To-Be | Current | To-Be | Current | To-Be | Current | To-Be |
| WG To/From WG | M | L | L | L | L | L | L | M | M | M |
| Ent. to WG | M | M | L | M | L | M | M | M | M | M |
| WG to Ent. | M | M | L | M | M | M | M | M | M | M |
| Customer to Partner | L | L | M | M | M | M | M | H | M | H |
| Partner To Customer | L | M | M | M | M | H | M | H | M | H |

Table 5.3-1: Current & Projected Bulk Data File Exchange

| | Commodity Design | | Black Box Design | | Grey Box Design | | Collaborative Design | | Customer Design | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Current | To-Be | Current | To-Be | Current | To-Be | Current | To-Be | Current | To-Be |
| WG To/From WG | M | L | L | L | L | L | L | M | M | L |
| Ent. to WG | M | M | L | M | L | M | M | M | M | M |
| WG to Ent. | M | L | L | M | M | M | M | M | M | M |
| Customer to Partner | L | M | M | M | M | M | M | H | M | H |
| Partner To Customer | L | M | M | M | M | M | M | H | M | M |

Table 5.3-2: Current & Projected Meta Data only Exchange

The percentage differences between the current and to-be usage are summarized below. The Customer to Partner interchange is further expanded to show what the changes are likely to be, though the preferred nature of the interchange (whether via the enterprise level or the workgroup levels) is yet to be finalized based on individual company policy and infrastructure. Blank entries reflect the absence of any "As-Is" data to base any benchmark on.

| | Commodity Design | | Black Box Design | | Grey Box Design | | Collaborative Design | | Customer Design | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Meta Data | Bulk Data | Meta Data | Bulk Data | Meta Data | Bulk Data | Meta Data | Bulk Data | Meta Data | Bulk Data |
| WG To/From WG | 25% | -45% | 0% | 0% | 100% | 60% | 350% | 29% | 20% | -18% |
| Ent. to WG | 43% | 0 | 160% | 63% | 140% | 63% | 133% | 56% | 71% | 27% |
| WG to Ent. | 75% | 0 | 100% | 71% | 120% | 44% | 114% | 50% | 86% | 27% |
| Customer Ent. to Partner Ent. | 80% | 75% | 88% | 78% | 113% | 78% | 110% | 100% | 54% | 109% |
| Customer Ent. To Partner WG | - | - | - | 133% | - | 200% | - | 200% | - | 700% |
| Customer WG to Partner Ent. | - | - | - | 200% | - | 200% | - | 75% | 150% | 33% |
| Customer WG to Partner WG | 33% | 33% | - | 33% | - | 167% | - | 100% | 67% | -11% |
| Partner Ent. To Customer Ent. | 30% | 67% | 114% | 31% | 129% | 38% | 82% | 47% | 36% | 33% |
| Partner Ent. To Customer WG | - | - | - | 400% | - | 500% | - | 800% | - | 500% |
| Partner WG to Customer Ent. | - | - | 400% | 167% | 400% | 200% | 187% | 60% | 33% | 33% |
| Partner WG to Customer WG | 150% | 100% | - | 33% | - | 200% | - | 167% | - | 0% |

Table 5.3-3: Deltas in Projected Data Exchange

The following product development relationships show an increase in PIM usage across enterprises:

- Collaborative
- White Box
- Grey Box

It shows the emphasis shifting to greater sharing and collaboration on designs than on simple exchange of designs.

## 5.4 Mapping into Product Development Processes

This section uses a generic Product Development Process [Ulrich and Eppinger] as an example and overlays the current and projected collaboration scenarios. Figures 5.4-1 shows the typical As-Is Product Development Process along with the current approach of using stand-alone systems and replication. The emphasis here is on the use of multiple systems with the transfer or exchange of data facilitating the collaboration.

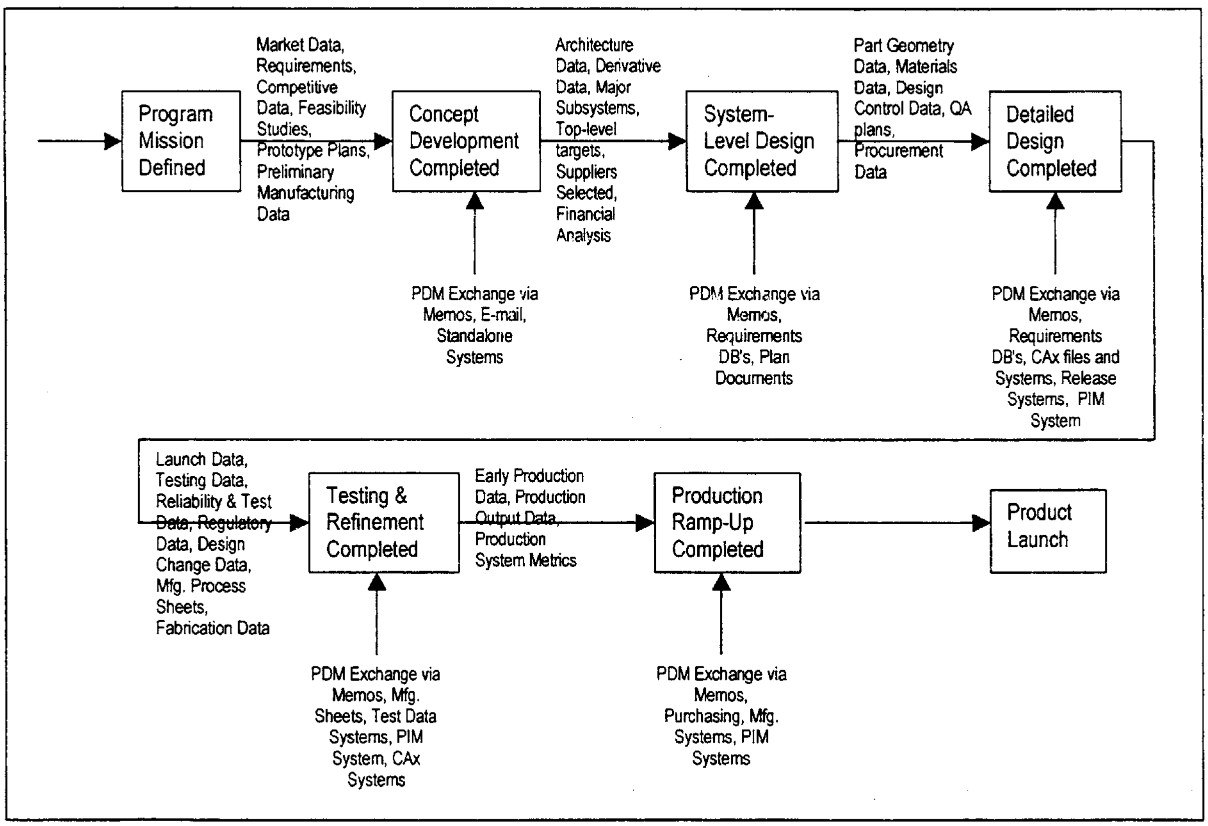


Figure 5.4-1 One Map of <u>As-Is</u> Information Exchange to Generic PDP

Figure 5.4-2 shows an example of how the To-Be high level collaborative Product Development Process might be achieved using shared PIM systems. The emphasis in each phase is on collaboration through shared systems. Note that this is only an attempt at documenting the kinds of data being shared in each phase and not meant to be exhaustive. It highlights where the emphasis might be during each phase and what may be done to facilitate collaboration.

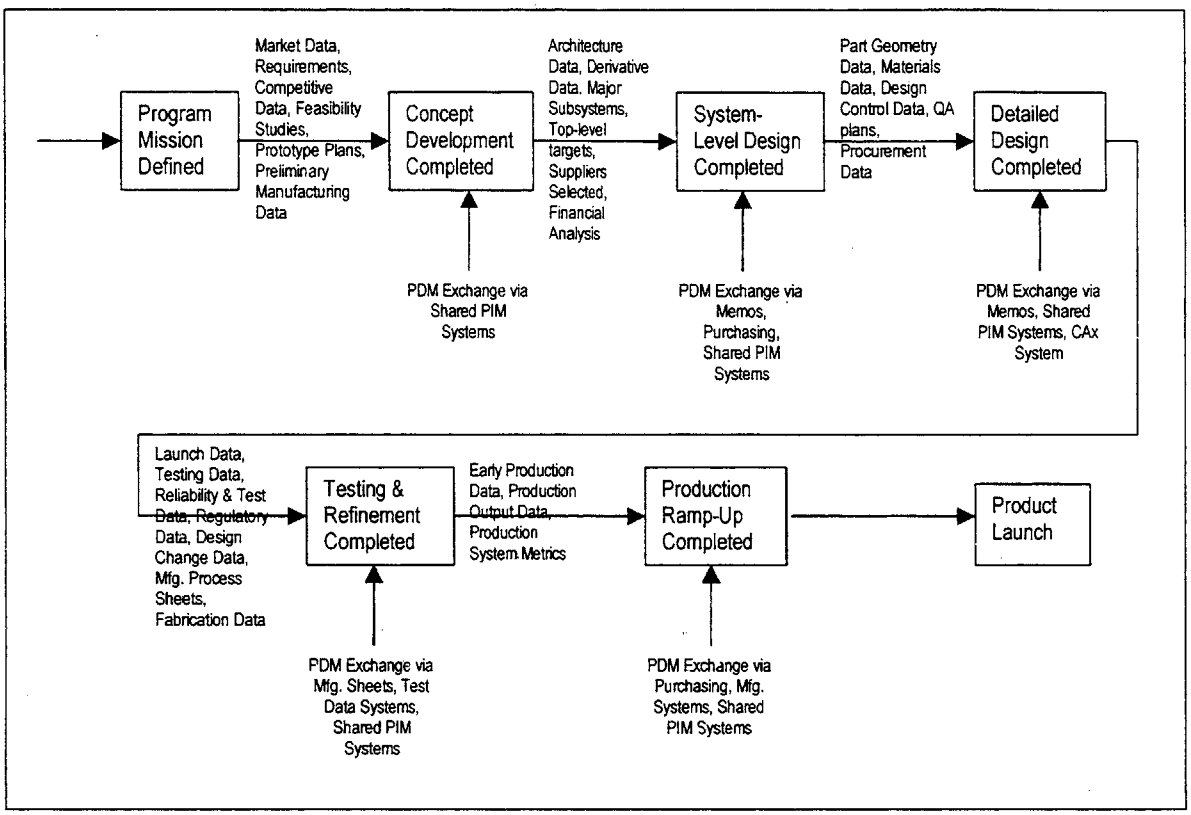


Figure 5.4-2: Example To-Be High Level Collaboration Mapped to Generic PDP

Figure 5.4-3 shows a current high level generalized Automotive Product Development System along with the existing processes by which product data is captured and shared. Once again, the information requirements captured are only a subset of what is actually generated and shared. The emphasis is clearly on integration of multiple systems with a high possibility of replication. The figure is adopted from the AIAG PIM Information Exchange Report.

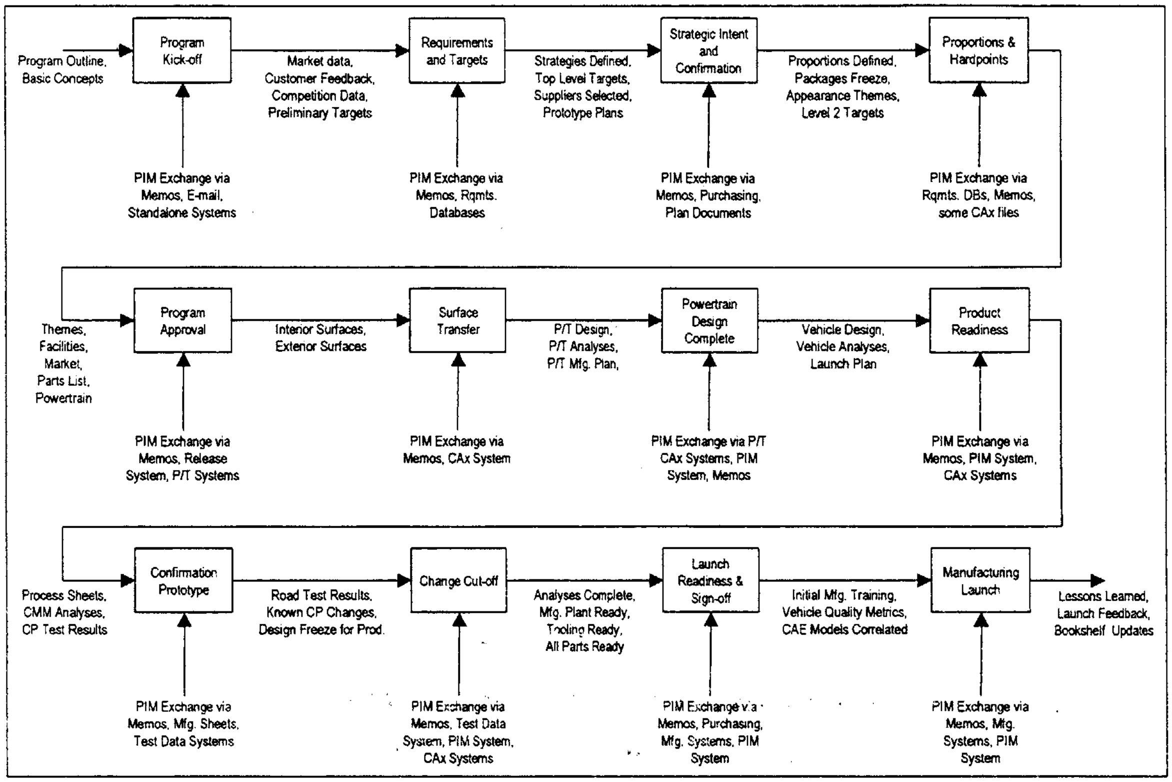


Figure 5.4-3: Generalized High-Level Automotive Product Development Process [adopted from AIAG Report]

Figure 5.4-5, on the following page, shows an example of how the PD process may be supported to facilitate collaboration. The emphasis here is on *shared* PIM systems.

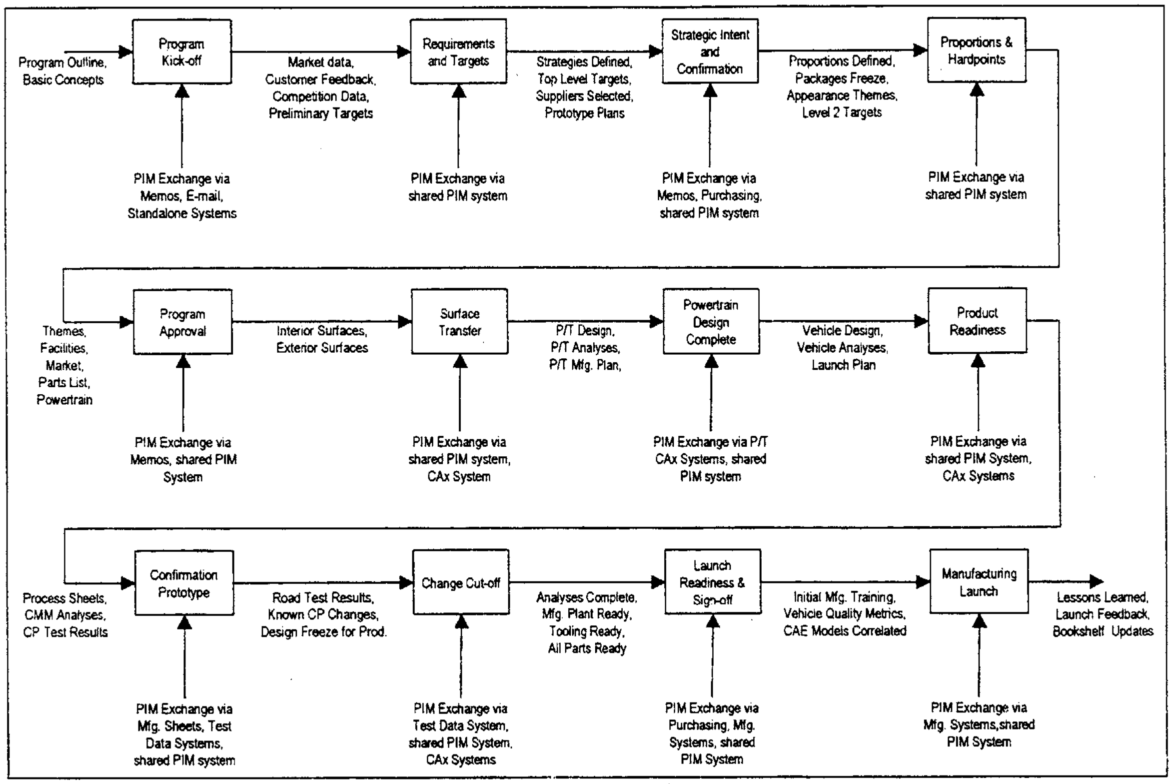


Figure 5.4-5: "To-Be" Generalized High Level Collaborative Automotive Product Development Process [adopted from AIAG Report]

## 5.5 Summary

A robust, open-architecture designed collaborative environment across the extended enterprise would offer a number of benefits such as faster information sharing, reduction in data traffic, reduction in late changes and improved re-use of data (catalogs). Using a single distributed source of product information eliminates the change traffic due to use of incorrect versions of the data. More importantly, increased data sharing and collaboration increases involvement in the design and engineering process and thus enables a more encompassing product development team.

# 6 PROPOSAL OF A PIM ARCHITECTURE TO SUPPORT PARTNER PROGRAMS

## 6.1 Introduction

Partner programs require two key PIM ingredients for success - richness in collaborative functionality and the ability to distribute this functionality to geographically dispersed teams. A centralized PIM architecture with all PIM functionality embedded in one installation cannot meet the needs of a distributed team due to an inability to support multiple phases in the design process (workgroup level vs. enterprise level) across installations.. This chapter proposes that a PIM architecture be segmented along two dimensions in order to provide rich collaboration across distributed teams in multiple partner enterprises. These dimensions include the Vertical Dimension separating the enterprise level from the workgroup level and the Horizontal Dimension that segments the architecture for decentralization across the extended enterprise. This approach serves to partition not only functionality but also the physical implementation, enabling the resulting systems to be optimized for a number of reasons such as performance and ease of administration. In essence, this moves a centralized architecture to a distributed architecture with support for federated information and processes. Figure 6.1-1 below shows this separation along the two dimensions:

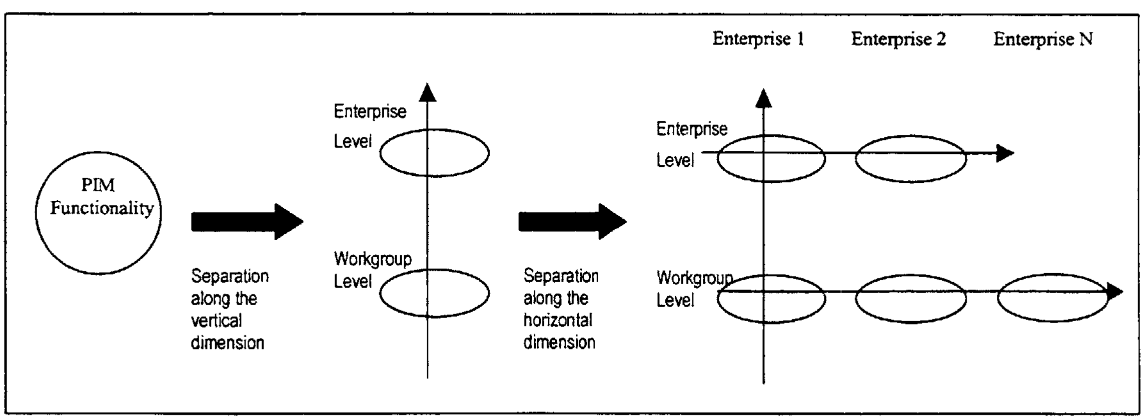


Figure 6.1-1: Partitioning of PIM functionality along Vertical and Horizontal Dimensions

## 6.2 Separation along the Vertical Dimension - Enterprise vs. Workgroup Levels

This section introduces the notion of two different levels of PIM along the Vertical Dimension in large, multidisciplinary corporations - the Enterprise Level and the Workgroup Levels. The discussion focuses on the fact that there is functionality that is very specific to each level. The need to minimize the complexity of a PIM system to enable system evolution, performance, flexibility and scalability forces a functional separation based on these differences. The current situation at Automotive OEM Company resulting from absence of a approach based on functional separation is briefly examined along with drivers for why this must change. Lastly, this section proposes an example of how typical CAD PIM functionality might be separated between the enterprise and workgroup levels and concludes with some remarks on the resulting form of the architecture.

The discussion also touches on the fact that the Enterprise and Workgroup Levels themselves may be logically partitioned based on specific disciplines or organizational "functions" in the product development process such as CAD, Purchasing and Testing/Verification [Sherbenou and Vedapudi]. As an example, a large corporation would have enterprise level CAD data as well as enterprise level purchasing data that is available to all users in the enterprise. Workgroup levels would be specific to *a* discipline, or a specific *combination of disciplines* that would enable a more integrated product development process. An example of this would be the combination of CAD, CAE and CAM disciplines in the same workgroup to enable integrated, geometry-based collaboration.

