

Enterprise PDM: Reconciling Multiple Views

PLM Integration/Product Definition

Collaborative Product
Development Associates, LLC
2001 West Main Street, Suite 222
Stamford, CT 06902
(800) 573-4756
www.cpd-associates.com

August 2006



CPDA: Collaborative Product Development Associates, LLC

CPDA's Product Lifecycle Management (PLM) research programs target the critical decisions in Product Lifecycle Management challenging Design, Engineering, Manufacturing, and Information Technology managers and executives. CPDA's PLM collaborative research programs provide in-depth analysis of strategies, products, issues, processes, technologies, trends, case studies, and surveys for assessing technology, business goals and objectives, and implementation road maps.

The cohesive suite of collaborative programs clarifies and evaluates new capabilities, standards for frameworks, and development issues; it highlights the most advanced uses of leading technologies, and it links the technical effort to the realization of business value. The four collaborative research programs include:

Design Creation and Validation: A bottom-up view of engineering requirements from the desktop across the enterprise. Advanced computer-aided design (CAD), engineering analysis, manufacturing technologies, collaboration, and visualization software serve as springboards for gaining a competitive advantage. The Design Creation and Validation service applies CPDA's structured methodology to the evaluation of new products and processes as well as to current projects in client organizations. A critical focus, the emerging technology of knowledge engineering with templates and rule-based architectures focuses on delivering the needed tools into the hands of product developers to capture knowledge, and to formalize its use. The use of direct geometry access and manipulation, data translation technology, XML alternatives, and JT options are also assessed for their ability to deliver interoperability across the diverse and disparate business and technical applications.

Design/Simulation Council: The Council promotes a standard framework employing common terminology to integrate and optimize the diverse and divergent specialist activities currently fragmenting design efforts. CAE must fully integrate with design, up front, to close the chasm between design and analysis. Analysts must actively participate continuously in design decisions and enter the mainstream. The impending breakthrough in CAE will rest on knowledge reuse, process capture, and streamlining.

PLM Integration / Product Definition: A top-down view provides a conceptual framework for collaboration across different product development perspectives, bridging customer needs, systems engineering and tradeoffs, design solutions, and fulfillment and manufacturing. Integration and interoperability in complex PLM environments pose substantial hurdles. The rapid transition to cross-enterprise collaboration, at all levels of design and supply, intensifies the pressure on existing, inwardly focused IT architectures to support and enable new modes of doing business.

Product Value Management: Common processes for design, development, and product introduction across the supply chain may be validated with reference models such as SCOR (Supply Chain Operational Reference model), or VCOR (Value Chain Operational Reference model). The first step, business process modeling (BPM), facilitates the building of consensus around a common understanding and terminology, across organizations and functional silos. Mapping BPM to a service-oriented architecture based on open standards represents a critical second step. An IT integration infrastructure in a Federated Enterprise Reference Architecture™ (FERA) supports a loose coupling between enterprises extending across the supply chain.

Collaborative Product Development Associates was formed by the PLM research team of D.H. Brown Associates, Inc. (DHBA).



Enterprise PDM: Reconciling Multiple Views

Michel Vrinat, Research Director

EXECUTIVE SUMMARY

A product's definition, from an engineering point of view, relies on its physical description through 3D models, schemas, or drawings. Since that view remains as the reference for many companies, many at the enterprise level in systems perceive engineering as aggressively contending for the ownership and management of product definition even though many functions contribute to the definition, delivery, and support of a product.

On one side, geometry remains the most important factor; on the other, effectivity, cost, and logistics represent the key drivers. The reconciliation of these contradictory views presents the challenge facing industry today in compressing the time to market for high quality and profitable products.

The concept of virtual product development requires at minimum that all engineering disciplines share a consistent view of the product definition at all stages of development from conceptual design, engineering, and validation through manufacturing and support. They must make decisions based on data that is consistent for the entire enterprise environment, with all relevant information reconciled in real time. At the same time, multiple reconciled views of the data present the product definition in the appropriate form or representation for each particular activity. Changes must be tracked, validated, and executed across the disciplines.

A holistic product definition involves different levels of information to enable a broad range of processes across multiple disciplines, within an enterprise and across its value chain. Two levels in particular represent a high priority for the formal management of a product definition, and create very different challenges for the supporting technologies.