Given such logical partitioning, it must be noted that the role of enterprise level PIM is to bring together all aspects of the corporation while the role of workgroup level PIM is to enable fast and flexible execution of one or more disciplines that feed the overall product development process.

Figure 6.2-1 very simplistically shows this vertical separation as it pertains to the CAD function where the vertical two-headed arrows imply control and publishing and the horizontal arrows imply sharing. A similar diagram may be drawn for other functions like Purchasing and Requirements Definition - the Workgroup CAD "boxes" would be replaced by Purchasing Workgroup or Requirements Definition Workgroup. Each workgroup has its own tools and data. Workgroups are used during the early concept design and analysis.

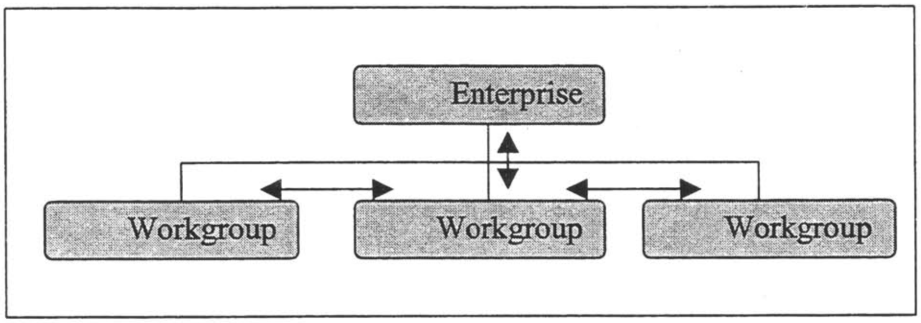


Figure 6.2-1: Enterprise and Workgroup Level Separation for CAD [Sherbenou]

A finer point to note is that it is not possible to completely separate the functionality across the levels. Rather, it is more appropriate to say that functionality tends to be dominant at one level with supporting capability at the other. For example, while security policies may be defined at the enterprise level, the capability to adhere to such security policy must be defined at the workgroup level. There needs to exist an interface between the two levels for each function that enables a holistic capability across the two levels. As discussed later on in this section, when this interface goes across two or more completely independent PIM systems, we have a Federated PIM system.

One set of distinguishing criteria between the enterprise level and workgroup level characteristics around data and processes is summarized in the table below which states what the focus is at each level e.g. at the enterprise level the focus of data usage is more on consumption while at the workgroup level it is more on creation.

| # | Characteristic | Enterprise Level | Workgroup Level |
|---|---|---|---|
| 1 | Data Usage | Consumption | Creation |
| 2 | Data Access | Reference | Authoring |
| 3 | Authority | Define Control | Compliance |
| 4 | State of the data | Complete | Work-in-progress |
| 5 | Tool Applicability | Tool Independent | Tool Specific |
| 6 | Functional Discipline | Discipline Independent | Discipline Specific |
| 7 | Temporal | Permanent or Long Term focus | Transient or Short Term Focus |
| 8 | Scope of Applicability | Enterprise-Wide Applicability | Workgroup Applicability |

Table 6.2-1: Distinguishing Criteria between Enterprise and Workgroup Levels

## 6.3 Enterprise Level PIM

Enterprise Level PIM includes data, information and processes that are accessible to all users across the entire enterprise. The role that enterprise PIM plays is one of consolidating all aspects of product data for true data management. Another way to put this is to say that at the enterprise level, the focus is predominantly on data *management* and only to a lesser extent on data *sharing*. At this point we introduce the symbol "$M_s$" to signify this dominance in "Management" versus "Sharing". Typical characteristics of Enterprise Level PIM include:

- Mature data generally captured at specific milestones. This data is reflective of design intent and is at a specific stage of maturity in the product development process. With a move to platform based product development, Automotive OEM Company has introduced a new state called "Program Intent" to signify maturity of data for re-use across vehicle Programs.
- Enterprise wide access to data. Data at the enterprise level is meant for global access and as such is shared across different disciplines at that milestone.
- Centralization - This characteristic reflects the view that certain functionality lends itself to a more centralized management approach. Examples are Security Policies and User Registration.
- More stable data that is less volatile - users across the enterprise can use this data without being subjected to major changes (changes are controlled through formal change control mechanisms that require the creation of newer versions)

- Relationships to data generated in different disciplines such CAD, CAE, CAM, Purchasing, Testing & Verification, Systems Engineering, etc. This is where the product structure is integrated in its entirety.
- Integration point for links to other enterprise or business systems. As an example, Automotive OEM Company's releasing system is being integrated with the PIM system at the enterprise level.
- Formal change control - Data that is present at the enterprise level will be subject to formal change control ensuring stability and compliance with corporate wide processes.

## 6.4 Workgroup Level PIM

Workgroup Level PIM includes data, information and processes that are very much work-in-progress and specific to a particular discipline. The role that Workgroup PIM plays is one of being a system for work-in-progress, rapidly changing data to be shared across users who the need such changes on a regular basis. Another way to put this is to say that at the workgroup level, the focus is predominantly on data *sharing* and only to a lesser extent on data *management*. Using the concept introduced earlier, we use the symbol "$S_m$" to denote this. Typical Workgroup PIM characteristics include:

- Immature data only meant for a very specific group of people who in most cases are very familiar with the work being done. Users needing access to the immature data early in the process may do so via workgroup level collaboration. It is proposed that anyone needing access to the rapidly changing work-in-progress data should be able to do so.
- High frequency of changes - there is no guarantee that the recipient or person using the data is using the most recent version
- Adherence to policies and processes defined at the enterprise level
- Function specialization (or specific discipline) e.g. CAD Workgroup, Systems Engineering Workgroup, Release Workgroup, etc. Discipline specific PIM functionality is defined and used at this level. An example of this is that the CAD function versions pieces of the part definition in particular way, while the Releasing function versions it in another i.e. at AOC, the CAD community prefers to replace or overwrite prior versions of CAD

data during design iterations. However, the CAE community prohibits this since their analysis models are derived from the CAD files and are tracked via relationships to the CAD file. Overwriting the CAD file would lose the relationship. As such, the CAE community prefers versions of CAD data to be preserved. A related example is that the business systems version the part definition when form, fit or function is changed while the current CAD PIM implementation forces versions to be created every time the data is checked in.

- Integration or links with other tools that enhance the workgroup activities.

Figure 6.4-1 shows this as it is used in the overall context of PIM in the automotive industry with different CAD workgroups interacting with each other and with the Enterprise CAD level.

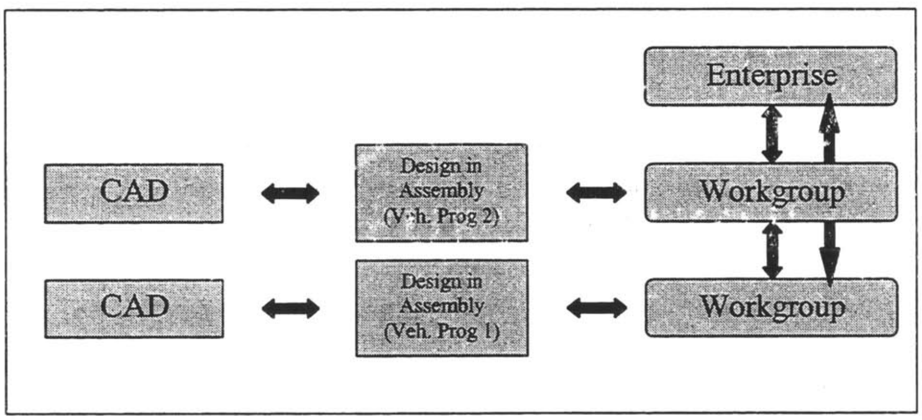


Figure 6.4-1: CAD PIM Levels in the Automotive Industry

## 6.5 Current situation at Automotive OEM Company

A few years back, Automotive OEM Company launched an initiative to use common CAD, CAM CAE and PIM tools. The vision was an integrated CAD, CAM and CAE system (tools and processes) to support the Product Development Process. Strategic technology partners included Structural Dynamics Research Corporation (SDRC) and Metaphase Technologies Inc. with SDRC providing AOC's CADCAM solutions called I-DEAS Master Series and Metaphase Technologies providing AOC's PIM system called Metaphase. Automotive OEM Company uses Metaphase as its enterprise PIM system. The vision called for the use of a single PIM system and the separation of workgroup and enterprise functionality. However, the CAD tool has its own data management system called Team Data Manager (TDM). Technology limitations in the CAD tool force the use of TDMs as the local CAD data management system. The result is that all PIM functionality at Automotive OEM Company is implemented at the enterprise level - there is a single system that embodies all the functionality, both enterprise and workgroup. Furthermore, the use of two completely different systems results in additional complexity due to differences in versioning strategies, ownership issues, etc.

Technology limitations forced the architecture to be developed based on an existing form. The two systems, TDMs and Metaphase are interfaced using the I-DEAS - Metaphase - Interface or IMI. This has led to an extremely unwieldy architecture that will not scale as more and more vehicle programs begin to use the common tools. Figure 6.5-1 shows the current PIM architecture at AOC.

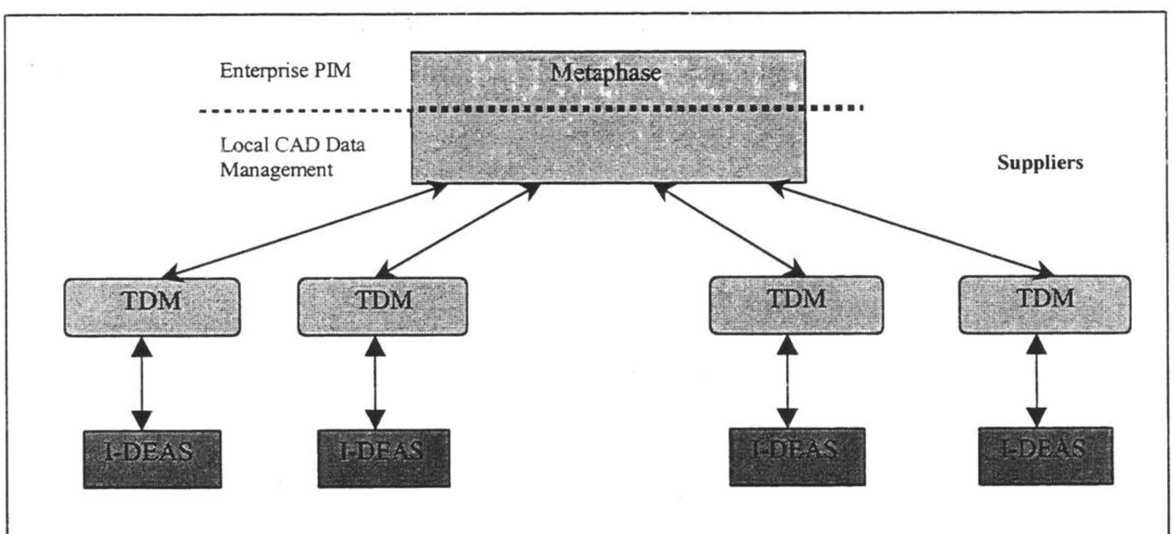


Figure 6.5-1: Current Situation at Automotive OEM Company

Limitations in the number of users who can operate concurrently in the TDMs have caused a breakup of vehicle program teams into an artificial set of smaller teams. With no convenient TDM - TDM sharing, users in one TDM have to check their data in to Metaphase for users in other TDMs to download. This has caused CAD-specific work-in-progress functionality to be implemented at the enterprise level. The result is that the enterprise repository is filled with multiple versions of work-in-progress CAD files that exist because of the need to share via the enterprise system and not because of the need to capture true design iterations. The CAD, CAE, CAM and Business PIM communities all have different requirements for versioning data. The customizations that provide such capabilities require a higher degree of maintenance with each software release. All these make for a very slow, unwieldy and inflexible system.

This architecture has resulted in several process and technology workarounds that prevent the company from progressing to the next step of integrating non-CAD functions into PIM. The PD process is starting to optimize around these in a sub-optimal manner. The following key issues are being addressed:

- Vehicle Programs are artificially broken up due to the limitations of TDMs.
- Duplication of user actions due to dual PIM system
- Poor support for global collaboration and sharing across AOC's extended enterprise due to poor PIM performance
- Synchronization issues slow down overall product development performance.

## 6.6 Drivers for change at Automotive OEM Company

There is an over emphasis on local CAD data management due to the continued need for maintenance of existing functionality, automation of workarounds and better performance in interfacing the two systems. This heavy investment of development and support resources every release prevents the allocation of resources to other non-CAD data management functionality. Local CAD data management issues are driving the enterprise in directions that will increase the cost of PIM implementation for non-CAD disciplines. Examples include:

- CAD Assembly Structure created at the local CAD workgroup level is driving product structure at the enterprise level. Product structure is more than just the CAD assembly structure. Unfortunately, the current implementation has no support for the creation of product structure driven by business reasons with the CAD assembly tying into it. As a result, product structure is created at the enterprise level by duplicating the assembly structure created at the workgroup level.

- Versioning schemes at the local CAD levels are driving complexity at the enterprise level - CAD requires versioning in a certain manner (discussed above). Since this drives the enterprise so much, the enterprise is being forced to version parts and data items based on CAD policies. The result is a number of process and technology workarounds that are non-value added to the PD process.
- AOC's entire PIM conceptual development is being tied to the current system architecture. The company is rapidly optimizing its processes and future development around existing limitations. This could very well lead the company into an expensive and unwieldy implementation that will not meet the company's requirements for fast and nimble product development. Workarounds created to circumvent existing limitations such as the lack of support for data created and owned by suppliers are becoming the process steps to be followed. Subsequent releases extend these capabilities making them more "efficient" instead of migrating to an architecture that will truly solve the problem of supporting data mastered in external systems.
- The current limitations are preventing the company from forging ahead with other critical PIM functionality such as Requirements PIM, Manufacturing PIM, Verification PIM, etc. A large percentage of the resources each release are allocated to incremental improvement of the limitations.

Current implementations are hitting the top of the S-curve for Performance, Scalability and cost. Figure 6.6-1 shows where the current TDM/IMI architecture may be spotted on an S-curve plotting performance improvements vs. resources to achieve them.

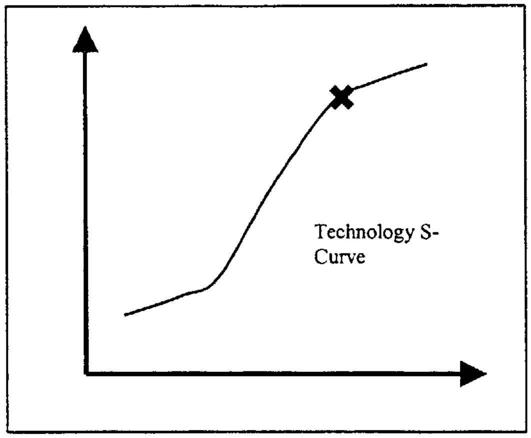


Figure 6.6-1: Hitting the top of the performance and functionality S-Curve with the current architecture

The cost of developing new functionality is increasing with each software release due to the complexity of including all functionality (enterprise and workgroup level) at the enterprise level. The benefits realized from such a high investment are beginning to taper off. Clearly, the project is at the spot marked with an "X" on the S-Curve.

## 6.7 Proposal for a Functional Separation of CAD PIM Functionality

This paper proposes that there is a need to separate or de-couple enterprise level functionality from workgroup level functionality. Such a functional separation will enable the rest of the disciplines such as Requirements PIM, Systems Engineering PIM, Business PIM and Test and Verification PIM to forge ahead with their implementations without being handicapped by the need to support CAD functionality at the enterprise level. This will allow AOC to make the jump to a new S-curve that will provide the infrastructure to support new requirements for global collaboration with suppliers and partners as discussed earlier. The following discussion visits the some typical CAD functionality.

A proposal for the functional separation of typical geometry based PIM functionality between the enterprise and workgroup levels is summarized in Table 6.7-1. This can be expanded to include other disciplines in a similar manner.

| Geometry - Enterprise versus Local | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Catalog Component Management | Product Structure Templates | View & Mark-up | Storage Management | Change Control | Geometry Management | Enterprise Member-ship |
| | Define Families | Platform Structure Templates | Published Geometry and Digital Buck | Data Retention | Authorization | Release Approval | Registry & Rights |
| Enterprise Functionality | Search Strategies | Parameters | | Long Term Storage | | Check-out and Check-in | Domain Definition |
| | Define Attributes | Constraints | | Restore & Backup | | | Security |
| | | | | Archive | | | |
| | | | | | | | |
| | Updates to Specific Content | Instantiate from templates | Digital Buck/ Mockup | Restore & Backup | Authorized Changes Only | Create, Update, Delete, Relate | Registration |
| Workgroup Functionality | Search & Retrieve Approved Components | Change Product Structure | Markup Working Changes | Data Retention | | Version Management | Local Security & Manage-ment |
| | | Operate within parameters & constraints | Working Tool for non-creators | | | CAD, CAM, CAE, Digital Buck | |
| | | | | | | Data Sharing | |

Table 6.7-1: Functional Separation between Enterprise CAD and Workgroup CAD Functionality

Each of the functions is briefly described below along with a rationale for why it belongs at the proposed level. Please note that the intent is to provide enough clarity on the functionality to ensure an understanding of why it belongs at a particular level and an insight into the separation. Each function is separated into the enterprise and workgroup level components.

### 6.7.1 Catalogs - Component Management

This functionality provides the ability to manage standard components with a view to reducing the number of similar parts in production and to eliminating design of new parts when existing parts meet a requirement. The functionality includes the ability to create templates for part and component definition (i.e. define families of similar parts), to navigate the hierarchy using quick and efficient algorithms and retrieve parts based on specific parameters or attributes. Some of the benefits include reduced time to market through reuse and a consolidation of standard parts.

#### 6.7.1.1 Enterprise Level Functions

- Define Part Family Hierarchy - This includes the ability to create families of parts, components and sub-assemblies. This capability would typically be accessed by a global CAD Committee that has responsibility to define the hierarchy of parts, subsystems and systems. All parts that are released by the company and the preferred or standard parts that are to be used by designers are classified using this hierarchy. Since such part family definition has corporate wide implication, it is proposed that this capability be provided at the enterprise level.
- Search Strategies - Catalogs may require a variety of search algorithms and hierarchy navigation, examples of which are parametric searching, flat attribute searching and navigation of specific parts first. Since the strategy or strategies are applicable to the entire enterprise and not likely to change very often, it is proposed that this capability be provided at the enterprise level.
- Define Attributes - This includes the definition of specific attributes associated with each part family. Since the part attributes such as Dimensions, Cost, Vendor, etc. do not change very often (though their values will) and there is a need to track specific attributes across the enterprise, it is proposed that this capability be provided at the enterprise level.

#### 6.7.1.2 Workgroup Level Functions

- Updates to specific content - This includes the ability to add new parts and components to the catalog when warranted. In the CAD domain, this capability includes the creation of the appropriate part geometry, the instantiation of the various attributes and the incorporation into the catalog. This is generally done in the workgroup environment. Since new part geometry is created as part of the workgroup activity, it is proposed that this capability be provided at the workgroup level. On successful inclusion into the catalog, the part or component then comes under formal change control at the enterprise level.
- Search and retrieve approved components - this includes the ability to query for catalog parts and components parametrically. This is generally made available to a CAD designer through a tight integration of the catalog query interface with the CAD authoring tool.

Appropriate attributes or parameters are used to narrow the search and the selected part geometry is brought down into the authoring tool. Since this is typical of a work-in-progress activity, it is proposed that this capability be provided at the workgroup level.

### 6.7.2 Platform Product Structure

As companies, including Automotive OEM Company move to a more platform-based approach to products and product development, there is a need to redefine Product Structure to be platform based as well.

#### 6.7.2.1 Enterprise Level Functions

- Platform structure templates - This is the ability to define the product structure that will be instantiated for a particular product line. As an example, at AOC, the product structure of an assembly includes relationships to tessellated files, CAE data, Manufacturing data, Notification Lists, Test data, Product Direction and Business data. This information is related to the assembly structure at specific points. Thus, product structure includes not only the assembly hierarchy of the product, but also the relationships between the assembly hierarchy and other relevant product information. Product Structure templates bring together the product definition as the company sees it to be. Since the template has enterprise wide implications (all disciplines tie into the same product structure), it is proposed that this capability be provided at the enterprise level.
- Parameters - These define the parameters that may be used to reference or search for systems and subsystems when navigation via product structure is required. An example of such a parameter is the "Where Used" parameter that defines all the products on which a particular structure is used.
- Constraints - This is the ability to define product diversity based on constraints in the product usage. These are defined up front in the product direction documentation, and as such, has enterprise wide implications. Product direction is subjected to formal change control and hence, it is proposed that this capability be provided at the enterprise level.

### 6.7.2.2 Workgroup Level Functions

- Instantiate from Templates - With the widespread use of catalogs, platform based product development and increased reuse across product lines, there is a push in the PIM industry to instantiate product structure in a top-down as well as bottom up manner. In the top-down approach, a product's base product structure is instantiated at the enterprise level from carryover product lines and minor changes are worked on in the workgroup level. In many cases, the product structure created at the enterprise level has Part definitions without any supporting geometry - this is the Meta data that defines a Part (or assembly) through attributes and relationships such as Part Number, Part Name, Usage, CAD Designer, etc. This geometry is created and attached to the product structure at the workgroup level. Since this involves the use of specific authoring tools it is proposed that this capability be provided at the workgroup level with appropriate checks to ensure that the changes comply with the defined templates. As an example, addition of a Part that is also related to a Manufacturing Process File when such a relationship is not defined in the product structure template being used would violate that template. One option to address this is to force a new template to be created accommodating the file. Once instantiated and released, the product structure may be elevated to the enterprise level where it will undergo formal change control.
- Change Product Structure - This capability provides support for a bottom-up design where parts or assemblies are created at the workgroup level and the base product structure is changed i.e. new parts and assemblies are created. While the instantiation of product structure provides geometry to existing product structure, changing it involves the addition or deletion of parts or assemblies in the product. It is proposed that this capability be provided at the workgroup level.
- Operate within parameters and constraints - This capability involves the manipulation of product structure within specified constraints. It involves the ability to manipulate product structure and have it verified against a given set of parameters or constraints. An example of such a constraint is the insulation that must be used when a cut-lead (wire) is run in close proximity to the engine. This checking against a specific set of constraints is conducted more at the workgroup level and hence, it is proposed that this capability be provided at the workgroup level.

### 6.7.3 View and Mark-up

View-and-Mark-up of an electronic document is rapidly becoming a core piece of the engineering process where-in, consumers of the geometric information up and down the value chain examine and mark-up the drawings for various reasons without altering the native CAD files. This provides the ability to electronically capture such feedback and react to it. In most implementations, the native CAD file is used to generate a file containing the geometry data in a format that most viewers can read.

#### 6.7.3.1 Enterprise Level Functions

- Published Geometry and Digital Buck at milestones - This is the capability to publish geometry and visualization data at the enterprise level for reference by various user communities at key milestones in the product development process. It includes the ability to baseline such data and allow users across the enterprise to reference or download copies for use. It is proposed that this capability be provided at the enterprise level.

#### 6.7.3.2 Workgroup Level Functions

- Build Digital Buck/Mock-up - This is the capability to use visualization data to create and analyze digital bucks of the product being built. It is critical to provide the ability to do this with work-in-process data at the workgroup level. It is very similar to the enterprise level functionality with the only difference being that the native CAD files used to create the visualization files at the workgroup level are work-in-process while the native CAD files used at the enterprise level are baselined files on process milestones. It is proposed that this capability to create digital mock-ups be provided at the workgroup level.
- Mark-up working changes - This is the capability to mark up changes at the work-in-process level and is provided through integration of various view and mark-up tools at the workgroup level. It is proposed that this functionality be provided at the workgroup level.

- Working tool for non-creators - There are several consumers of geometry and visualization information who don't require authoring tools to execute their work. This is accomplished though viewers such as EAI's VisPlus. Such viewing only capability does not require the native CAD files; generated visualization data would be sufficient. It is proposed that working tools for non-creators be provided at the workgroup level. However, it is quite conceivable that such tools would also reference baselined visualization data at the enterprise level as mentioned above.

### 6.7.4 Storage Management

This capability addresses strategies for data storage management.

#### 6.7.4.1 Enterprise Level Functions

- Data Retention - This includes the ability to define corporate data retention policies for specific kinds of data. As an example, transient product development data at Automotive OEM Company such as e-mail and draft informal versions of specifications must be deleted within a year of its creation. On the other hand, test data (including the test results) must be retained for approximately 20 years. Due to its enterprise wide implication this capability is best provided at the enterprise level.
- Long Term Usage - This capability is provided through catalog functionality for re-use or through simple storage of data for long term use. Since workgroup level data is transient in nature, it is proposed that this capability is best provided at the enterprise level.
- Backup and Restore - This capability includes the ability to backup selected data to off-line storage and the ability to subsequently retrieve all or portions of it without losing the integrity of the data. The risks of incompatibility due to different versions of software and current data model are somewhat mitigated by using industry standards and storing versions of the software themselves. It is proposed that this capability be provided at the enterprise level.
- Archive - This is the ability to take large volumes of data off-line and still be able to search it for specific items and bring it back on-line. Archiving strategies are best

implemented enterprise wide and hence, it is proposed that this capability be provided at the enterprise level.

#### 6.7.4.2 Workgroup Level Functions

- Restore and Backup - The same functionality specified above for the enterprise level is applicable at the workgroup level as well.
- Data Retention (different from above) - As mentioned above, corporate data retention policies dictate that transient data must be deleted with a specific timeframe. It is proposed that the ability to capture such policies for work-in-process data be provided at the workgroup level.

### 6.7.5 Change Control

The ability to provide change control or change management functionality in PIM systems is rapidly growing in importance in the product development world. Change management, particularly with respect to reducing the time needed to capture change requests, authorize change actions and log their completion, is one of the key enablers for cycle time reduction.

#### 6.7.5.1 Enterprise Level Functions

- Change Authorization - Given the nature of collaborative product development and the expanding use of the catalogs and the top-down approach to product design, it is important to implement a formal change control mechanism. The authority to implement a change request on a particular catalog or released item has enterprise wide implications. It is proposed that this capability be provided at the enterprise level.

#### 6.7.5.2 Workgroup Level Functions

- Work allowed on authorized changes only - The ability to control and allow modification of data only on authorized changes is a workgroup level capability. It is proposed that this capability be provided at the workgroup level.

Clearly there is a handshake between the two levels in implementing change control. Change requests and change authorization comes from the enterprise level, while change implementation and change notification are carried out at the workgroup levels. It is quite possible for change notification to be an enterprise level capability and for change requests to be a workgroup level capability too. The challenges of coordinating such change control across a federated system will be one of the critical success factors of the proposed architecture.

### 6.7.6 Geometry Management

#### 6.7.6.1 Enterprise Level Functions

- Release approval - This includes the ability to formalize release approval steps for downstream product development activities. Very often, this step results in several actions being kicked off, such as part set up steps in corporate business systems, development of process sheets and other manufacturing activities, addition to the corporate catalog and sourcing activities in the Purchasing systems. Due to the enterprise wide implication of this action, it is proposed that this capability be provided at the enterprise level.
- Check-out and Check-in - This is the ability to move data into and out of the enterprise system while creating appropriate versions of the data. It is proposed that this capability be provided at the enterprise level.

#### 6.7.6.2 Workgroup Level Functions

- Create, Update, Delete, Relate data - This is the ability to manipulate work-in-process data prior to releasing it to the enterprise and includes typical PIM functionality that manages data. It is proposed that this capability be provided at the workgroup level.
- Version Management - This is the ability to create versions of the data as appropriate to capture design iterations. The versioning scheme is entirely dependent on the workgroup discipline and on the company implementing it. For example, at Automotive OEM Company, every design iteration results in a version bump of all changed data. Support for

flexible Version Management is a very critical requirement and is one of the drivers for the de-coupling of enterprise and workgroup levels into separate systems. To further elaborate on the implementation at Automotive OEM Company, the versioning mechanism desired by different workgroup activities is different; the cost of providing such complexity is enormous. It is proposed that such capability be provided at the workgroup level to allow versioning independent of enterprise level versioning. Reconciliation at the enterprise level is done through mutual agreement on what drives versions at the enterprise level.

- CAD, CAM, CAE, Digital Buck - This includes support for all geometry based data to be integrated at the workgroup level to enable integrated product teams. Very specifically, this includes the ability to create relationships between CAD, CAE and CAM data to provide a consolidated product structure. It is proposed that consolidation of such related disciplines be provided at the workgroup level.
- Data Sharing - This includes the ability to access work-in-progress data by all users who need such access to rapidly changing data on a regular basis. It is proposed that this capability be provided only at the workgroup level i.e. if access to work-in-progress data is needed, then access to the workgroup environment must be provided.

### 6.7.7 Enterprise Membership

This paper proposes several criteria that could be evaluated to determine what constitutes an enterprise (discussed later in the paper). In a federated environment as is being proposed by this paper, it is critical to determine which systems are a part of an enterprise and hence, part of the same policies, processes and administrative domain.

#### 6.7.7.1 Enterprise Level Functions

- Registry and Rights - This functionality includes the ability to register all the systems that participate in an enterprise as well as all the PIM systems in the Federation that could communicate with the enterprise. It is proposed that such registry along with appropriate access rights will form the backbone of the security and control in the extended enterprise (discussed later in the paper). It is proposed that this functionality be provided at the enterprise level.

- Domain Definition - This functionality includes the ability to select a specific set of PIM installations and aggregate them into a higher level entity for administrative, policy or other purposes. One example of such a purpose is the need to define uniqueness across a given set of PIM systems. Automotive OEM Company anticipates using several PIM systems within its enterprise definition and the ability to define a unique part number across all these separate installations will be critical. The functionality takes the physical elements of the PIM architecture and combines them into logical partitions.
- Security - The functionality includes the definition of security policies of an enterprise particularly as it pertains to supplier and partner systems. It serves to centralize the security administration for an enterprise for ease of administration and control. It is proposed that this functionality be provided at the enterprise level.

#### 6.7.7.2 Workgroup Level Functions

- Registration - This is the functionality by which a workgroup level PIM installation registers itself with the enterprise level system either to be included as part of the enterprise definition or as a PIM system that can communicate with it. It is proposed that this functionality be provided at the workgroup level. However, as discussed later in the chapter on extended enterprises, it is very likely that the federation will also include enterprise level systems communicating with each other.
- Local Security adherence and management - This functionality includes the definition of local, transient security measures as well as the ability to ensure compliance with the security policy defined at the enterprise level. For example, a Body CAD designer in a vehicle program at Automotive OEM Company should not be able to change work-in-process data that a Chassis CAD designer is working on. It is proposed that this functionality be provided at the workgroup level.

This is one proposal of a functional separation of CAD PIM functions (each company will have a different set of these functions based on the kinds of tools they have integrated into the enterprise and workgroup systems). Each discipline will have a similar functional separation across the two levels. Figure 6.7.7.2-1 shows how the functional separation would modify the current situation at Automotive OEM Company.

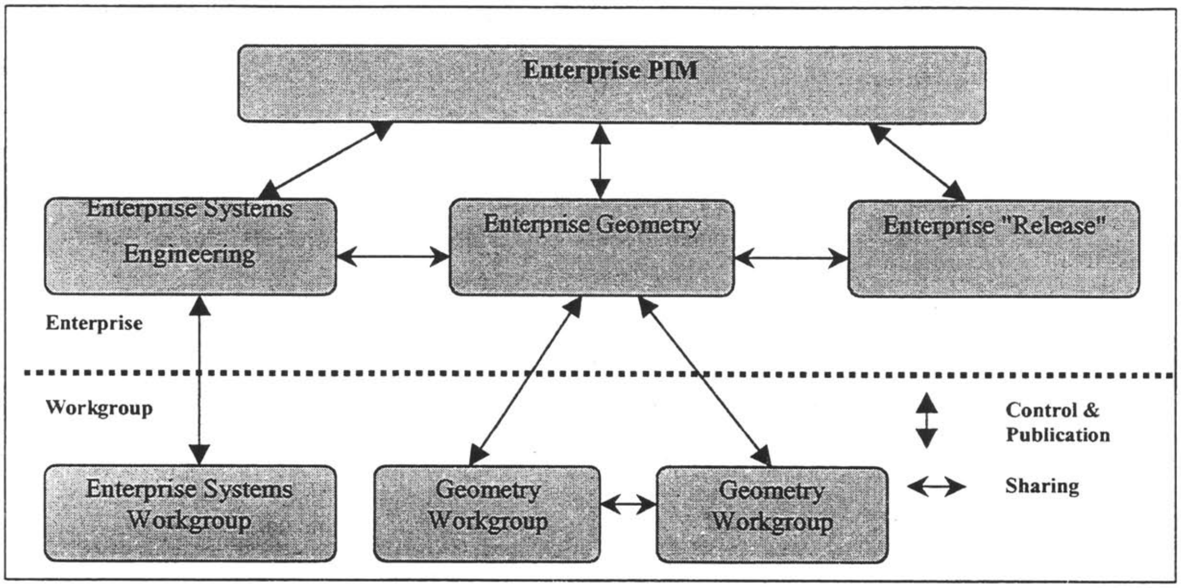


Figure 6.7.7.2-1: Functional Separation at Automotive OEM Company [Sherbenou]

## 6.8 Separation along the Horizontal Dimension

This section discusses the separation of a PIM architecture along the Horizontal Dimension. It starts with a brief discussion on Teams or workgroups and data sharing patterns - concepts that Structural Research Dynamics Corporation (SDRC) has developed. It then builds on these constructs to develop the requirements for a PIM architecture that would meet the needs of an extended enterprise. The discussion is made easier to comprehend by blending in the physical nature of the architecture along with the logical separation. The section concludes with a summary of the functional requirements for the proposed architecture. It should be noted that some of these concepts have been discussed with SDRC for inclusion into its tool suite.

### 6.8.1 Teams

The systems lessons learned from the XYZ Partner Program at Automotive OEM Company clearly highlight that fact that in most large organizations, data sharing patterns can be very complex. The concept of a Team or workgroup serves to simplify the data sharing and access management by providing a useful implementation construct. It defines the subset of a product development organization that works on a common product or program requiring fast work-in-progress level data sharing. Teams define the scope for data access and thereby, the security around a specific product development activity. Data sharing in such a team environment can typically be of three kinds [adopted from SDRC]:

- Group centric or organizationally oriented data sharing patterns where the data is made available along organizational lines i.e. it is first available only to the creating individual (by default), then with the team, possibly the program and eventually to the entire enterprise. The number of levels is dependent on the product development organization. Work-in-progress data sharing typically falls under this pattern.
- Data centric or informal cross team sharing patterns where sharing is conducted based on the characteristics of the data itself and is independent of the organizational structure or creating organization e.g. Lifecycle State. Enterprise level data sharing such as the use of CAD catalogs typically falls under this pattern.
- A mixture of group centric and data centric data sharing patterns that typically exists in very large and often geographically dispersed teams.

It is important to facilitate both data sharing patterns. Teams provide a useful data-sharing construct to build on. As the complexity of such data sharing grows, so does the need to share data quickly and efficiently. This complexity exists and is a reflection of the automotive business environment of rapidly established products and programs discussed in previous chapters.

Within Teams, data sharing may be further enabled through team membership and roles that each team member has in the context of the team [SDRC and Automotive OEM Company]. Team members may be assigned a role in the context of a project. Rules may then be defined that enable a user with a specific role to execute specific operations on data. For example, a user who has CAD Release role may release CAD data to the enterprise. The number of roles that a team member can take on within a team must be traded-off against the team size/complexity. The greater the number of roles and the resulting sub-teams, the greater is the administrative burden of managing the data access within a Team. It is proposed that teams be related to other teams creating an organizational structure [adopted from SDRC]. Such relationships enable data within the team to be made available to other teams without replication [Bsharah]. Given the concept of Teams as proposed by SDRC discussed, it is proposed this does not adequately support the business needs. Team to Team relationships must be driven by business decisions. An example of such a relationship would be that between a lead vehicle program and its follow-on or carryover program - a considerable amount of data in the lead vehicle program must be made available to the carryover program along with appropriate notification of changes.

From a physical view, a Team sets up a common repository for data that is generated by members of the Team. Very simplistically, it involves a database and the file repository that contains the bulk data made available to the Team [adopted from SDRC].

### 6.8.2 Work-in-Progress (WIP) Server

This section introduces the concept of a WIP server and only serves as a foundation for the subsequent proposal of a PIM architecture. Team based services at the work-in-progress level are provided by the WIP server - PIM software executing on a server class machine on which the team database and file repository are defined [SDRC]. In typical server fashion, multiple Teams are defined in the context of a WIP server. It is useful at this time to view Teams as being defined or associated with a WIP server, blending the physical and logical pieces of the architecture. The goal is to keep the data as close to the teams as possible to enable quick access and minimize the volume of data that moves across the networks. It is envisaged that a single WIP server may be adequate to define and server the team-based work-in-progress needs of multiple teams. Typical services provided by the WIP server include Change Notification Support, Catalog Support, Team Query, Product Structure manipulation, Data Translation if needed, Version Control, Check-in/Check-out operations to interface the authoring and Team environments and Enterprise level interaction support. Figure 6.8.2-1 depicts a WIP server and the Teams defined to be served by it highlights that there is a one-to-many relationship between a server and the teams it provides services for. It shows a WIP server called "North American WIP" that has Teams A, B and C defined on it. This depiction of a WIP server and its teams will be used in subsequent discussions.

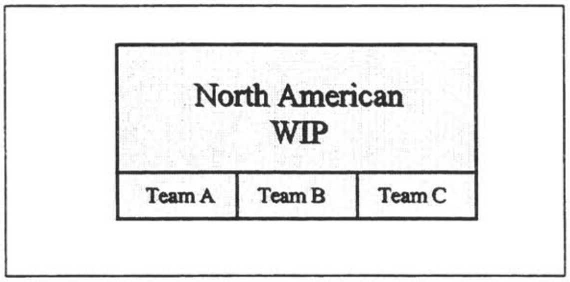


Figure 6.8.2-1 Teams defined in the context of a WIP Server

An interface to the Team, which we will call the Team User Interface or Team UI, is provided as a client to the WIP server. The Team UI may be launched from any authoring or referencing tool that is required to interface with the Team data. Figure 6.8.2-2 shows how this client interfaces authoring or data referencing tools and the Team repository. The figure is a simplistic representation of the North American WIP server with three teams defined, Team A1, Team B and Team C. Team A1 has two members, Team B has 3 members and Team C has one member, all shown using the client interface generically denoted as Software Tool or S/W tool. It may also be noted that users may belong to more that one team.

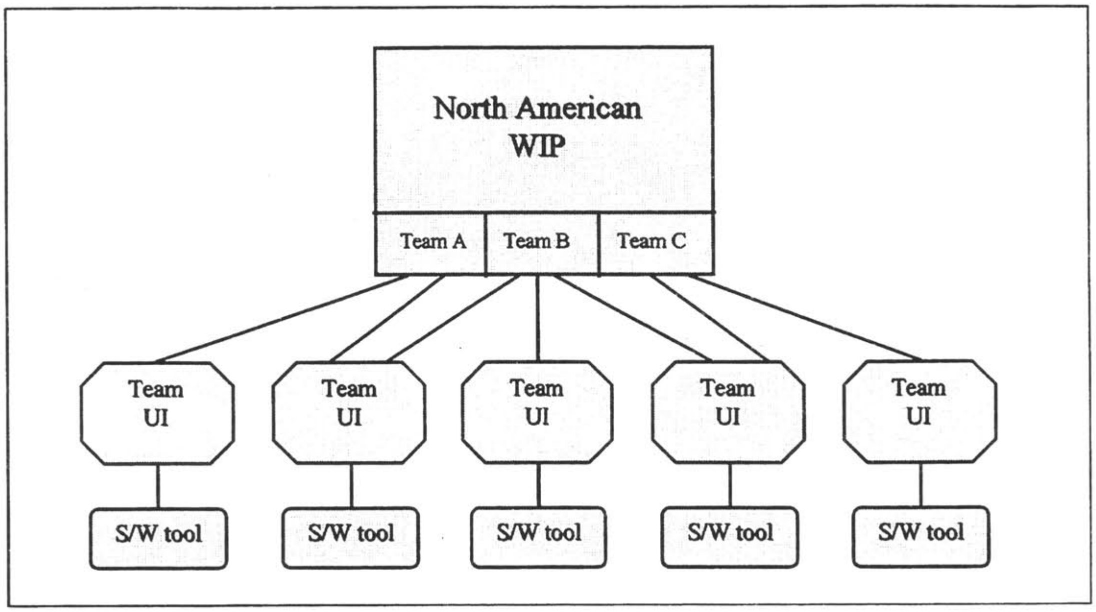


Figure 6.8.2-2: WIP Server with teams and team members

In SDRC's implementation of WIP capability, the browser client is called "Team Browser" and the authoring tool is I-DEAS Master Series as shown in Figure 6.8.2-3. When connected to an organization's regional WIP server, it has the following structure:

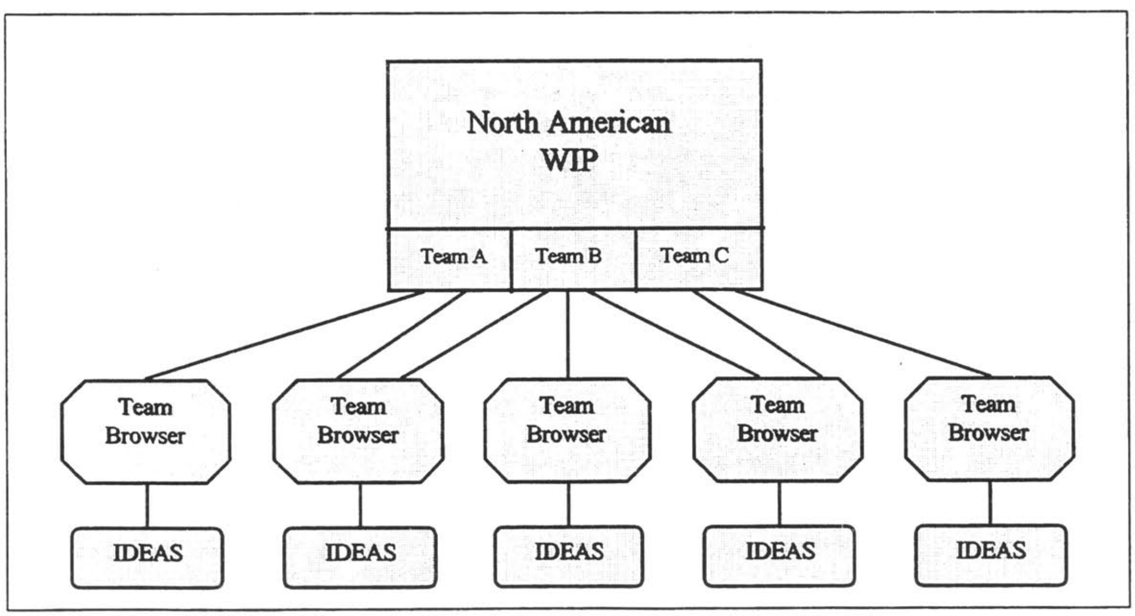


Figure 6.8.2-3: North American WIP Server and I-DEAS client and CAD authoring tool

### 6.8.3 Enterprise Product Information Management (EPIM)

We introduce the concept of an Enterprise Product Information Management (EPIM) system where enterprise level functionality and product information is made available to all users defined in the PIM system [adopted from SDRC]. The EPIM is where control, security and authority to interact are defined - these are defined at the enterprise level and cascaded down as opposed to CAD data for example, which is authored in Teams at the WIP level and progressed upward to the EPIM at specific product development milestones. Typical EPIM level functionality includes product structure definition, lifecycle definition, catalog definition, integration with external business systems, part structure definition, security policy, registry of WIP servers and enterprises that participate in the PIM architecture. Teams at the WIP level interact with the EPIM through a number of mechanisms e.g. release to enterprise (at specific milestones), check out for change from the enterprise, obtain change notices and check-out product structure.