On one hand, tight integration with authoring and simulation tools supports access to fine-grain data in a detailed context for the management of engineering knowledge and relationships. Tight integration provides direct and targeted support to engineering decisions in a dynamic collaborative environment where changes have to be evaluated quickly, based on multi-disciplinary analysis with

precise technical information.¹ The support of fine-grain data involves very different data models than those serving the needs to reconcile high-level views across the enterprise, although the same tools can serve both domains.

On the other hand, the enterprise level supports a higher level of integration with access to the full definition of the product covering a broad scope of information at a more abstract level. Enterprise PDM reconciles disparate views and promotes enterprise-wide collaboration across multiple departments and disciplines that may involve multiple sites as well as multiple organizations, including customers, partners, and suppliers. Consensus across technical and non-technical participants is achieved based on multiple documents and information sources. Enterprise PDM functions provide valuable support for consolidating original data, for reconciling decisions across multiple disciplines, and for rectifying gaps in the information flow. These are especially critical capabilities for enterprise integration. In serving product portfolio management, sourcing needs, the supply chain, or production, the requirements for product definition at the enterprise level involve the reconciliation of very different views of the data.

The enterprise level also involves a relatively high level of abstraction. Given the mushrooming mountains of data accumulating by ever deeper and more incisive efforts within each discipline, the flood of data extends well beyond the ability of any individual or group to understand. The information for decision making relevant to each discipline must be abstracted and minimized to the critical factors.

Again, all engineering disciplines at all stages of product development should share a consistent view of the product definition. The alternative of everyone continuing on their independent paths delays the discovery of mistakes until well after the fact, when the resolution becomes prohibitively expensive. The profoundly challenging task of reconciling multiple views becomes more troubling every day, as the experts drive ever deeper in their individual silos in applying technical advances within their own disciplines. There is a completely different language from one discipline to another; they use different semantics, assemble product components under different breakdown structures, and accumulate massive amounts of data that is impossible to reconcile in detail.

Several industry users presented their strategy and discussed their current status as well as their expectations for an enterprise product definition. Given the lead enjoyed by UGS with large-scale PDM deployments that directly address the needs of enterprise PDM, Teamcenter users were targeted.

Mercury Marine, a U.S.-based marine-propulsion company, has engaged in an ambitious plan for its enterprise PLM with the objective of maintaining a consistent and complete reference model for product definition. The system must serve both CAD and multiple analysis tools, quality inspection applications, and a home-grown ERP solution. Requirements management, reconciliation of the

¹ See *Critical Issues for PDM Integration*, Michel Vrinat, Collaborative Product Development Associates, September 2005.

eBOM with the mBOM, and the application of DFSS (Design for Six Sigma) at the conceptual phase are all major functions targeted in the initiative.

ELTA Systems, a wholly owned subsidiary of Israeli Aircraft Industries (IAI), specializes in Defense and Intelligence Systems. It has built its enterprise reference data model on top of Teamcenter. Roughly one thousand engineers specialized in system design and engineering as well as personnel in the mechanical, electronics, microwave, and software development groups rely on the systems. Each authoring application covering mechanical, electronics, and software has its own tightly integrated data management that is reconciled with the enterprise data model.

A large **Aerospace and Defense company** has a very ambitious program for enterprise data management under deployment. With over two thousand five hundred engineers all gathered on the same site, the company designs and builds an extremely complex system with up to one million parts. The current PDM solution is a fully customized version of Enovia that will evolve to a more standard version with the new releases of Teamcenter.

This document is copyrighted © by Collaborative Product Development Associates, LLC (CPDA) and is protected by U.S. and international copyright laws and conventions. This document may not be copied, reproduced, stored in a retrieval system, transmitted in any form, posted on a public or private website or bulletin board, or sublicensed to a third party without the written consent of CPDA. No copyright may be obscured or removed from the paper. Collaborative Product Development Associates, LLC and CPDA are trademarks of Collaborative Product Development Associates, LLC All trademarks and registered marks of products and companies referred to in this paper are protected.