For large companies particularly those that are present in multiple geographic locations, it is proposed that there be multiple WIP servers, enabling product data and services to be as close to the team members as possible. As an example, it is proposed that AOC may wish to consider installing WIP's in Europe, Asia and England to serve their major design centers. This could be augmented with WIP's in other ancillary locations. These multiple WIP servers could all connect to the same EPIM for enterprise level functionality. Figure 6.8.3-1 shows an example of this architecture. The horizontal arrows indicate communication and data sharing across WIP's to facilitate work-in-progress level sharing between teams located on different WIP servers. The vertical arrows indicate the interaction between the workgroup and enterprise levels.

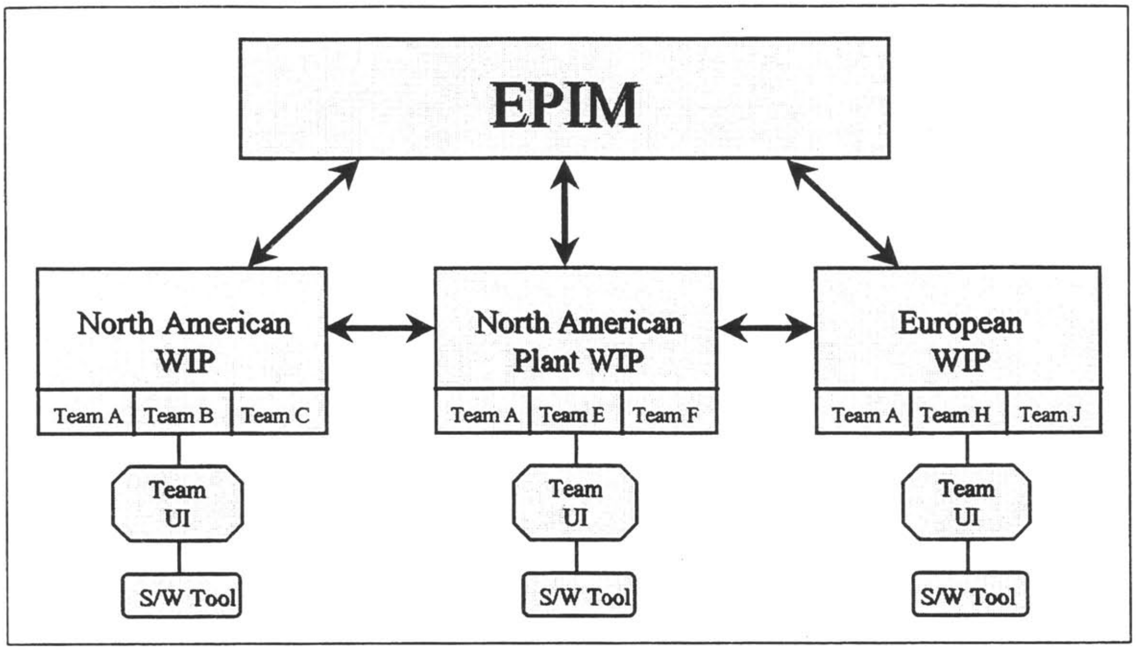


Figure 6.8.3-1: EPIM with multiple WIP Servers

### 6.8.4 Distributed Teams

Having introduced the basic components in the previous sections, we now introduce the concept of a Distributed Team. In large organizations or in organizations that have multiple, geographically dispersed design centers, it is very likely to have team members located in multiple sites working on the same product or program. We refer to such a team as a Distributed Team. Currently, distributed team members who work on the same product or program, in reality work in isolated environments or in some cases, duplicated environments. These result in an environment that is fraught with errors due to non-communicated changes, lack of coordination, work being done on incorrect versions of the data, etc. The XYZ Partner Program referenced in previous chapters is an example of such an environment. While it is possible to have a Team with members who are geographically dispersed but connected to the same WIP server, for the purposes of this discussion, we will not refer to that team as a Distributed Team. In that case, the option of working in the context of the same WIP server always exists. In fact, there would be very little reason not to operate in the same environment. In our analysis, we define a Distributed Team as one that spans multiple WIP servers. Figure 6.8.4-1 shows a product development team, called Team C, with two members located in North America and two others in Europe. Such a Distributed Team structure requires the capability to not only define the Team, but define "Distributed Team Instances" that are the various geographically dispersed sites that contain members of the Distributed Team. In this case, we have a Distributed Team C with Team Instances C1 on the North American WIP and Team Instance C2 on the European WIP.

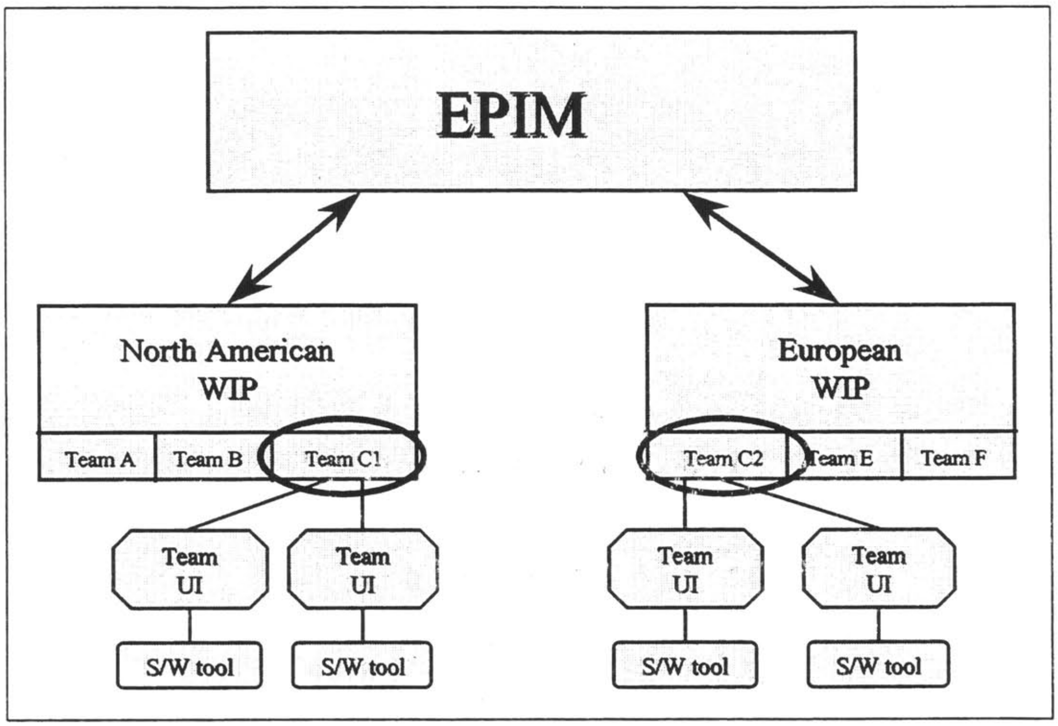


Figure 6.8.4-1: Distributed Team across WIP Servers

### 6.8.5 Collaborative Team Environment (CTE)

In order to facilitate collaboration, a Distributed Team requires the ability to consolidate the data that is generated by the individual distributed team instances, but which belongs to the Distributed Team in general. This data must be made available to the entire Distributed Team in a manner that allows the user to operate in a "scope" that includes the entire Distributed Team, not just the local Distributed Team Instance. We introduce the concept of a Collaborative Team Environment (CTE) to define a virtual PIM environment that contains product information from all the defined Distributed Team Instances. A Collaborative Team

Environment (CTE) virtually brings together a distributed team. In a simplistic manner, it is the "join" of Meta data (no bulk data) that exists on all the Distributed Team Instances. While Teams are generally defined at the WIP level, a Distributed Team must be made known at the EPIM level to account for security and connectivity issues.

It is envisaged that the CTE is created for a user when the user logs in. Without going into implementation details, the goal is for the user to have access to his local Distributed Team Instance by default. An explicit action to set scope to the CTE would create the CTE for the user to ensure that it contains the latest state of the data. Figure 6.8.5-1 shows the CTE of Team C. The dotted circle implies that there isn't a physical existence behind the structure, but only a logical consolidation of it.

At this point we introduce the following notation to make the discussion easier:

- A Team with the designated name C is denoted by the symbol T(C).
- A Distributed Team with the designated name C is denoted by the symbol DT(C).
- The symbol DTI (C1) and DTI (C2) denote individual Team Instances C1 and C2 of a Distributed Team called C. When one wishes to reference the WIP servers explicitly, this may be done so using by augmenting the Distributed Team Instance symbol with the WIP server reference. The above example would then written as DTI (C1) @ W (North American WIP) and DTI (C2) @ W (European WIP).
- The CTE of Team C is denoted by the symbol CTE (C) = { DTI (C1), DTI (C2) }
- A team member User 1 on DTI (C1) is referenced using the symbol TM (User 1) @ DTI (C1).

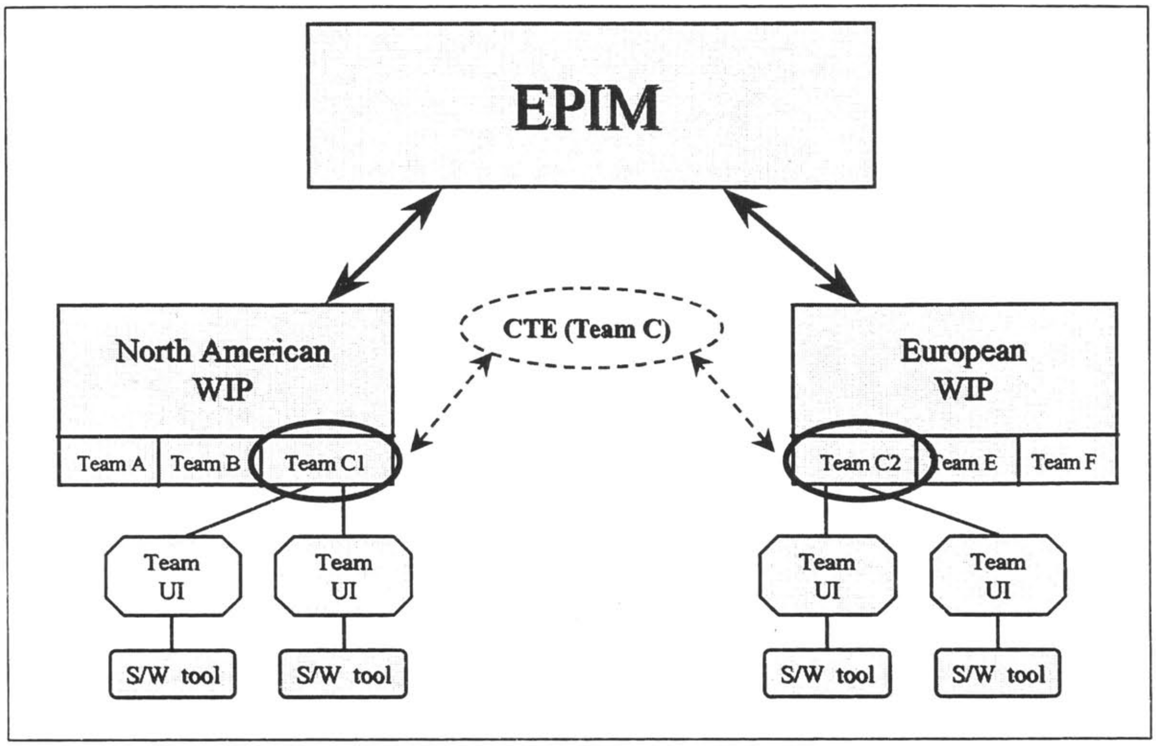


Figure 6.8.5-1: Distributed Teams and their Collaborative Team Environment (CTE)

Figure 6.8.5-2 below describes a simple Distributed Team C which has Distributed Team Instances DTI (C1) and DTI (C2) on the North American and European WIP servers respectively. User 1 is a member of DTI (C1) @ W (North American) and User 2 is a member of DTI (C2) @ W (European). It should be noted that both are members of Distributed Team C. CTE (C) is the collaborative team environment of team C and is denoted by:

CTE (C) = { DTI (C1) @ W (North American),
DTI (C2) @ W (European)
}

Figure 6.8.5-2 also shows that User 1 has created Part P1 and User 2 has created Part P2. These part definitions exist on the individual team instances, but are made available to the distributed team C via the CTE. Taking this further, 6.8.5-2 also shows that User 1 has created an assembly A1 that references parts P1 and P2. The Assembly definition along with the relationships to parts P1 and P2 exist in DTI (C1). When User 1 queries his team, all he sees are Part P1 and Assembly A1. When User 2 queries his team, he sees only Part P2. However, when either User 1 or User 2 sets their scope to the Distributed Team Environment CTE (C), they both see Parts P1, P2 and Assembly A1 along with the relationships to P1 and P2. They both see the same version of the data, the person who has it checked out for modification, etc.

As mentioned earlier, the data is physically stored on the WIP server that the creator is defined on. Therefore, Part P1 and Assembly A1 are stored on the North American WIP and Part P2 is stored on the European WIP.

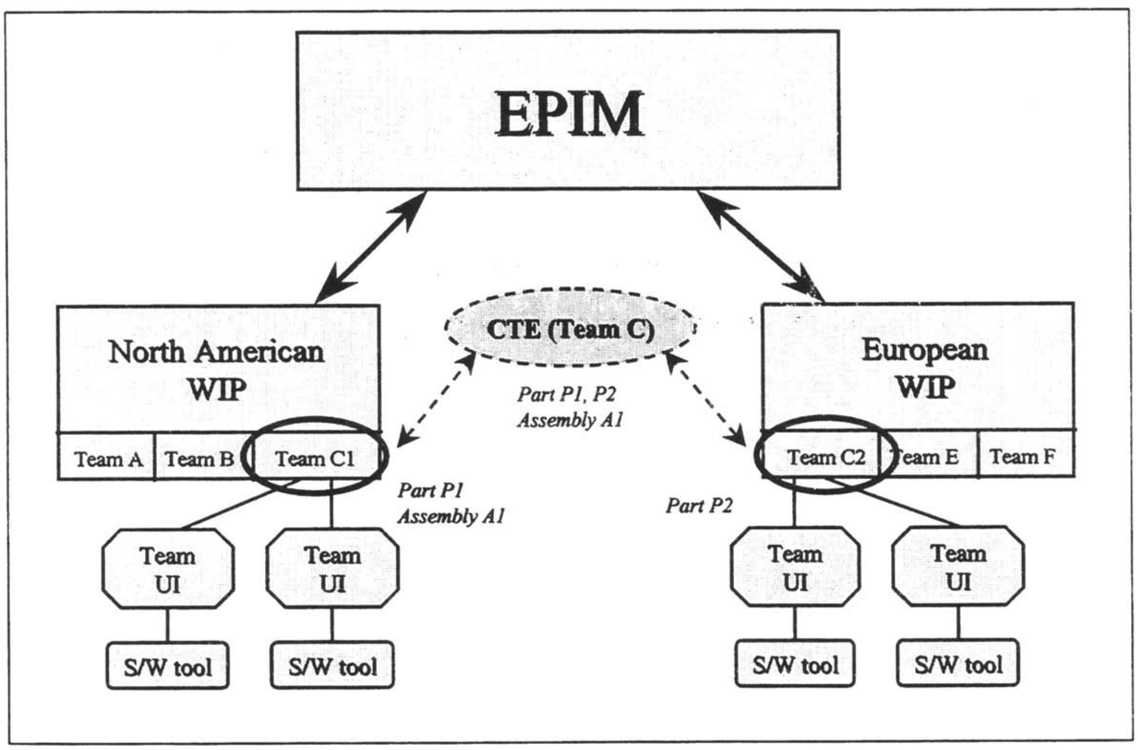


Figure 6.8.5-2: User Data in the context of a CTE

### 6.8.6 Organizational Domain

In most large organizations, there is always the possibility of differing processes or business practices. We propose a means by which specific WIP servers may be aggregated for a variety of reasons such as common business practice, performance, geographic proximity or distance and administrative jurisdiction. Whatever the reason, these WIP's share the same EPIM. The concept was originally introduced as a means of enabling multiple business processes or Federated Processes even within the same organization. After initial analysis, it quickly became evident that common business practice may not be the only reason one would want to partition PIM architectures by. Figure 6.8.6-1 shows what the AOC Operations domain may look like - a consolidation of the North American, European and North American Plant WIPs. These are tied together due to common business practice. However, Figure 6.8.6-2 shows another AOC domain, the AOC of Australia (AOA) domain comprising of the AOA and AOA Plant WIPs. Even though Automotive OEM of Australia makes use of essentially the same processes, for performance reasons, they are better treated as a separate domain. As mentioned before, each Organizational Domain has its own EPIM. Business analysis would dictate whether these need to be kept in sync with each other or not. A distributed team can span multiple domains and team collaboration is once again facilitated via the CTE. In this case, the EPIMs need to contain the Distributed Team and WIP definitions More formal interaction can be conducted at the enterprise level only. Due to possibly differing business practices, interaction across domains generally requires a mapping (either process or data).

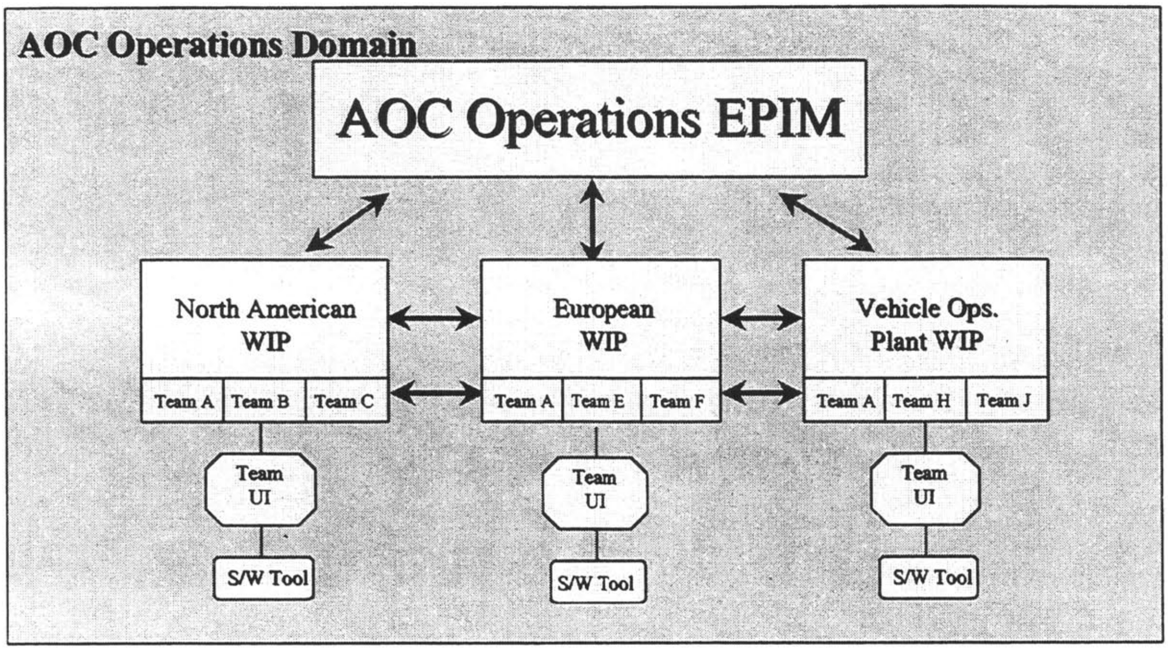


Figure 6.8.6-1: The AOC Operations Organizational Domain

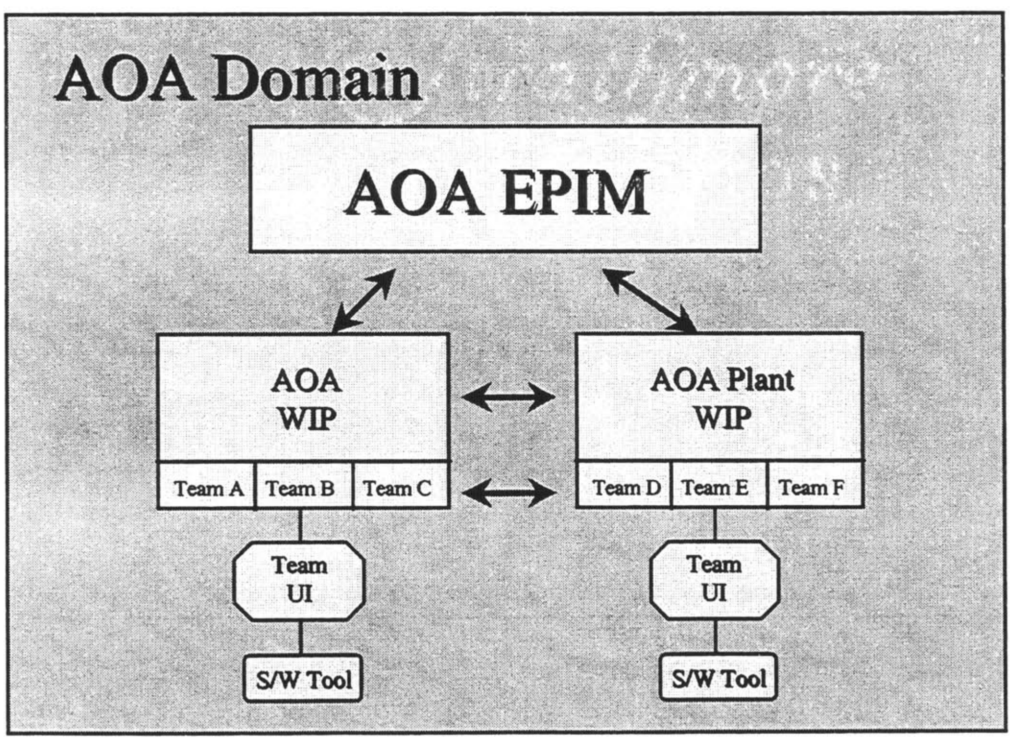


Figure 6.8.6-2: Automotive OEM of Australia (AOA) Organizational Domain

Clearly, Distributed Teams can span domains within an enterprise as is shown by Figure 6.8.2-3. In this case, Distributed Team C has its DTI's in the AOC Operations and AOA domains respectively. It is proposed that a data model level mapping on each end serves to map any differences in the data models.

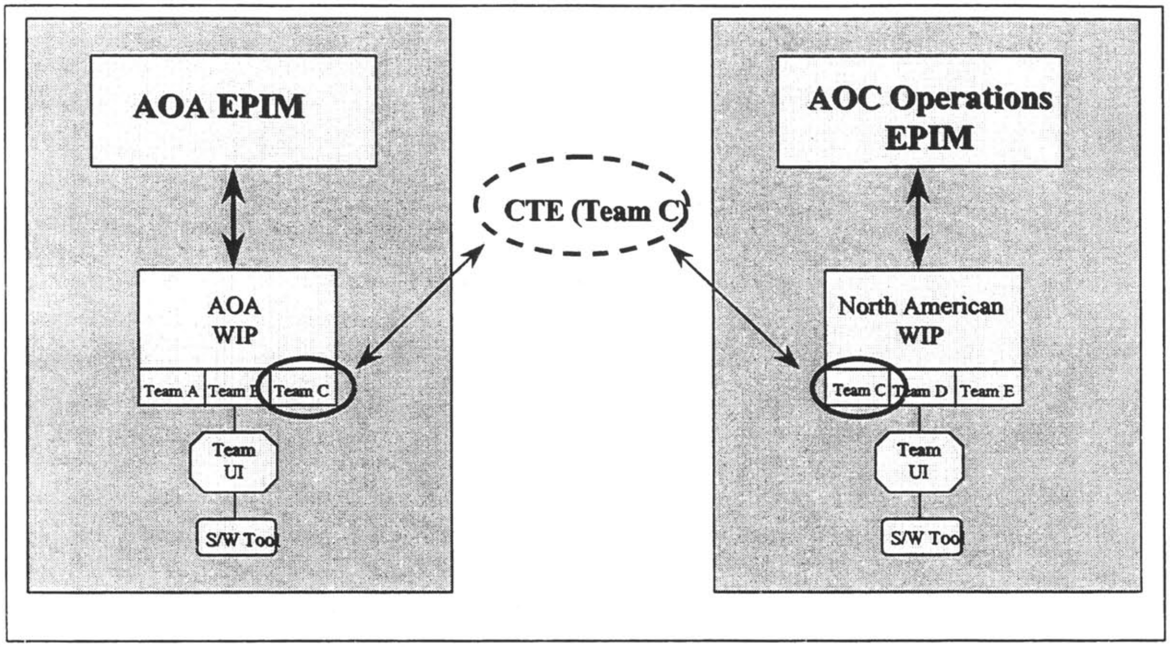


Figure 6.8.2-3: Distributed Teams spanning Organizational Domains

### 6.8.7 Enterprise

Taking this along hierarchical or organizational lines as described above (as one data-sharing pattern), all the domains in an independent business unit comprise an Enterprise. For example, the AOC Operations, AOA and AOC of S. America domains comprise the AOC Enterprise (note: this is only an example - the analysis on exactly what the AOC domains will be is not yet complete). Figure 6.8.7-1 is an attempt at showing the AOC Enterprise comprising only of the AOA and AOC Operations domains. In some sense, the aggregation of Organizational Domains into an enterprise is the result of existing infrastructure limits - one could view the enterprise as being of the same scope as that of the company's Intranet. It serves to define capabilities at the corporate level.

We introduce the symbol E (Enterprise Name) to denote the existence of the Enterprise e.g. E (Automotive OEM Company).

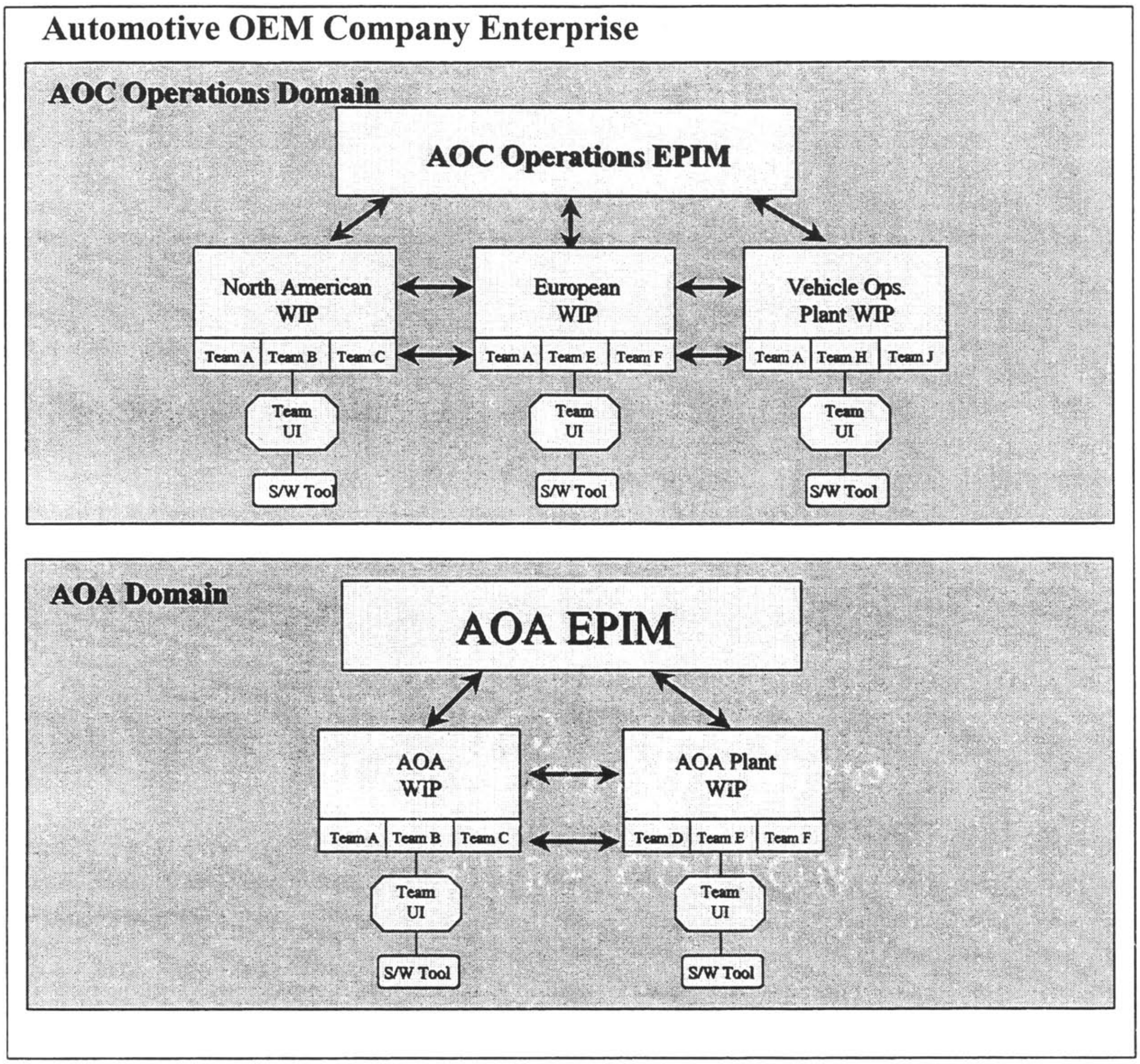


Figure 6.8.7-1: AOC Enterprise defined with the AOA and AOC Operations Organizational Domains

### 6.8.8 Extended Enterprise

In keeping with the discussions in this paper, most product development is conducted as collaborations with partners (other independent organizations at the same level or with the supplier community). We define the concept of an Extended Enterprise as the business units that partner together to collaboratively design, develop and deliver a product. An example of such an Extended Enterprise is that set of enterprises defined by AOC, POC and their supplier communities for the development of a common product such as the XYZ Partner Program. Figure 6.8.8-1 below depicts another AOC partner program called Vehicle Program A involving AOC, POC and suppliers.

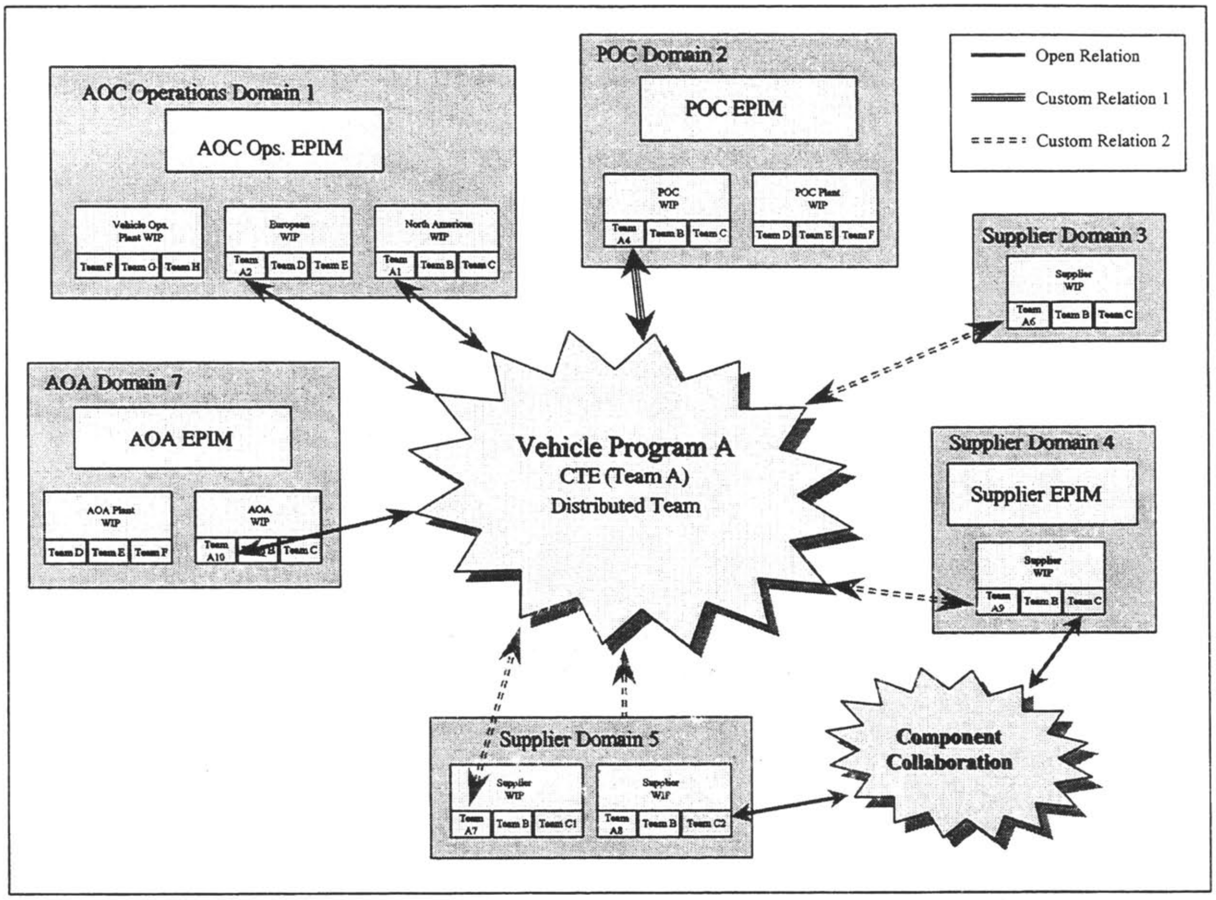


Figure 6.8.8-1: Example of the Extended Enterprise (AOC Partner Program)

The Extended Enterprise CTE for Vehicle Program A depicted in Figure 6.8.8-1 is defined as follows:

- Define a Distributed Team called Vehicle Program A - DT (Vehicle Program A).
- Define the following Distributed Team Instances:

1. DTI (A1) @ W (North American WIP) @ D (AOC Operations Domain 1) @ E (AOC)
2. DTI (A2) @ W (European WIP) @ D (AOC Operations Domain 1) @ E (AOC)
3. DTI (A10) @ W (AOA WIP) @ D (AOA Domain 7) @ E (AOC)

4. DTI (A4) @ W (POC WIP) @ D (POC Domain 2) @ E (POC)
5. DTI (A5) @ W (POC-2 WIP) @ D (POC-2 Domain 6) @ E (POC-2)
6. DTI (A7) @ W (Supplier WIP) @ D (Supplier Domain 5) @ E (Supplier Enterprise)
7. DTI (A8) @ W (Supplier WIP) @ D (Supplier Domain 5) @ E (Supplier Enterprise)
8. DTI (A9) @ W (Supplier WIP) @ D (Supplier Domain 4) @ E (Supplier Enterprise)
9. DTI (A6) @ W (Supplier WIP) @ D (Supplier Domain 3) @ E (Supplier Enterprise)

- Define the Collaborative Team Environment - CTE (Vehicle Program A).
- If necessary, individual component level CTE's may also be defined (Figure 6.8.8-1).

It is proposed that in a PIM infrastructure, there can be multiple such CTE's, each one dedicated to a product or program. This is shown in figure 6.8.8-2 where there is a CTE for Product X and a CTE for Team A. Additionally, local collaboration environments such as that for component design between suppliers are also feasible.

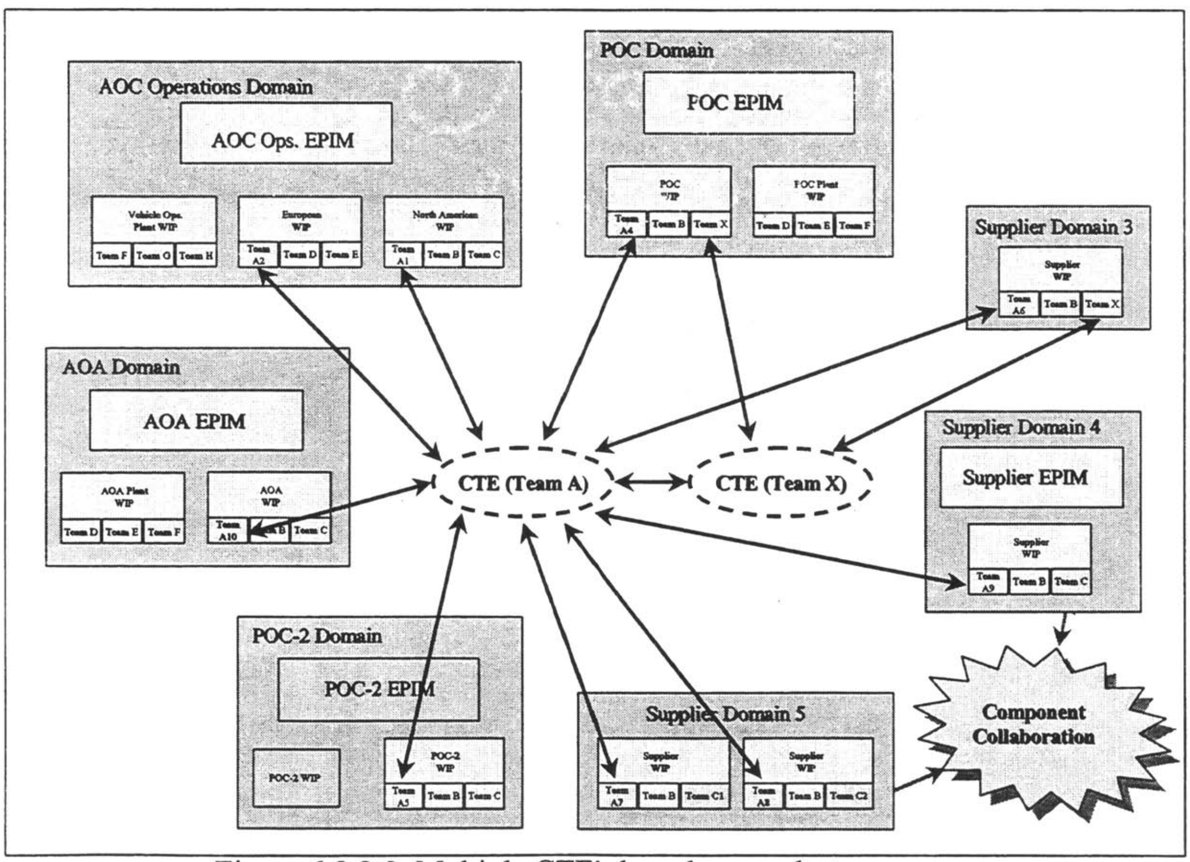


Figure 6.8.8-2: Multiple CTE's based on products or programs

#### 6.8.8.1 Automatic Dynamic Configuration of CTE's

Business relationships drive the creation of the virtual Extended Enterprise PIM infrastructure. Given that the Distributed Team can be expressed in a formal manner using the notation described above, it is possible for external systems to define the relationships for automatic creation. Sourcing decisions made by Purchasing Organizations may be captured and the CTE for the program automatically configured resulting in the virtual PIM environment being created. As an example, it is very possible for the Distributed Team definition for a vehicle program and its CTE based on sourcing decisions to be automatically created when sourcing decisions are made. Such a PIM infrastructure would truly be dynamic and business relationship driven. If we were to source a major supplier for a program, the CTE is augmented with the supplier site if necessary. This way we allow a flexible structure that can be created based on external systems and scaled as necessary to facilitate WIP sharing.

### 6.8.9 Typical CTE Functions

This section briefly discusses a few typical CTE capabilities. We assume that the state of the CTE is as shown in Figure 6.8.5-2 and that User 2 on Distributed Team Instance C2 is the person initiating the action. Once again the goal is to describe desired behaviors and not implementations of the capabilities. Each capability is expressed in terms of intent, an action, the expected behavior and any potential impact to other users in the Distributed Team. A brief scenario is presented when the action might be better explained using one.

#### 6.8.9.1 Check-out From CTE for Modification

**Intent**

This capability is used when the user wishes to lock data in the CTE for modification purposes. The intent is to let all the team members know that the person who has checked the data out for modification is working on the data and that the person now has the master. All others may continue to reference the data.

**Action**

The user sets his browser scope to the CTE for Team C. He then queries the CTE for the data type he is interested in and then selects the item in the resulting browser. Based on the data type selected, other options may also be presented. He then selects the Check-out-From-CTE-For-Modification Action. Based on the data type, the user may be presented with a number of options that ensure the integrity of the data e.g. checkout entire product structure or check-out Meta data only.

**Scenario**

User 2 sets his scope to CTE (C) and queries for Assemblies.

The query results in a list of Assemblies in the CTE for Team C i.e. Assembly A1.

User 2 selects A1 and then selects the Check-Out-From-CTE-For-Modification action.