This document was developed on the basis of information and sources believed to be reliable. This document is to be used "as is." CPDA makes no guarantees or representations regarding, and shall have no liability for the accuracy of, data, subject matter, quality, or timeliness of the content.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
THE QUEST FOR A REFERENCE DATA MODEL.....	5
FUNCTIONAL REQUIREMENTS FOR ENTERPRISE PDM.....	8
MORE THAN CAD/PDM TOOLS	8
A SYSTEM ENGINEERING FRAMEWORK FOR THE ENTERPRISE	9
SMOOTHER TRANSITIONS.....	10
END-USER STRATEGIES, STATUS, AND EXPECTATIONS.....	12
MERCURY MARINE	12
ELTA SYSTEMS.....	14
A LARGE AEROSPACE AND DEFENSE COMPANY	15
CONCLUSIONS.....	18



Enterprise PDM: Reconciling Multiple Views

THE QUEST FOR A REFERENCE DATA MODEL

The concept of virtual product development requires at minimum that all engineering disciplines at all stages of product development from conceptual design, engineering, and validation through manufacturing and support share a consistent view of the product definition. They must be able to make decisions based on data that is consistent across the entire enterprise environment with all relevant information reconciled in real time. Concurrently, multiple reconciled views of the data present the product definition in the appropriate form or representation for each particular activity. Changes must be tracked, validated, and executed across the disciplines.

The alternative of everyone continuing on their independent paths becomes more troubling daily, because the experts drive ever deeper in their individual silos in applying technical advances within their own disciplines. As mistakes compound, costs rise as their after-the-fact discovery becomes prohibitively expensive.

From customer needs to detailed design, simulation, and test, manufacturing engineering, and service support, each engineering discipline needs access to different views and levels of representation. For example, a system engineer will not be interested in the details of design implementation, but will have to check that requirements have been properly expressed, matched, and tested.

The key enabling factor relates to the ability to identify the decision variables, which must be defined at a high level of abstraction to reconcile different views and support a sharable representation. That was introduced by Collaborative Product Development Associates in the late 1990s with the concepts summarized in the 12-Fold Way™. At a high level of abstraction, the sharing of the product definition may resolve the difficult challenge of maintaining consistency and accuracy.

Toyota clearly understood the critical importance of abstraction to avoid flooding every individual with massive data many, many years ago:

Toyota seems to believe that design participants should obtain (i.e., “pull”) the information they need when they need it and in the right amounts. What’s more, ideally the system is a demand-pull system – if you need information, it is your responsibility to find it. As one general manager stated, “lack of information is not an excuse to delay development.”

... [At] Chrysler ... the pervading philosophy is that of immersion, more like a push system than a pull. The platform pushes as much information as possible on the design participants. As the platform general manager said, ‘we try to inundate everybody with information, so that everybody knows everything that’s going on.’ Manufacturing knows the marketing data; engineers know the customer data and cost information. Chrysler seems to believe that it is not possible to predict in advance whether someone will have insight into a problem or spot a potential conflict. It is best to gather everyone around the table to address a problem, so the solution will be effective from all angles and nothing will be overlooked.”²

The need arises for a multi-tier architecture with Product Data Management directly meeting the need for data at multiple levels of abstraction. For engineering, tight integration with authoring and simulation tools, with access to fine-grain product data, allows for deep and detailed representation of models and relationships. At the enterprise level, loose integration at a higher level of abstraction of a very large and diverse scope of information provides the means to reconcile multiple representations.

There is simply no other way to address the requirements across the full range of design efforts without either losing accuracy or sacrificing performance. The vision for a PLM framework has to address the realities of multiple levels of need. When managed properly, serving that diversity effectively presents a clear and massive added value.

In serving the needs for enterprise integration, an enterprise PDM solution supports several major functions:

- A reference data model meets the needs across disciplines and activities, abstracting any information that contributes to effective decision making of the product definition at any stage of the full product development cycle.
- Development addresses all product requirements through end of life, including feedback for improvement, support or service, and disposal compliance.
- Multiple product breakdowns involve the organization of the data into tree structures, with relationships, links, attributes, features, and related functions

² *Principles that Shape Product Development Systems: A Toyota-Chrysler Comparison*, Durward K. Sobek, II, Ph.D. dissertation, the University of Michigan, 1997.

for configuration management of options and variants, according to usage, life cycle, and discipline.

- Multiple product configurations must be mapped to meet different sets of rules that may involve different degrees of fidelity of the representation of the components.
- Support of process execution must meet the needs of multiple activities and tools, such as validation and distribution, or change management.

Reconciliation and translation across areas of expertise dominate the functional requirements that an enterprise PDM solution must bring to people who are talking a totally different language from one silo to another. The single biggest contribution relates to ensuring their direct participation in the right decisions, up front.

The list of data types that have to be managed by an enterprise PDM solution is quite long. Without being an exhaustive list, critical requirements include:

- customer requirements
- functional design data and models
- function allocation
- conceptual model
- system design data and models
- physical design and system decomposition
- work break-down structures
- physical break-down structures
- cost data
- configuration rules
- design rules
- detailed design models
- numerical simulation models and results
- test definition and results
- standard configurations and variance
- logistical data and service requirements

In the context of engineering, data management solutions hide these functions from the user as much as possible to relieve them of data management tasks, by executing in the background without involving the engineers.

Most PDM solution providers readily support primary system functions such as safe storage, meta-data management, tree structures, and validation processes. Some have sustained large deployments for a number of years. These functions generally do not meet the needs generated by multiple data sources such as mechanical, electronic, or software engineering. They do not address the requirements for serving multiple functions such as system design, validation, cost

analysis, marketing, or production. Moreover, they do not adapt to diverse user profiles that include engineering, sales and marketing, procurement, or manufacturing. As a result, the strengths of most PDM offerings with high level systems functions simply fail to address the critical requirements for serving the diversity of needs across the design cycle. This represents a constant challenge to the PLM vendors, which have concentrated in the past on serving design and manufacturing users. This is now undergoing significant change. All three leading vendors are extending the scope of their product capabilities to include several ERP system functions. They are also adapting their application architectures to host non-native components, and targeting customers outside of their traditional markets in mechanical design.

UGS, with the largest deployment in the industry, has proven its ability to scale in terms of content and usage. Dassault Systèmes, with the MatrixOne acquisition, has demonstrated its willingness to move outside of the engineering walls. Agile has successfully served the mechatronics world where mechanical, software and electronics development have to coordinate and integrate. PTC has taken a tentative step in extending its reach to electronics with the OHIO acquisition, a relatively small contender. More significantly, the acquisition of Arbortext, with a document content management solution, may enhance information sharing across disciplines although the depth of the solution will be limited by the document orientation.

The latent challenge, however, derives from far larger players serving ERP and Systems because of their size and industry position. Vendors such as SAP and Oracle hold the position as the “master” data keeper for a directly complementary data archive in manufacturing. Most often they ignore the diverse requirements of the engineering community for a more dynamic environment. IBM, with WebSphere Data Center, and Microsoft with InfoPath and SharePoint initiatives, provide partial solutions aimed at some of the requirements for an enterprise repository covering product definition. To date, however, these systems vendors appear to lack the experience and the motivation to directly address the deep and diverse complexity across the engineering and design specialties.

FUNCTIONAL REQUIREMENTS FOR ENTERPRISE PDM

MORE THAN CAD/PDM TOOLS

Most PDM deployments simply manage CAD files, sometimes associated to drawings or 3D models, assembled into an engineering break-down structure or eBOM. They generally offer limited, if any, capability to manage variants, options, and re-use.

They usually do not manage manufacturing information that too quickly migrates into the ERP system, or the legacy MRP. They do not at all support CAE models and simulation data. The two domains of manufacturing and validation/simulation remain separate, not at all served by CAD-dependent PDM

solutions, which lack the ability to reconcile data and information serving very different views. The objective is not to capture the detailed information from the authoring tool, such as those serving CAD, CAM, or CAE. The semantics and the organization of the data covering the geometric description for design, validation, or manufacturing have to be managed by a dedicated data model. The semantics and the structure or ontology will be radically different for each discipline. Nonetheless, the views need to be reconciled and coordinated at the enterprise level to maintain consistency across operations. That requires abstraction levels, additional meta-data, conditional links and dependencies, and configuration rules.

Managing product definition at the enterprise level presents far more complexity than traditional management of documents or master data. It involves all players of the development process from conceptual design, detailed design, simulation and validation, manufacturing process design and implementation, production, sourcing, to after-sales support.

A SYSTEM ENGINEERING FRAMEWORK FOR THE ENTERPRISE

The concept of virtual product development requires that all disciplines from system design and validation to engineering and manufacturing are able to find what they need, in their language. They must make decisions that are consistent, sharing the relevant information in real time, in the appropriate form of representation. Changes must be validated, tracked, reconciled, and executed across the disciplines, which may involve access to detailed data and support of specific change management processes within each of those disciplines.