**Expected Behavior**

If the selected item is the master (i.e. the item has not been checked out for modification by another team member), a successor flag is created with the Version attribute set to one higher than the original value and the item is brought to the Distributed Team Instance the user is on. If the selected item is not the master, the action is denied.

**Scenario**

Assuming User 2 opts to check-out only the Assembly A1 with the bulk data associated with it, the successor flag for Assembly A1 is created and its Version attribute set to 2. The Meta data for Assembly A1 is brought into the database for DTI (C2) along with a copy of the bulk data (CAD file).

**Potential Impact on Team Members**

All other users querying the CTE would see that the item has been checked out and by whom.

**Scenario**

Team members would see that User 2 has checked out Assembly A1 for modification and the successor flag, "A1 Version 2".

#### 6.8.9.2 Check-in To CTE

**Intent**

This action enables a user to check data back into DTI relinquishing ownership and allowing the CTE to reflect the updated information i.e. the Distributed Team is now the owner of the item. The intent of this function is to distinguish from a more localized Check-in, which is not automatically reflected in the CTE allowing ownership to be retained at the Distributed Team Instance. It is very likely that the users may not want to distinguish between the two, in which case, a configurable option would dictate the characteristic of the check-in.

**Scenario**

User 1 wishes to check Part P1 into his Distributed Team Instance for the first time making it available for reference to the other team members.

**Action**

The user selects the data in the authoring tool and picks the Check-in To CTE option.

**Expected Behavior**

The CTE will reflect the presence of the data and its availability for reference or subsequent check-out.

**Potential Impact on Team Members**

Members who have registered their interest in being notified of the check-in of the selected item will be notified either via e-mail or via an automatic update of their CTE cache or both. If the check-in implies new data (as it generally does), a specific set of users may have to respond appropriately. It is not clear at this point where the list of users subscribing to the operation will be stored to initiate the automatic notification.

**Scenario**

Assuming User 2 is checking in Part P2 for the first time, he or she selects it in the authoring tool browser and checks it in. The CTE automatically registers its presence. Assuming User 1 has subscribed to this operation, he will be notified via an automatic update of this CTE cache.

#### 6.8.9.3 Dissociated Copy from CTE

**Intent**

This action allows a user to make a copy of data in the CTE by creating a brand new entity. No relationships are carried forward. The new item is instantiated only in the user's DTI database. Its existence, of course, will be made known to all team members.

**Action**

The user sets his scope to the CTE, selects a part or assembly and then selects the Dissociated Copy from CTE option.

**Expected Behavior**

This action will create a copy of the part or assembly in his local Distributed Team Instance using a part number or part name supplied by the user during this interaction. The existence of the new part will be reflected in the CTE.

**Potential Impact on Team Members**

None

#### 6.8.9.4 Copy for Reference from CTE

**Intent**

This action allows an item to be physically copied into the user's local DTI for performance. A relationship to the original item is maintained to enable change notification and tracking. Data that is copied for reference is visible only in the Distributed Team Instance and not in the CTE.

**Action**

The user sets his scope to the CTE, selects a part or assembly and then selects the Copy for Reference from CTE option.

**Expected Behavior**

A copy of the part is made in the user's Distributed Team Instance. A relationship is created between the original and the source to track its history and reflect updates. It has its own identifier and is visible to members of the Distributed Team Instance but not at the CTE level.

**Potential Impact on Team Members**

Any attempt to delete the original part will flag a warning that a reference copy of the part exists in a specific Distributed Team Instance. New versions of the data will automatically trigger a notification to the users who have made reference copies. Optionally, the new version itself is copied over in a similar manner.

#### 6.8.9.5 Transfer from CTE

**Intent**

This action moves Meta and Bulk data between DTI's.

**Scenario**

User 2 wishes to bring over a copy of the native data file of Part P1 from the Distributed Team Instance on which it exists.

**Action**

The user sets his scope to the CTE, selects the part and picks the Transfer from CTE option.

**Expected Behavior**

A copy of the data file associated with Part P1 is transferred to the Distributed Team Instance of the user initiating the action.

**Potential Impact on Team Members**

None.

#### 6.8.9.6 Find (Query/Search) CTE

**Intent**

This action enables a user to search the CTE for data items of choice. The user may either query for a particular data item or all items. An option would be to force a refresh of the cache to ensure the latest state of the CTE.

**Scenario**

User 2 wishes to query the CTE for all parts having a particular base part number.

**Action**

The user sets his scope to the CTE and selects initiates the Query action. The search parameters are entered into the Query dialog box and are used to narrow the search.

**Expected Behavior**

The CTE is searched for all parts that match the search criteria. The results are presented to the user.

**Potential Impact on Team Members**

None.

**Scenario**

User 1 sets his scope to the CTE and queries for all parts that have a Part Number starting with 'P'. The results (Parts P1 and P2) are presented to him.

#### 6.8.9.7 Replicate Meta-data from CTE

**Intent**

This action tags the selected item for replication across the DTI's. A new version of the item, when created is automatically replicated across the DTI's for performance.

**Action**

The user selects data in the local Distributed Team Instance and picks this option. The user must then specify which Distributed Team Instances this data must be replicated on. This decision is made based on common agreement and requests from distributed team members.

**Expected Behavior**

The Meta data of the selected item is copied to the specified DTI's and is available as a local copy to the members of those DTI's. Subsequent versions of the Meta data are also replicated.

**Potential Impact on Team Members**

None.

#### 6.8.9.8 Replicate Bulk-data from CTE

**Intent**

This action tags the selected bulk data for automatic replication across the DTI's. Care must be taken when using this action to ensure that a vast amount of data is not replicated.

**Action**

The user selects data in the local Distributed Team Instance and picks this option. The user must then specify which Distributed Team Instances this data must be replicated on.

This decision is made based on common agreement and requests from distributed team members.

**Expected Behavior**

The Meta data and bulk data of the selected item is copied to the specified DTI's and is available as a local copy to the members of those DTI's. Subsequent versions of the data are also replicated.

**Potential Impact on Team Members**

None.

#### 6.8.9.9 Update Cache from CTE

**Intent**

This action forces an update of the CTE cache. Based on the Distributed Team definition it triggers a query across all the DTI's and retrieves the Meta data.

**Action**

This option is selected via a menu pick. The option to automatically update the CTE cache periodically may be selected as a configurable item.

**Expected Behavior**

The user's CTE cache is updated after multiple distributed queries to the DTI's are executed and the results consolidated.

**Potential Impact on Team Members**

None.

The above functions are only a handful of the capabilities that need to be made available at the CTE level. They provide a flavor for the kinds of functionality that will take on importance in such a distributed team environment.

# 7 ARCHITECTURAL PROVE-OUT

This chapter discusses how the proposed collaborative PIM architecture outlined in chapter 6 might solve some of the PIM issues with supporting partner programs to meet the needs of the business. Some of the generic issues faced in AOC's current PIM implementation are also identified and addressed. In addition, the issues identified in Chapter 4: XYZ Case Study and listed in Table 4.3-2 - "Summary of Issues", are used as the context to describe how they may be resolved. Where necessary, diagrams are used to augment the discussion. In some cases a scenario that is typical of the issue is selected and discussed in an attempt to show how it is resolved.

## 7.1 AOC's PIM Environment

AOC's PIM environment is described in Section 6.5 Current Situation at Automotive OEM Company and graphically depicted in Figure 6.5-1. It is reproduced here in Figure 7.1-1: AOC's Current PIM Architecture.

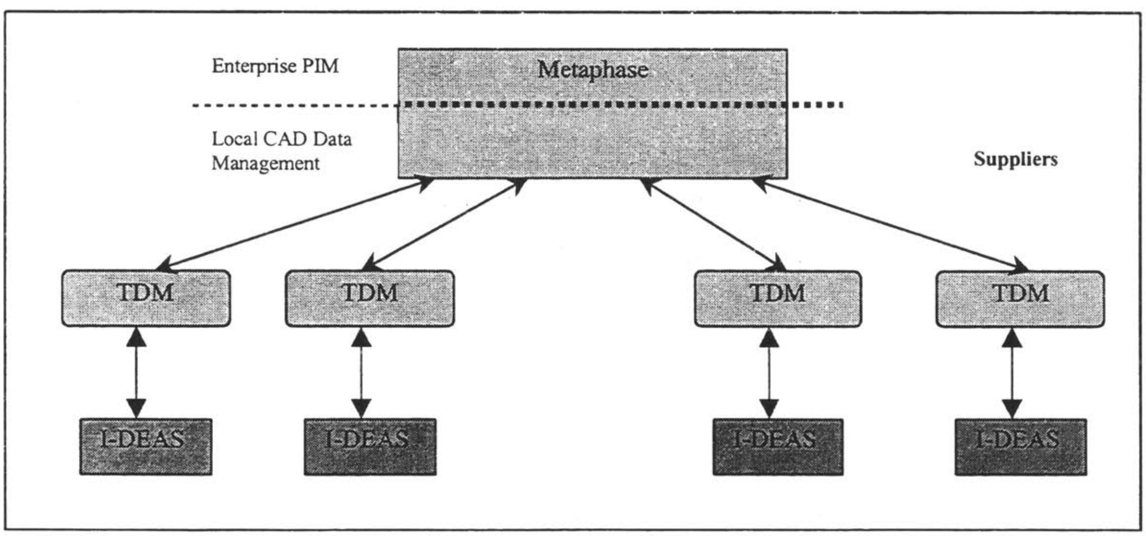


Figure 7.1-1: AOC's Current PIM Architecture

## 7.2 Generic AOC Issues

This section discusses some of the generic PIM issues faced by Automotive OEM Company due to its current architecture. The format adopted includes a description of the issue, what the limitations are and a description of how the issue can be resolved using the proposed architecture. In some cases, it will be necessary to explain PIM functionality available in the specific PIM tool used in the study, Metaphase, and how they may be leveraged. However, in most cases, these are capabilities that already exist in most PIM systems, or may be added in the near future. No attempt is made to discuss PIM in general in this discussion.

### 7.2.1 Issue 1 - Artificial Team Separation

Limitations in the current TDM architecture force the number of users on a TDM to be very low (the actual number is withheld for confidentiality reasons). Users on TDMs containing more than the specified number of users start experiencing performance degradation and data corruption due to contention for system resources. This has resulted in an artificial separation of teams into multiple TDMs and a separation of team members into multiple environments.

This situation does not exist in the proposed architecture. Due to the use of a PIM system with a commercial database management system as the underlying technology for local workgroup-level data management, the number of members on a team can be very high, in the region of a couple of thousand. All members of a team function in the same environment. Since teams are distributed across multiple installations, the architecture is scalable to include a large number of widely dispersed team members.

### 7.2.2 Issue 2 - Multiple steps to share data with distributed remote team members

Current TDMs are not capable of communicating directly with each other in a simple manner. This hinders work-in-progress data sharing and collaboration. Users are forced to share work-in-progress CAD data with other team members on different TDMs by performing the following steps:

- Sender saves the Part or Assembly to the local TDM
- Sender then selects the Part or Assembly in the TDM and checks it into Metaphase using PIM system interfacing tool. An unnecessary later version of the part or assembly along with all its product structure relations is created in Metaphase if prior versions of the assembly already exist.
- Sender then informs the recipient(s) of the data in Metaphase
- Recipient queries Metaphase, selects the assembly structure and checks it out to his/her local TDM for reference (or modification if desired and if the master is in Metaphase).
- Recipient then imports the Assembly into I-DEAS

The check in and subsequent check out from the PIM system purely for sharing purposes is a non-value added step that is time consuming due to the transfer of large volumes of data. A secondary impact is the unnecessary creation of versions and a proliferation of relationships in the PIM system that exist purely due to system inefficiency. These greatly affect the performance of subsequent operations such as "Renumbering a Part", because of the number of relationships that have to be traversed.

In the proposed architecture, the steps outlined above are replaced by:

- The Sender saves the Part or Assembly to the Team environment. The Recipient is made aware of the existence through proactive notification.
- The Recipient checks the data from the Team environment into I-DEAS. If the team member is located in a geographically remote area, the team member may query the CTE(Team) and retrieve the assembly from there. A copy of the data is moved from the sender's Distributed Team Instance (DTI) if necessary.

In essence, a 4-step sharing operation is reduced to a 2-step sharing operation.

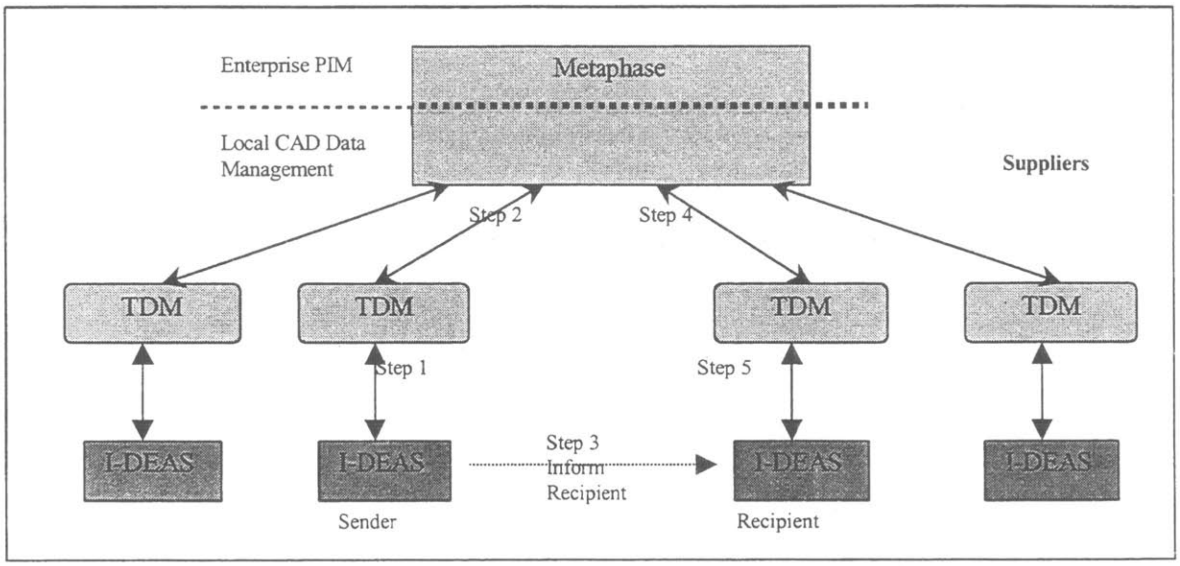


Figure 7.2.2-1: The steps involved in sharing CAD data

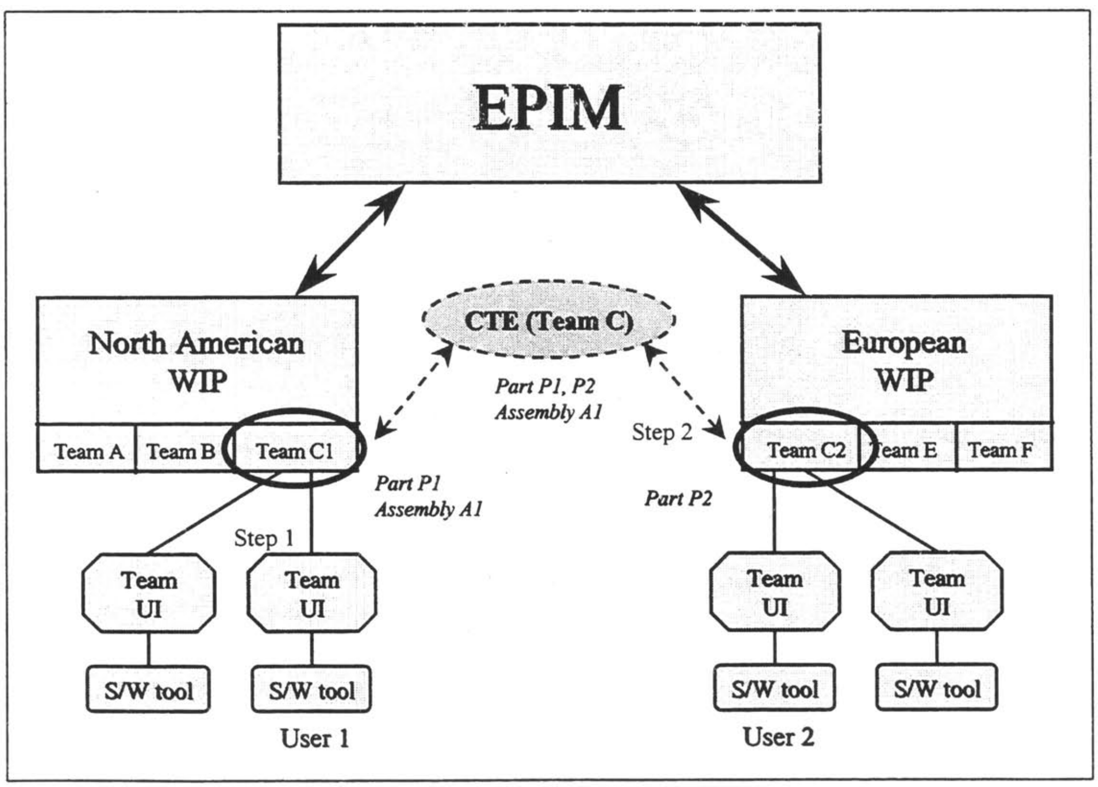


Figure 7.2.2-2 The steps to share CAD data in the proposed architecture

As noted in Figure 7.2.2-2 above, there are only two steps to retrieve the data.

### 7.2.3 Issue 3 - Single PIM System

In AOC's case, there are two completely different data management systems at the workgroup and enterprise levels - TDM and Metaphase respectively. These operate with different and sometimes conflicting paradigms e.g. Metaphase creates the successor of an object on check-out, while the TDM creates the successor object only on check-in.

The recommended architecture proposes the use of the same PIM system at the enterprise and workgroup levels along with a corresponding support for functionality that is separated along those dimensions. Users working at the enterprise or workgroup levels will experience the same behavior. Custom logic to bridge different paradigms such as those in methods that check data in and out from either repository may be eliminated.

### 7.2.4 Issue 4 - Forced Movement of Bulk Data

The current PIM architecture forces the movement of large volumes of CAD data files. This is the result of closed systems where most data is embedded in the files or in custom formats that require very specific logic to process. In the current architecture, the orientation of the components in an assembly is embedded in the CAD files and stored as part of a transformation matrix at the highest level node of the assembly structure. Since the transformation matrix is stored in the CAD file associated with the assembly definition, even if one component is changed, the entire assembly structure must be moved. AOC deals with the concept of Master Packages, which are assembly structures that have all components in vehicle position. Without the transformation matrix, the parts are positioned in free space.

The recommended architecture shifts the focus away from bulk data to Meta data leveraging the storing of data on product structure relationships e.g. concept of Pruning assemblies [SDRC]. When embedded data is exposed as Meta data, only changed components need be transferred between members. Not only does this capability offer much better performance, but more importantly, it enables a substantial change in the vehicle development process to communicate only changes instead of the entire data set.

### 7.2.5 Issue 5 - Supplier Data in AOC Systems

The current implementation forces suppliers to exchange work-in-progress data with AOC via Metaphase. This forces AOC systems to contain work-in-progress supplier data forcing AOC to bear the expense and burden of managing supplier data. AOC has made a strategic decision to get supplier and partners to manage their own data in their own systems. This is not possible using the current architecture which forces the use of the same data repository.

The recommended architecture enables a distributed PIM environment that allows suppliers to have their own systems and to store their work-in-progress data at their own sites. Business process decisions can determine how and when data is made available to AOC.

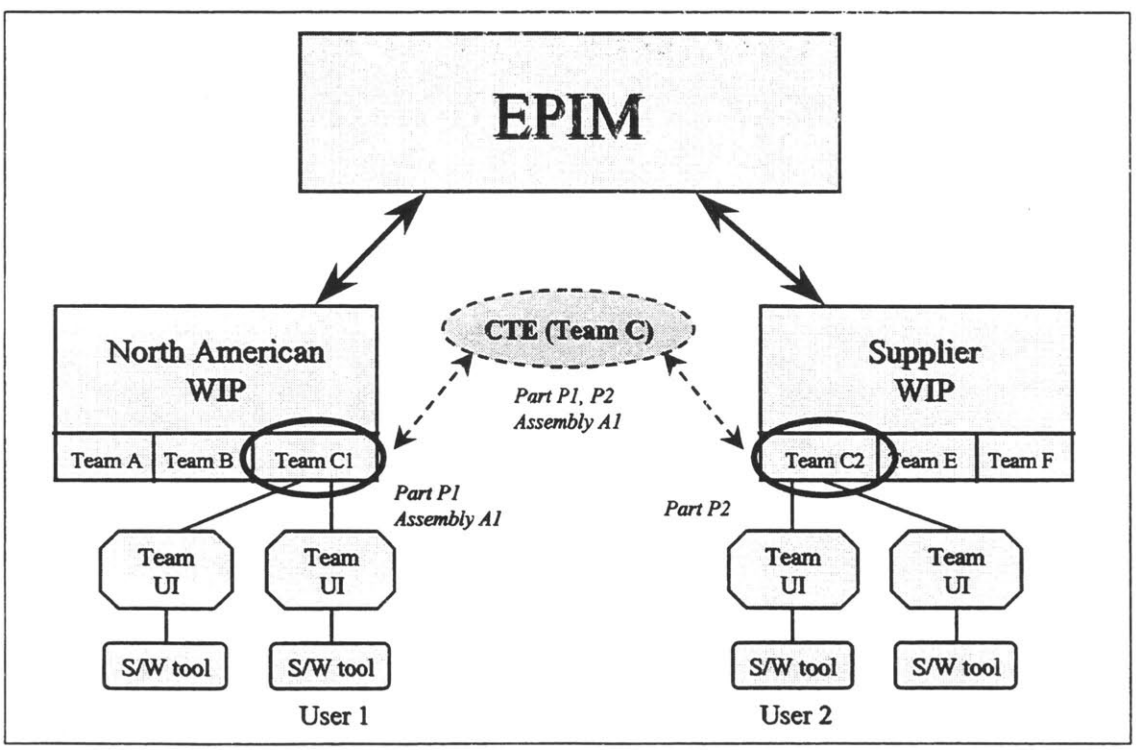


Figure 7.2.5-1: Supplier data resides on supplier's systems

As seen in Figure 7.2.5-1, the supplier data resides on the supplier's system.