The need for shared decisions is particularly important to ensure lean design. Variation in manufacturing must be measured, and factored in to design tradeoffs in applying probabilistic design techniques (DFSS) to drive down time-to-quality and total product cost. Several additional criteria are especially critical:

- Decision up front, early in conceptual design, must be directly supported and emphasized before the cost of a change gets too expensive.
- Everyone must contribute directly to decisions, providing input when that decision violates the conclusions or rules of their domain.
- Everyone must critique the specific aspects of the decision that impact their domain.
- A common language should be supported that is understandable across the domains.

Requirements, starting with customer needs in conceptual design, represent the common language that applies across all engineering functions. Moreover, requirements management involves a set of tools and processes that support high-level abstraction to serve multiple domains. Indeed, systems engineering approaches for managing requirements across the full lifecycle potentially support

a common language that promotes the direct participation of all disciplines in the decision making process.

SMOOTHER TRANSITIONS

Too often, four major cracks widen into chasms in the design of industrial products today, across all industries. Requirements management crosses all of the cracks, and serves to bridge any gaps before they expand into major challenges:

- Transitioning from system design or conceptual design to engineering
- Managing a multi-disciplinary engineering environment
- Transitioning from engineering to manufacturing
- Transitioning from engineering to after-sales support

Many others cracks appear as well, but these four cause the most of the damage in terms of cost and time.

At the conceptual stage, system engineers or program architects apply totally different tools than traditional CAD/CAE applications. Beside Excel, the universal design and data management tool, they make extensive use of specific design and simulation tools such as Matlab, Simulink, or Easy5. A distinguishing characteristic of this set of tools, they address design issues at a high level of abstraction, when geometry is not yet available and logical or functional specifications apply across all disciplines such as mechanical, electronics, or software.

Today, the transition from conceptual design to engineering is done manually, based on reports and documents, or on isolated result files. There is no process support, and consistent data management and tracking tools are lacking in terms of addressing the needs for analysis of the impact changes have across the two domains. If a change occurs in the initial set of customer or market requirements, it may be tracked down in the system design environment. It usually will not pass directly through to engineering. Vice versa, an engineering decision affecting the product performance will not be caught before the formal review of the project. The risk arises of discovering discrepancies too late, after tooling has been ordered or built, or worse, after the product has already hit the street, forcing a recall.

An enterprise PDM solution is perfectly capable of managing this transition today. The recent evolution of systems architectures with SOA and web services allows for easier and less costly integration of multiple tools. Solutions such as Teamcenter SE (System Engineering), SmarTeam CSE (Collaborative System Engineering), or more recently KollabNet have dedicated features to manage requirements, simulation and engineering data, and processes.³

³ For an assessment and comparison of nine offerings in the area, see *Requirements Management: Solutions Review*, Michel Vrinat, Collaborative Product Development Associates, June, 2006. Note that the other six offering in requirements management do not address the transition from conceptual design to engineering.

At the engineering stage, CAD, CAE, and CAM today usually drive the course of events on their own. Most often, the first level of integration has yet to be achieved so that these three main components of the engineering effort can share a representation of the product adapted to their particular needs.

CAD represents a heterogeneous world onto itself for multiple reasons:

- Multiple MCAD solutions are often used across a company, or even more often, with suppliers.
- Multiple disciplines are often involved across mechanical, electronics, and software domains with different and incompatible tools.
- Multiple domains create specific data models with different tools concentrating on structure, style, propulsion, or manufacturing equipment.

Too many times, CAE data is just not managed at all, and CAM data is kept hostage to legacy applications and separate teams. Indeed, as many as 95% of CAE users do not use any kind of data management. Even more significant, 65% do not consider this as an issue.⁴ In any case, CAE and CAM have very different needs from design in terms of data models, breakdown structures, and tools.

Here again, enterprise level PDM can provide consistency and data sharing capabilities through a higher level of abstraction and the appropriate meta-data. Multiple structures and relationship models as well as process modeling and execution may also be supported.

Another critical chasm, from a data management standpoint, relates to the transitioning from engineering to manufacturing. The perpetual debate on BOM involves un-reconciled variants such as the engineering BOM (eBOM), the manufacturing BOM (mBOM), the bill of process (BOP), and the bill of analysis (BOA). The maintenance of these variants has generated far too much waste for too many years. The automotive industry is especially impacted because of product families that may share the same platform while supporting ever more variants. Annual updates, as well as high production volumes, intensify the challenge.

Beyond the ownership issue concerning who owns the BOM, PLM, or ERP, a real technical difficulty relates to the different requirements with break-down structures and semantics. One emphasizes parts and reuse while the other concentrates on material and the different steps in the manufacturing process. The design/functional structure differs significantly from the assembly structure for manufacturing. A new set of tools and capabilities may be needed to resolve the dilemma, and UGS is developing significant new capabilities in this area.

Many technologies and approaches are available today that represent key enablers for an enterprise-wide PDM solution. These include loose coupling and federation of native data, the management of dependencies and relationships

⁴ See *CAE Data and Knowledge Schema: Pilot*, Michel Vrinat, Collaborative Product Development Associates, August, 2005, which includes the results of a survey of participants in the Design/Simulation Council.

based on rules and conditions, the support and synchronization of multiple views, and process modeling and execution.

The missing ingredient, however, is the ability to embrace the challenge at the right scale. Response time and affordability must be kept at a level that will allow an industry and company to make the leap, in the face of necessary changes in culture and organization that will follow.

Several companies have addressed the challenge and are able to gain the benefits right now. These are large companies that undertake a multi-year effort with a sustained budget, but the lessons learned and the practice can be applied to many other situations.

END-USER STRATEGIES, STATUS, AND EXPECTATIONS

MERCURY MARINE

Mercury Marine, a U.S.-based marine-propulsion company with \$2.6 billion in sales and more than six thousand employees worldwide in 2005, has engaged in an ambitious plan for its enterprise PLM.

Mercury employs more than four hundred engineers around the globe and conducts substantial design work at multiple sites. The increase of co-developed work across multiple sites entails a huge effort by the organization and the appropriate use of state-of-the-art product-development tools. Teamcenter Engineering, Teamcenter Community, and Teamcenter Visualization with JTOpen will play significant roles in this program with the sharing of CAD models, specifications, and other key product data.

Maintaining a consistent and complete product definition is not a simple task. The system must serve CAD tools – mainly Pro/E – for part, assembly, mold design, and electronic design applications; multiple analysis packages including ANSYS, MATHLAB, and Fluent; quality inspection applications such as PC-DMIS; and a home-grown ERP solution. Manual transfer and repetitive data entry is targeted for immediate resolution.

Mercury Marine products are relatively complex, with eight hundred to fourteen hundred parts on some product lines. They require integration across multiple technologies including mechanical, electronics, and hydraulics as well as involving specific know-how for propulsion components such as shafts, gears, and propellers. The need to maintain a very high level of quality is a must.

Mercury Marine has advanced beyond the classical “make and break” mind set and embraced virtual prototyping. Most of the products have a very high re-usability level. All new projects rely from the start on a standard configuration that may be analyzed to match new product specifications with existing

alternatives while minimizing differences. The cost of making a change is analyzed and validated even before design begins.

The functional breakdown of the product is standardized, based on systems and subsystems. A standardized process breakdown links each breakdown structure. This is currently supported by Teamcenter at a pilot level.

Requirements management is a key component of Mercury Marine's strategy for reducing product development and production cost. Currently relying on Microsoft Excel, Mercury Marine expects Teamcenter System Engineering to facilitate the flow of requirements to the actual design of parts and the support of the change management process while tightly integrating all the steps of the development process. These targets represent a challenge.

Reconciliation of the eBOM, currently managed by PTC Pro/Intralink, with the mBOM, currently owned by a home-grown ERP system, extends from design to manufacturing to after-sales support. This is the target for Teamcenter as a second challenge for the coming months.

DFSS is applied at the conceptual phase. Innovation is managed separately, before the project is started. This is not part of the development process. The cycle time for a new model to go from concept to production is eighteen to twenty-two months. Family iteration cycle times are from nine to eighteen months. All projects follow the same stage-gate process.

Mercury Marine expects to integrate all phases of the product development process, including:

- requirements management
- system and conceptual design
- detailed design
- simulation
- manufacturing engineering
- after-sales support

A master data or reference model will be made available across the company. The level of granularity extends all the way to attributes including both the classification and measurements. A feature will be an attribute linked to the part. The objective of Mercury Marine is to cover the entire product lifecycle, from the voice of the customer to requirements for product development, through production and service. Teamcenter Engineering will author the BOM covering parts and the bill of process (BOP), according to configuration management rules. It will serve as the gatekeeper and the master reference.

All BOMs, including customer BOM, will be stored in an Oracle 11 database for use by production departments, accessed through a home-grown user interface.