### 7.2.6 Issue 6 - Lack of support for geographically distant enterprises

The current centralized PIM architecture at AOC forces the use of a single core server across the entire PIM installation worldwide. The implication is that there is only one database to ensure uniqueness across the installation. The impact is that all PIM operations requiring manipulation of the key tables (e.g. create, delete, change, etc.) are forced to communicate directly with the central core server. For small transactions this is not an issue other than the forced transfer of Meta data to databases located in North America. However, for long transactions the performance is unacceptable. The differences in communication infrastructures across the extended enterprise further exacerbate the problem.

The recommended architecture enables a decentralized implementation. All communication takes place with local servers eliminating needless network traffic. Where uniqueness is desired or required, it is maintained at the Meta data level using the Domain definitions i.e. a configurable option enables uniqueness across all servers in an Organizational Domain. Figure 7.2.6 -1 depicts this.

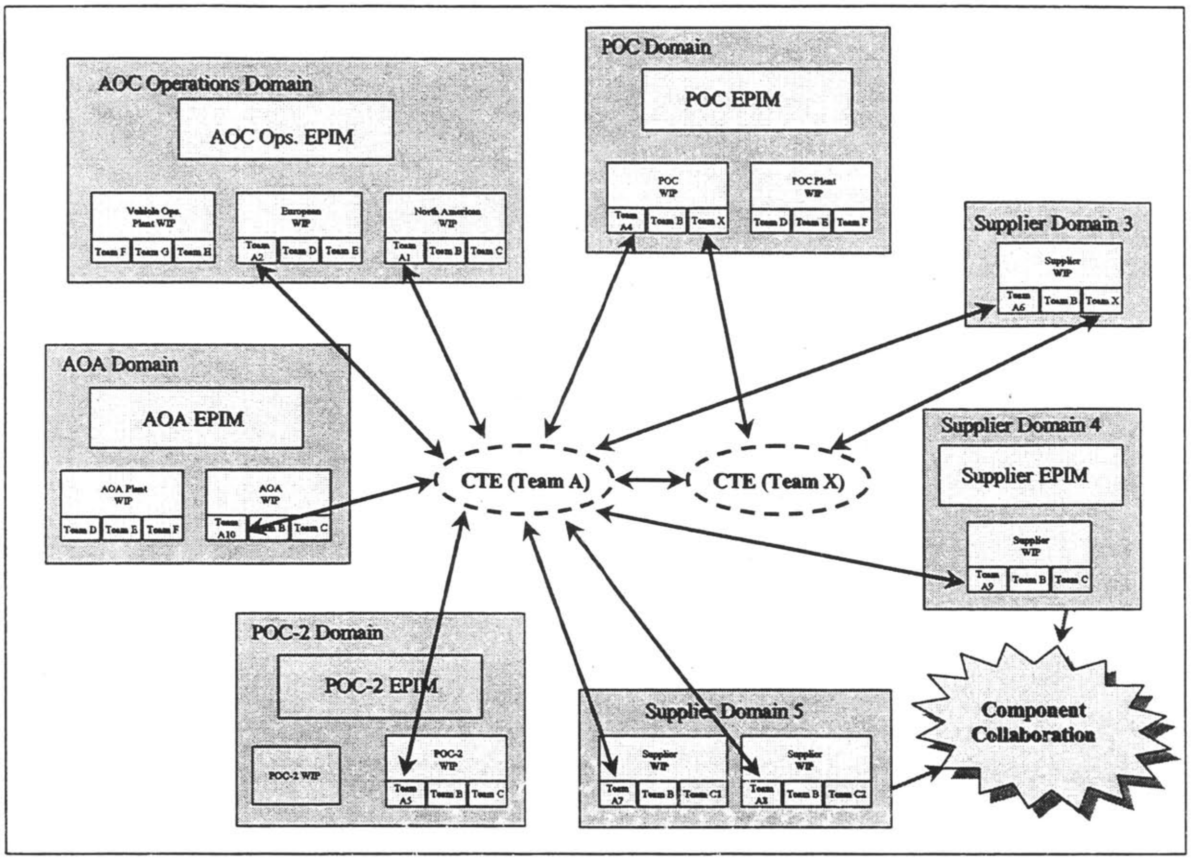


Figure 7.2.6-1: Support for Geographically distributed teams via the CTE

## 7.3 Specific Partner Program Issues

This section addresses some of the generic partner program issues.

### 7.3.1 Simplified Data Sharing Process with Partners

As explained in Chapter 4: XYZ Case Study and in Chapter 6, the existing PIM architecture does not support the extended enterprise very well. This is a combination of a number of factors such as the need to share bulk data, the lack of adequate bandwidth in existing PIM infrastructures to support large volumes of data movements, the lack of communication and the version control across multiple, independent systems. All these deficiencies contribute to a very complex data sharing process with partners. For example, in its condensed form, the steps required to exchange data between AOC and POC on the XYZ Partner Program included the following:

a) POC designer requests AOC designer for latest version of CAD data via e-mail (assumption is that the request is for an assembly).
b) AOC designer checks the requested assembly into a TDM running the AOC template to ensure that the TDM reflects the latest data that was sent to POC. The TDM template is customized to ensure that the collection of projects and libraries (constructs defined in the TDM) reflect the AOC vehicle structure. Unless the projects and libraries are the same across TDMs, data that is exported from one TDM cannot be imported into another receiving. Both TDMs must have the same template of projects and libraries.
c) AOC designer checks the assembly from the TDM into Metaphase and retains the next version for modification. This step ensures that the copy promoted to the enterprise level in Metaphase can only be referenced out.
d) For an unconnected POC designer i.e. one that does not have an IMI connection to the AOC Metaphase system:
e) POC designee at the AOC site checks the data out for reference to a TDM on behalf of POC.
f) POC designee at the AOC site exports the data from the TDM to a package file (the only means of sharing data across TDMs).
g) POC designee tars up the package file and puts in onto an FTP site on a AOC server and informs the POC designer of the availability
h) POC designee (generally a person in the CADCAM department who is not the recipient designer) retrieves the package file, un-tars it and informs the POC designer.
i) POC designer then imports the package into a POC TDM running the AOC and POC joint template (a template that consists of the union of the POC and AOC TDM templates).
j) POC designer then exports the package the assembly into a package file.
k) POC designer executes a custom software tool that swaps the structure of the AOC part numbers in the package file to the POC part number structure.
l) POC designer imports the assembly package file into a TDM running the POC only template.
m) POC designer if necessary, checks the assembly into POC's Metaphase.

For a connected POC designer i.e. one that does have an IMI connection to the AOC Metaphase system:

- POC designer logs onto the AOC system using a custom client
- POC queries for and checks out the assembly for reference to a POC TDM running the AOC and POC joint template
- POC designer then follows the same steps as the unconnected designer starting at step f).

n) A similar series of steps is followed when a AOC person requests POC CAD data. It was agreed in advance that the recipient would pay the penalty to convert the part numbers into the desired format.

o) If portions of the assembly are with different suppliers or partners, multiple such requests have to be made. This results in an explicit re-assembly step in the receiving TDM.

In the recommended PIM architecture, all team members have access to the Collaborative Team Environment. The part structure in the workgroup-level systems is product structure driven with no custom template. All members (local or distributed) have access to the data by setting their scope to the CTE for the team. Members then query for the required data, select it and check it out for reference. Optionally, only Meta data can be checked out. Since all manipulations are based on product structure, when native CAD files are required, only the changed components are retrieved. This operation would traverse the product structure relationships determining what has changed and only transfer the changed data. Since all team members may view the data in the CTE for the team, there are no explicit requests for data made to the other partner enterprises. In the case of distributed development, where portions of the assembly are in different partner organizations, a single action can retrieve all the data, since the CTE has access to the physical locations of the bulk data. It is proposed that Federated Query, Federated Copy and Federated Check-out functions [SDRC] be extended to retrieve data from independent systems based on the Distributed Team and CTE definition. Furthermore, no re-assembly of the assembly structure is required since all team members of the partner program operate in the same environment. Figure 7.3.1-1 shows the simplified data sharing.

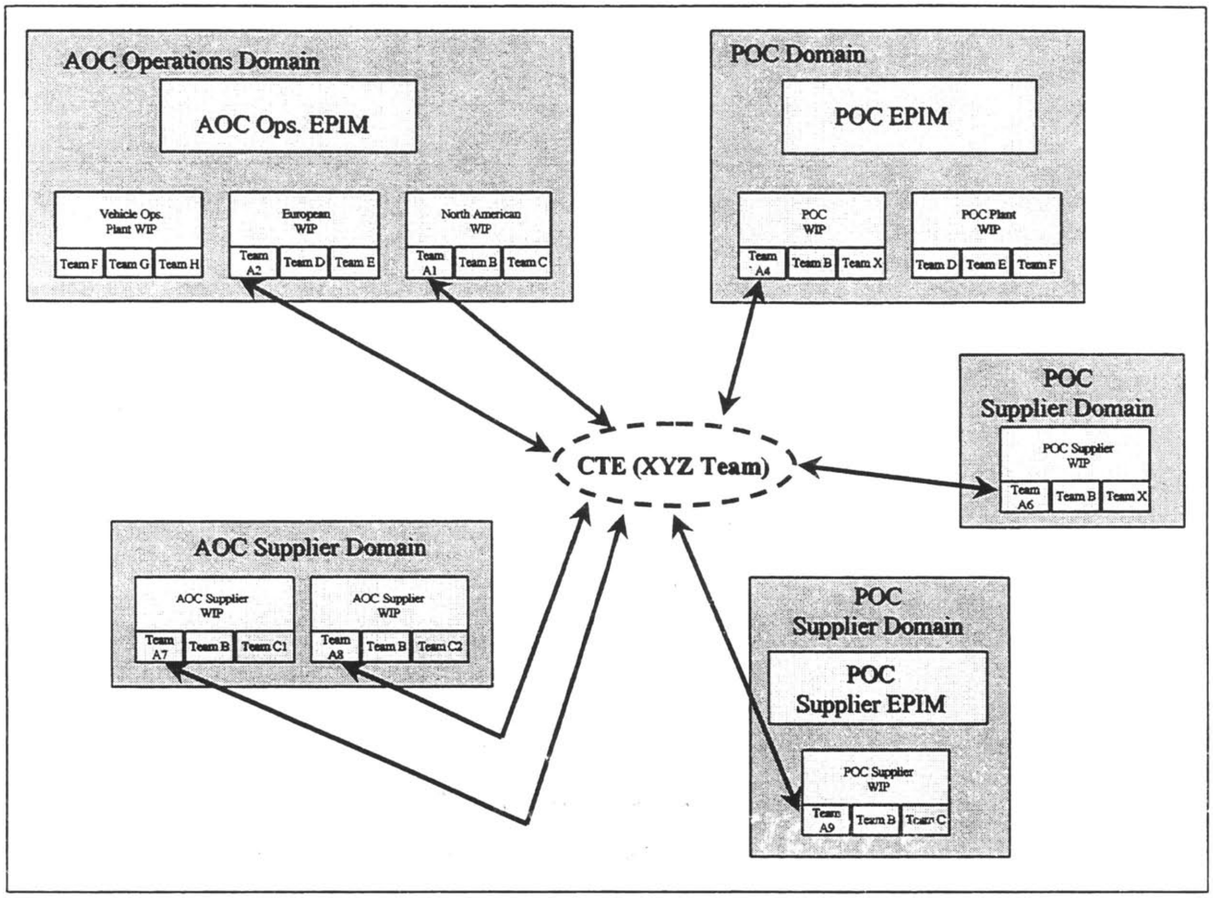


Figure 7.3.1-1: Simplified Data Sharing between AOC and POC using the CTE

### 7.3.2 Support for Multiple Supplier/Partner Enterprises

As described in Chapter 3: The Current Business Environment and in Chapter 5: The Need for Collaborative PD, there is a need to support multiple enterprises that collaborate on a particular product or program. While the current PIM architecture at AOC does provide the ability to re-assemble data from multiple enterprises, it does so in a highly centralized manner in AOC's PIM system. Subsequent access and distribution is entirely AOC's responsibility. If direct access to AOC's PIM system via IMI is not available, for example, the workarounds in place make use of the TDM import/export capabilities resulting in the complexities mentioned in the previous section. Furthermore, this jeopardizes the integrity of the data uniqueness (TDMs cannot enforce this integrity since they are independent of each other).

The recommended architecture allows multiple independent systems to be connected through federated technology. At the core of the ability to decentralize a single system into multiple independent systems is a suite of capabilities that allow PIM operations such as Connect To, Validate Access, Query, Copy, Copy for Reference, Cache, Check-out Product Structure, etc. across independent systems. The ability to define a Distributed Team that includes Distributed Team Instances along with references to their physical locations allows several independent systems to be logically and physical connected as well as to distribute a team structure across multiple supplier and partner enterprises. The data generated by these enterprises is located at their sites. Connectivity to create the CTE is expected to be lightweight with only Meta data being pulled into the browser (or cached). The concept of Organizational Domains aggregates multiple instances to implement common business practices.

It is expected that such architecture will provide suppliers and partners with a complete data management solution instead of a suite of design and engineering tools that are difficult to pull together into a solution. It is envisaged that the PIM software will be provided to the supplier and partner communities when they are sourced. Actual ability to connect to the defined Team will be controlled at the enterprise level using the Distributed Team definition at the OEM site.

The following section proposes a Distributed Team structure for the XYZ Partner Program discussed in Chapter 4: XYZ Vehicle Program Case Study.

#### 7.3.2.1 XYZ Distributed Team Definition

The following steps define the XYZ distributed team:

1) Define Distributed Team XYZ Program Team:

    DT (XYZ Program Team)

2) Define Distributed Team Instances for DT (XYZ Program Team):

- DTI (XYZ US) @ W (North American WIP) @ D(AOC Operations Domain) @ E (AOC)
- DTI (XYZ Asia) @ W (POC WIP) @ D (POC Domain) @ E (POC)
- DTI (North American Plant) @ W (Vehicle Operations Plant WIP) @ D (AOC Operations Domain) @ E (AOC)
- DTI (Asian Plant) @ W (POC Plant WIP) @ D (POC Domain) @ E (POC)
- DTI (US Suppliers) @ W (US Supplier WIP) @ D (US Supplier) @ E (US Supplier)
- DTI (Asian Suppliers) @ W (Asian Supplier WIP) @ D (Asian Supplier) @ E (Asian Supplier)

Note: The last two DTI definitions will be repeated for each supplier that the team wishes to include in its CTE. The groups are generically referenced to as "US Suppliers" and "Asian Suppliers" respectively.

3) Define the Collaborative Team Environment for DT (XYZ Program Team)

CTE (XYZ Program Team) = {
DTI (XYZ US),
DTI (XYZ Asia),
DTI (North American Plant),
DTI (Asian Plant),
DTI (US Suppliers),
DTI (Asian Suppliers)
}

Figure 7.3.2.1-1 shows the framework for a complex program that involves AOC, POC and POC-2 (Partner OEM Company - 2) in a possible joint development venture.

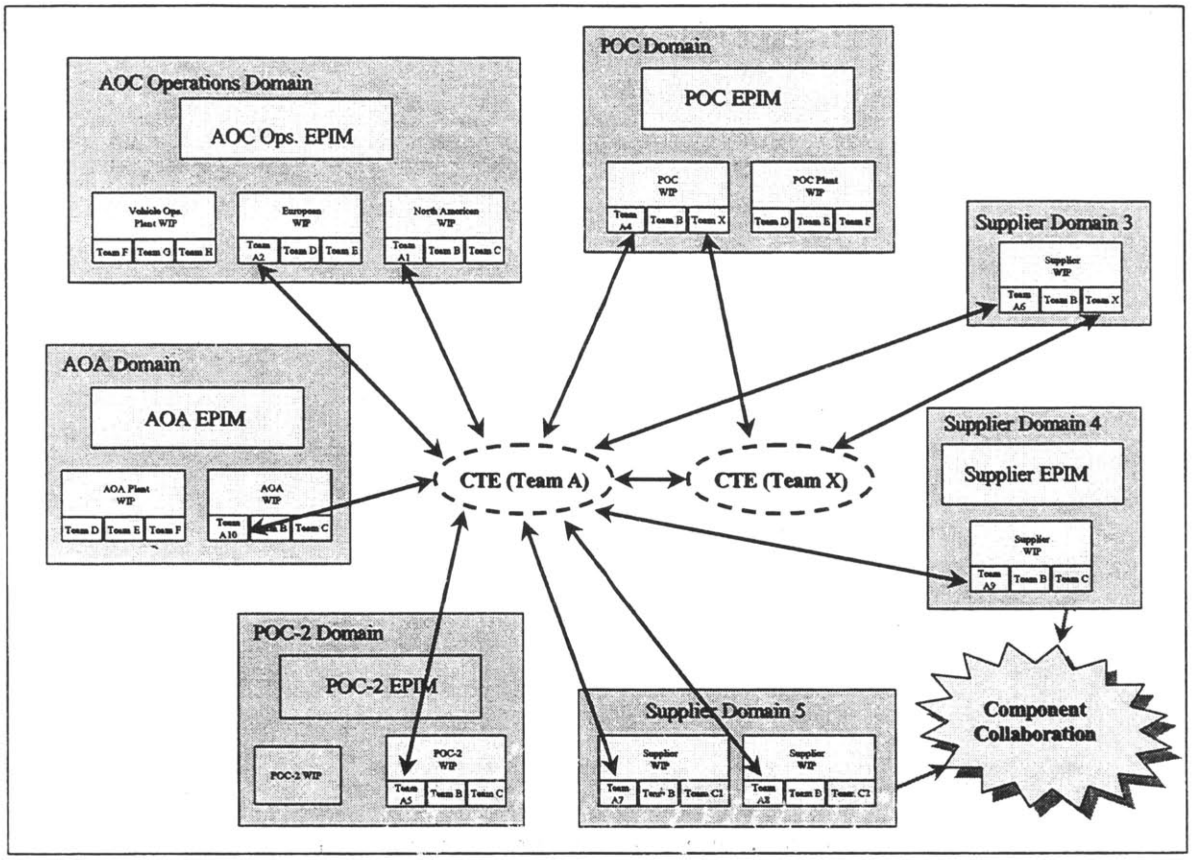


Figure 7.3.2.1-1: Multiple partners working via the CTE e.g. Partner Program between AOC, POC and POC-2

### 7.3.3 Support for Multiple Part Number Structures

The current environment has no support for multiple part number structures. All users in the context of a single system must use the same data model. However, in an extended enterprise implementation this is not very likely. There are bound to be extensions or further customizations to the data model.

The use of multiple systems and concept of Organizational Domains allows for a mapping of different business practices. One of the differences lies in the data model definition. The recommended architecture proposes extending the existing capabilities to support disparate data models through a mapping mechanism that is determined at run time. It is proposed that this mapping be a configurable capability that would preclude the need for a compilation. This would provide the ability to define a Part or Assembly structure differently in different organizations.

### 7.3.4 Support for a Single Distributed Environment

In order to facilitate true scalability in terms of size and geographic distribution, it is imperative that the PIM infrastructure be decentralized. However, along with this de-centralization or partitioning comes the issue of having multiple design environments that all need to be kept in sync. The trade-off lies in the degree of support for a distributed environment versus complexity of maintaining multiple design environments in sync. The recommended PIM infrastructure allows multiple independent environments at the enterprise and workgroup levels. These are virtually connected via the CTE as described in Chapter 6 enabling a single distributed design and engineering environment where all communities can function as part of the same team. The single environment allows broader participation allowing CAE, CAM and Business data for example, to be related to each other in the same environment. The architecture eliminates any need for re-assembly - a CAD issue with the existing architecture. Retrieval of a CAD structure from the CTE ensures the transfer of a complete structure regardless of where the components are defined or stored.

Figure 7.3.4-1 reproduced from Chapter 6 shows this single environment.

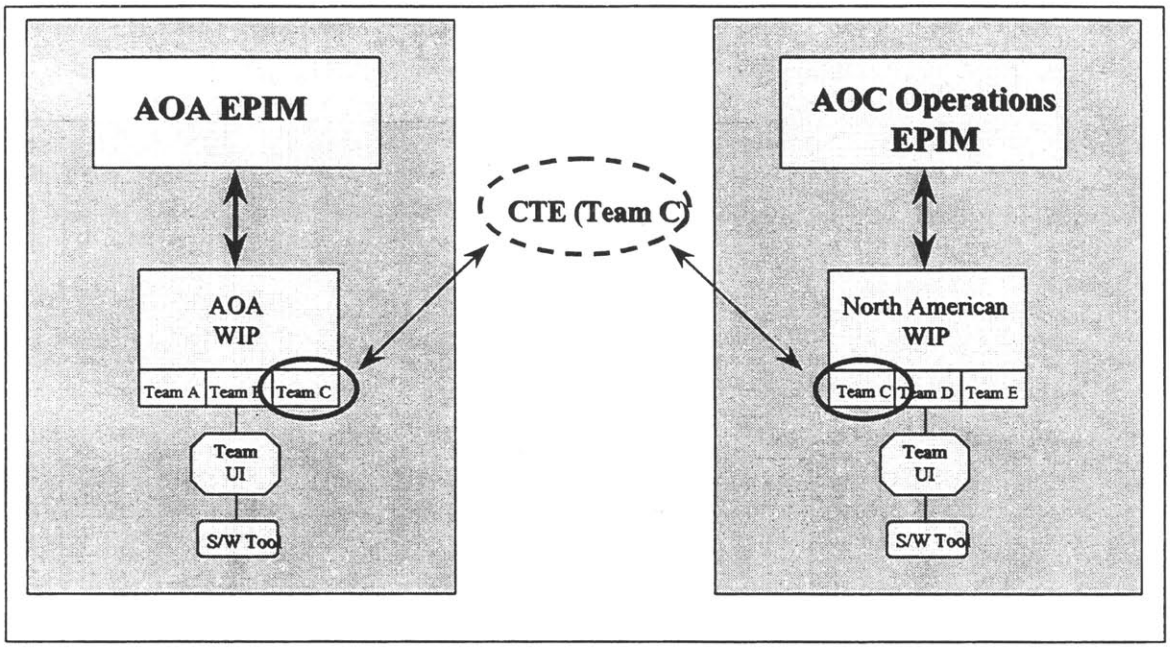


Figure 7.3.4-1: Single Collaborative Team Environment for Team C that spans multiple installations and geographic areas

### 7.3.5 Support for Version Control across Enterprises

One of the critical issues identified in the XYZ Partner Program case study was the inability to properly manage versions of the data and ensure that all designers are working with the most recent data that the creator wishes to be used. The current PIM environment does not provide such fine-grained version control across enterprises, resulting in designers at POC working on AOC data that is not always at the correct version level and vice versa. This has resulted in numerous changes and considerable re-work. The problem is, of course, exacerbated by the lack of communication stemming from differences in culture, language, design process, etc.

In the current AOC PIM environment, if the data in Metaphase (enterprise level) is the master, i.e. no one has checked it out for modification, members with appropriate permissions may check the data out for modification. A new version of the data is created when the modified data is checked back into Metaphase. A successor relationship is created between the previous and current versions to denote that the later version is the successor to the previous version. In other words, there is a successor relationship from the (n-1)th version to the nth version. The following sequence of steps shows this:

1) User selects data for check-out with intent to modify
2) If the data being checked out is not the master, the action is denied. This happens when the selected version has a successor or it is already checkout by another team member.
3) If the data being checked out is the master, a successor version is created as a placeholder and a copy is brought down to the User.
4) After modification, the User checks the data back into Metaphase
5) The modified data is attached to the successor version; the master is now in Metaphase.
6) All members with appropriate permissions now have access to the latest version for reference or modification.

This is appropriate and desired behavior once the change is authorized. However, it does not work across independent installations. When new versions are created in one installation they are not reflected in the other. Unless there is active communication, the user in the second installation continues to reference the previous version. This problem is particularly severe in the later phases of PD when turn around times for changes are expected to be very low. At that time, it is very easy for designers to inadvertently revert to a "silo" mode of operation without communicating changes with partner organizations.

The proposed architecture enables the use of change control across multiple installations via the Distributed Team definition. Formal change control will be driven top down with Change Notices driving changes to the vehicle program data once the program is in those phases of the PDP that involve formal change control. The proposed architecture uses the CTE of a team to ensure that team data is made available across the distributed teams. When a user in a DTI sets his scope to the CTE of the team he is a member of, the Meta data returned from a query across the Distributed Team Instances reflects the latest state of the data. It is proposed that a configurable option would allow for a more proactive refreshing of the cache periodically. The tradeoff is one of taking a performance hit for frequent updates to the CTE cache versus need for the latest state of the data. The configurable option allows the system to respond to the various phases of the design process e.g. allow high frequencies of DTI cache update approaching critical milestones and reduce them later. In this manner, the infrastructure becomes more dynamic and is tuned to meet the requirements of the process.

The following set of steps replaces the above for version control:

1) User sets scope to the CTE for the team
2) User selects data (in the local DTI) for check-out with intent to modify
3) If the data being checked out is not the master, the action is denied. This happens when the selected version has a successor or it is already checkout by another team member.
4) If the data being checked out is the master, a successor version is created as a placeholder and a copy is brought down to the User.
5) The successor version is made known to the entire distributed team. Based on how DTI caches are set, the change in the state of the data is proactively reflected in their browsers or notification occurs through a subscription capability (described later).
6) After modification, the User checks the data back into Metaphase
7) The modified data is attached to the successor version.
8) This change is once again made known to all team members across the distributed team.
9) Distributed Team Members with appropriate permission now have access to the latest version for reference or modification independent of their specific DTI.

The above version control across installations is made possible through federated PIM functionality and the CTE for the distributed team.

### 7.3.6 Support for Communication via Subscription/Notification

One of the key benefits of a PIM system is the ability to provide a consistent view of the data including versions, relationships to other data, state of the data, etc. In a typical product development environment, very often, specific changes need to be communicated to a specific set of users. AOC has developed a subscribe and notification capability that enables users to log their interest in specific actions on specific sets of data so that they may be automatically notified via e-mail, should that action occur. For example, CAE analysts may subscribe to version changes of a selected assembly such as the Front Fender. CAE analysts are automatically notified when the lead designer on the Front Fender creates a new version. This capability facilitates a more proactive communication across the design activities.

The recommended architecture extends this capability to the CTE of a team such that Subscription to specific actions on data is possible by any team member in any of the DTI's.

### 7.3.7 Support for Shift in Emphasis from Bulk Data Movement to Meta Data Movement

Please see similar section above.

### 7.3.8 Support for Remote Users

This capability is provided by the Distributed Team concept discussed in detail in Chapter 6.

### 7.3.9 Support for Independent Processes

Each enterprise has its own design and development process that works best for them. While there are considerable benefits to working with a single, broad process across enterprises, this reduces the ability of enterprises to be nimble or leverage their expertise. For example, AOC and POC have their own processes that allow them to leverage their existing systems and organizations more effectively. The XYZ Partner Program forced POC to adopt AOC's design process resulting in considerably higher consumption of resources. The lessons learned identified areas where POC could have been more productive had they used their own processes e.g. part number allocation and the CAD and CAE interaction.

The recommended architecture enables multiple installations that can function independently. Each installation can define its own processes and life cycle for the data. The critical element here is coordinating any automatic interfaces across independent installations such as the automatic triggering of a workflow in one installation based on the life cycle defined in another. It is proposed that a Life Cycle mapping between Organizational Domains provides the necessary information although this can be very complex. While the architecture would support such mapping across Organizational Domains (since this is only Meta data exchange and response), the implications on work practices would be very significant and would warrant up-front agreements before implementation.

### 7.3.10 Support for Heterogeneous Design and Engineering Tools

One of the issues highlighted by the XYZ Partner Program was that the use of different engineering and business systems required complex and costly data manipulation and conversion. There is no easy solution to this problem. The current AOC PIM architecture uses a data model that is significantly different from the AP214 data model. Integration of CAD tools will require significant custom interfaces that would be costly and complex.

The recommended architecture proposes that the data model be built on standards that are recognized across a suite of tools, both for design and engineering as well as for other design process capture such as requirements definition and cascade, systems engineering and test and verification. For example, it is proposed that the AP214 STEP standard for the representation of product structure be used. This would facilitate integration of the PIM environment with multiple CAD and CAE tools.

However, even though the proposed architecture has support for multiple CAD authoring and referencing tools, customization cannot be avoided. The solution lies in using a single system or in ensuring that the software vendors comprehensively comply with industry-wide standards to minimize risks to data integrity.

### 7.3.11 Support for Better System Performance

The decentralization of data and services providing for a local and collaborative environment enables the use of multiple servers to spread the processing. This allows for a more scalable solution. Furthermore, the shift in emphasis to greater use of Meta data reduces the need to move large volumes of bulk data for processing e.g. Pruning capabilities discussed above.

Even if a system supporting one of the DTI's were to go down, only that specific DTI is affected. The rest of the Distributed Team may continue to function, albeit without the data from that DTI. The architecture takes away a single point of failure that exposes a team to considerable downtime should the system go down.

### 7.3.12 Support for Distributed Administration

The proposed distributed architecture allows the administrative responsibilities to be decentralized as well. It is difficult for a single organization to be responsible for administration of the entire system. For example, the current AOC PIM system has workgroup servers in most of the continents with multiple bulk data servers connected to each. The administrative jurisdiction includes work-in-progress supplier data that is saved in AOC's PIM system. Along with this responsibility comes the legal issues of managing the integrity of each suppliers' data. Clearly, AOC wishes to get out of managing supplier data.

A partitioning of the PIM system as discussed in Chapter 6, serves to decentralize administrative responsibilities as well. However, it is best to view this as a spectrum and choose where one would want the administration to be. At one end of the spectrum is the use of the same administrative organizations (as in the current case) while at the other end of the spectrum is the ability to allow every independent installation to be administered in completely different ways. Clearly, the ideal position is in the middle where there is coordination of administration such that policies are collectively established and implementation e.g. defining system configuration parameters. The use of Organizational Domains and Enterprise concepts along with the vertical separation of functionality helps to assign administrative responsibilities where they are applicable. For example, security and system registry discussed in Chapter 6 are more applicable at the enterprise levels while data retention policies for work-in-progress data are more applicable at the workgroup level. Such a separation makes for an easier administrative task.

### 7.3.13 Support for Collaborative Product Development

It must be noted that collaboration implies more than just CAD, CAE and CAM sharing at milestones. In addition to CAD data sharing, it examples of other functionality include:

- the ability to define, cascade and relate functional requirements to system, sub-system and component definitions across enterprises
- Sharing of design information across geographically dispersed teams in a real-time or near real-time manner (zero latency for information availability)
- Distributed testing and verification
- Distributed functional capability such as digital bucks
- Distributed change control and configuration management (product diversity)

All the above are imperative for a shift away from Black Box PD to Grey Box or Collaborative PD and involve a greater emphasis on distributed relationship management accompanied by supporting processes. The recommended architecture supports the focus on Meta data through the use of a PIM system as the underlying providing a holistic product development environment.

### 7.3.14 Support for Cross Team Collaboration

It is imperative that PIM systems support the capability to easily and efficiently re-use data across product programs. Current re-usability targets are hovering in the 50 - 70% ranges with the PD focus shifting to platform based programs. The proposed architecture facilitates this level of re-use at two levels:

1) <u>Top - Down Product Structure</u> - this capability allows a business decision to create a derivative program to be captured and to make a copy of the product structure of the lead

vehicle program. This product structure may then be pushed to the various design and engineering activities based on sourcing decisions. As an example, a product structure from Program A is copied to a Program B and the data is cascaded to partners based on the sourcing decision on each item.

2) <u>CTE - To - CTE Relationships</u> - this capability allows work-in-progress distributed teams to be related to each other based on business decisions across installations. Using the same example as in the previous bullet, this enables Distributed Team B to be related to Distributed Team A such that, all members of Distributed Team B have access to Team A's data via the teams' CTE's. The level of access provided can be configured at the team level. This enables much tighter collaboration between the program teams for change control, communication, re-use, etc.

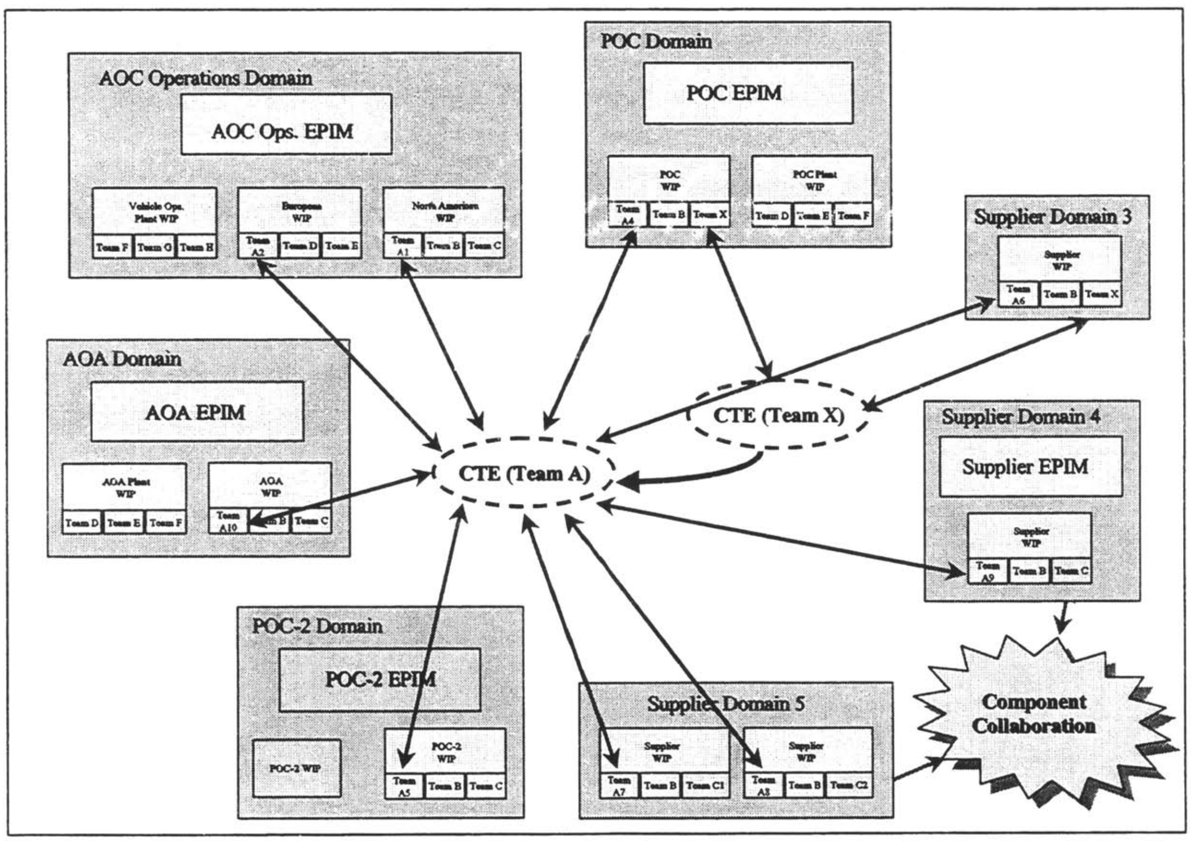


Figure 7.3.14-1: CTE to CTE Sharing Relationships

Figure 7.3.14-1 shows a simplified version of Figure 7.3.2.1-1 with a CTE-to-CTE sharing relationship between Team X and Team A. The direction implied by the arrow grants permission for Team X to access data in Team A's CTE, but not vice versa. The exact set of permissions is a configurable set determined specified at the time the relationship is created.

## 7.4 Summary

Based on the discussions above, the proposed distributed PIM architecture addresses or has the ability to address most of the shortcomings identified in Chapter 4: XYZ Partner Program Case Study. It provides a scalable architecture that spans installation and enterprise boundaries allowing a truly distributed business to business collaborative product development environment. Distributed team members function in the same environment with real-time or near real-time access to distributed team data. The architecture provides a platform that emphasizes the distributed relationships between various product development elements and leverages cross-installation PIM capabilities to build a single collaborative team environment.

# 8 CONCLUSIONS

This chapter summarizes some of the main conclusions and recommendations derived from the thesis as well as potential limitations in the proposed PIM architecture. The chapter concludes with a brief discussion on future work that might take this study forward.

## 8.1 Summary

Some of the business environment implications may be summarized as follows:

- The automotive business model has been and continues to evolve. Competitive pressures stemming from an industry-wide over-capacity and a consumer demand for innovative and rapidly changing product lines have been and will continue to push the automotive OEMs to shorter product development cycles. The need to become more efficient in all PD areas from engineering and manufacturing to marketing and distribution will continue to force a shift away from the traditional hub-and-spoke model that emphasizes a 1-1 relationship to a more networked one allowing an emphasis on n - n relationships.

- This shift will not be restricted to the automotive business alone, but will permeate all engineering and manufacturing operations.

- Increasing globalization and competitive pressures will drive mergers and partnerships resulting in the need for technology and processes to support geographically distributed teams and multidimensional partner programs to leverage expertise in engineering and manufacturing as well as asset specificity [B. Enslow]. Such a shift from vertical integration to virtual integration will increase the need for inter-enterprise visibility and tighter integration during product development [Francis Pahng, Nicola Senin and David Wallace].

- As the business model shifts to increased outsourcing and partnering, the nature of the technical interaction in the automotive industry will shift to increased joint development.

- The combination of increased joint development and geographically distributed teams will drive the need for increased work-in-progress collaboration i.e. there will be a shift towards the outer reaches of the Distribution-Collaboration-Richness of Information space discussed Chapter 1.

- Business dynamics will put greater pressure on IT driven restructuring to facilitate tighter supply and partner chain integration due to the anticipated higher frequency of interactions between trading partners [K. Bergstrom].

Some of the technology implications may be summarized as follows:

- Competitive forces in the PIM industry will force PIM vendors to focus more upstream in the product development space by supporting global work-in-progress collaboration.

- Current PIM systems are geared towards a centralized architecture that will prove inadequate for current and future business needs for product development

- A partitioning of PIM systems along vertical and horizontal dimensions as discussed in this thesis will enable scalability in performance, size and geographic reach.

- PIM systems will have to support distributed teams to increase productivity growth. The concepts of Distributed Teams, Distributed Team Instances and Collaborative Team Environments or CTE's introduced in this thesis provide the ability to define a single distributed environment to support work-in-progress collaboration. The concept of a CTE to CTE relationship enables one distributed team to be related to another, providing specific data access for reusability. The concept of Organizational Domains will provide support for different business practices within or across enterprise boundaries allowing a combination of tight and loose collaborations.

- The single CTE's extend the size of the collaborating community across enterprises enabling distributed and decentralized activities. They allow multidisciplinary design and analysis tasks to be decomposed and allocated to appropriate teams leveraging their expertise. By doing so, they enable new strategies, processes and organizations - the three crucial elements needed to maximize the benefit of IT [Brynjolfsson and Hitt].

- The recommended PIM infrastructure will support coupled interactions across enterprises [Ali Yassine, Donald Falkenburg and Kenneth Chelst], providing support for a DSM that is created using a set of activities and teams that span multiple organizations.

- The shift in emphasis from bulk data to Meta data will allow a focus on relationships between entities and hence, the ability to relate various types of data to product structure e.g. requirements, specifications, test and verification, version control and configuration management - elements that increase the richness of collaboration.

- Partner program cultures can be strengthened using the proposed architecture to align or map business processes and information. However, not all PIM issues around support for the extended enterprise are technology or process related. Several social and cultural issues dominate e.g. the need for a re-education of the user community to leverage the new capabilities that the proposed PIM infrastructure will bring e.g. the need for open data sharing and access. Users will have to learn to function in distributed teams enabling a tighter integration between enterprises. Such a change in PD processes to take advantage of distributed team capability will be challenging.

## 8.2 Limitations of the Recommended Architecture

Potential limitations in the recommended architecture may be summarized as follows:

- Creating and maintaining the CTE for all members of a distributed team will require substantial systems resources. As the number of CTE's grows, there may be a need to decentralize the distributed team services even more.

- System performance must be carefully monitored unless the CTE data can be effectively cached.

- The distributed nature of the recommended architecture will force standardization of services and data architecture for easier implementation. However, vendors have not been very swift in adopting standards in the past. The initial lack of compliance to standards will force a mapping of information rather than a seamless implementation.

- Depending on how the capability is implemented, the recommended architecture may force one installation to be the master where the Distributed Team and its Collaborative Team Environment are defined, forcing replication of team definitions.

- At least initially, the decentralized PIM architecture recommended would require a higher degree of expertise at the supplier and partner sites for administration and use.

## 8.3 Future Work

The following are suggestions for future work that may carry this study forward and enable a quicker validation and deployment to Product Development organizations:

- Validation of the recommended architecture through user scenarios from multiple disciplines and industry segments.

- Development of a web-based prototype that validates the architecture from a functional, organizational and process viewpoint.

- Development of inter-enterprise Use Models to document templates for interaction and subsequent packaging of the software based on the business relationships between partners.

- Inter-enterprise collaboration through an integrated data model will be impossible; there will be need to explore data independence in the context of the recommended architecture [Bsharah].

- Analyze the forces that drive a company along the 3 axes of distribution, collaboration and Richness of Information with a view to defining business strategy.

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