Mercury Marine adopted a systematic approach in defining its enterprise PLM solution. The project team was built with a group of experts participating from each domain, driving external integration services work. The three-year plan started in 2004 and included three major steps:

- analysis of business needs (2004)
- defining process needs (2005)
- mapping and deploying the technology in support of the development process (2006)

The most difficult part related to the integration of all the applications. By the conclusion of 2006 however, the design-tools integration should be well developed. The next step will be the linking to the new Oracle ERP system.

Before the project was begun, many actions were undertaken to gain management's understanding and approval, and to establish buy-in from key individuals. An executive committee meets monthly, with senior management participation, to review issues and progress.

ELTA SYSTEMS

ELTA Systems, a wholly owned subsidiary of Israeli Aircraft Industries (IAI), specializes in defense and intelligence systems with \$700 million in revenue and three thousand people employed. ELTA operates as a defense systems house, based on electromagnetic technologies for radar, electronic warfare, and communication, and information technology. ELTA's products are applicable to all theatres of operations – land, sea, and air.

ELTA build its enterprise reference data model on top of Teamcenter. More than two thousand users access the product definition database from all departments at ELTA. There are today over three hundred thousand documents in the Teamcenter database, all on one site. After a well organized transition from the legacy PDM application, ELTA was able to turn it off after four months, and received very positive feedback from users. The change process was unified for all disciplines across the company a long time ago, and is now supported by Teamcenter. It covers documents, specifications, parts, drawings, electronics, and software.

Its one thousand engineers specialized in system design and engineering, as well as the personnel in the mechanical, electronics, microwave, and software development groups, rely on different authoring tools such as Mentor Graphics and UGS NX, and simulation tools such as ANSYS and FlowTherm. All product definition data is accessible from one source: Teamcenter Engineering. Core from Vitek manages their software requirements, although they are presently reviewing Teamcenter System Engineering as a more general tool.

ELTA Systems' products are extremely complex in terms of components and technology with up to ten thousand parts. Development cycle time is two to

three years, and may be part of a solution with sophisticated electronics and software that are produced in relatively small volumes. Most of the design work is done in house.

All product definition information, from requirements documents, engineering data, drawings, and CAD models, to CAE data, result files, and software packages are released and managed for changes in configuration with Teamcenter.

Each authoring application covering mechanical, electronics, and software has its own tightly integrated data management. The deliverables are released through a common process into one unique reference data base. CAE data and results files are released with a link back to the original CAD model used to build it.

The eBOM is built in Teamcenter and transferred to ERP (SAP) with minimal adaptation, such as additional “phantom” items, to identify non-material parts or intermediate models. The eBOM is built upfront with manufacturing constraints and assembly sequences taken into account. Tooling is part of the overall project design work. When a change has to be applied, a specific tool developed by TESIS, a German company specializing in software integration for UGS and SAP, browses the BOM and checks for differences.

The next step for ELTA will involve the definition of a standard product structure in order to maximize re-use of parts and subsystems, and to allow for the automatic definition of a project-specific product structure directly from customers requirements. A pilot is currently running. Within six months, an automated procedure will allow any engineer to work from this standard product structure, shared with the configuration management team. In the following twelve to twenty-four months, a standard product structure will be built directly from requirements.

A LARGE AEROSPACE AND DEFENSE COMPANY

A large **Aerospace and Defense** company has a very ambitious program for enterprise data management under deployment. With over two thousand five hundred engineers all gathered on the same site, and a total of eight thousand people and \$6 billion in revenue, the company builds an extremely complex system with up to one million parts.

The current PDM solution is a fully customized version of ENOVIA that will evolve to a more standard version with the new releases of Teamcenter. The major CAD tool is CATIA, and the CAE work relies on hundreds of home-grown applications on top of commercial solutions such as NASTRAN, FlowMaster, or PipeStress.

In common with any complex systems today, multiple engineering disciplines and technologies are involved in the design of the product: systems engineering, mechanical, electronics, hydraulics, structure, and software development. With a very low volume of production, the level of re-use is very high at 80% to 90%.

While some subsystems are totally outsourced, most of the integration work is done in house.

The company's expansive vision for PLM extends well beyond the capabilities supported in actual deployment, or even planned in terms of implementation. Many gaps in the technology remain, and in the ability of the vendors to support the vision, which limits the effective adoption of PLM. Teamcenter Engineering is the solution of choice as an enterprise PDM, because of its flexibility, reliability, functional richness, and scalability. Over time, the planned solution for a merge of technologies by UGS is expected in two phases with a migration to an SOA-based framework.

The current plan for the next twelve months targets the deployment in production of a change management process at the system-engineering level, including requirements management. The technology, however, is not yet capable of supporting the required data model and relationships. The company will not use a specific requirement management solution, but will directly create the requirements data model and the links in the PDM solution. A complete enterprise data model has been defined that is not yet implemented due to missing functionalities with the current implementation, including a business modeler, configuration authoring, behavior definition and consistency with standard unified modeling language (UML).

System engineering includes the logical definition of the product extending across multiple disciplines. It covers requirements through functional definitions. It does not yet address the physical decomposition, which is targeted for the following year. Some of the CAE data used for upfront analysis is managed, but not the detailed design analysis. Software is not always covered by data management. Control logic data will be managed, but the embedded software represents a future target.

Teamcenter will manage data from any authoring tools using XML models. Many tools, with a high proportion of them home grown, must be integrated in the PLM framework, raising the need for an open architecture that has been the basis for adopting PLM XML as the core technology.

A legacy MRP system manages manufacturing data. Because of changes in the manufacturing approaches, the whole product has to be re-planned for each new delivery. The mBOM will be authored in the PDM and synchronized to the MRP for consumers, and synchronized with dependant applications linked to the MRP. Since the frontiers between PLM and ERP are moving, some functions from ERP will be included in the PLM system. After sales support data will also be managed by the PLM, not by the MRP, as defined in the mid-term plan covering the next three to four years.

The company has had a well defined change management process for many years. Only two-thirds of the functions can be supported by the PDM today, and just half have been implemented. The challenge relates to the level of granularity

which extends down to an end item, not just a CAD file that may contain an assembly. A CAD package includes multiple parts, and the level of granularity has to be at the end item level, otherwise the entire work package is copied when a change is applied to one component.

Specific interfaces maintain the consistency between the MRP and PLM data point-to-point, based upon file documents that make the systems very difficult to maintain and run. This is the major motivation driving the company to define its integrated development environment and its enterprise data model. Synchronization functions will have to be put in place on top, targeting the next three to four years. This master data or reference model will then be used across the company.

The integration with local work within each discipline covering mechanical, electronics, or software is done through a data model abstraction at three levels. The first is a logical data model defined within the PDM as a representation of the business view. The second is a translation into PLM XML. And the third is an independent logical data model based on a customized STEP standard. Several tools support a mapping across all three models with PLM/XML as the hub, and with point-to-point synchronization. The transformation is done once, but the mapping is a two-step process. This is completed for logical design at this time, and will eventually cover all authoring tools. That requires a stable public API for accessing the data model, which is not available today from CATIA.

A difficult issue remains, of integrating authoring tools – they must be quick and easy to use. The company decided it had to develop its own technology after comparing many framework vendors' solutions. The independent model has to be built with all the required connectors. The company is following OMG efforts, which in its view has yet to establish a complete solution.

Another issue is the huge investment in legacy data. The rollout of the new PLM will involve a slow migration due to the difficulties of integrating legacy, and the lack of support from PLM vendors in addressing the related issues. The main concern relates to the extraction and reformatting of the data for access by the new PLM system.

On a final note, considering the expense of PLM, the growing pressures on funding, the company faces a risk in meeting the ongoing costs of the planned solution. A strong commitment from management needs to be established, and continuously reinforced.

CONCLUSIONS

The simple sharing of documents or parts files has never covered the full spectrum of PLM deployment requirements, and the gap has widened in the face of escalating pressures on the expected return on investment, the pressures of compressed product cycles, and the challenges of intensified global competition.

Application data models grow more complex in support of rising expectations among users across design and engineering, including simulation and manufacturing. The tight integration of authoring and simulation tools supports access to fine-grain data in a detailed context for the management of engineering knowledge and relationships. Tight integration provides direct and targeted support to engineering decisions in a dynamic collaborative environment where changes have to be evaluated quickly, based on multi-disciplinary analysis with precise technical information.

At the other end of the spectrum, the enterprise level supports greater integration, with access to the full product definition covering a broad range of information at a more abstract level. Enterprise PDM reconciles disparate views and promotes enterprise-wide collaboration across multiple departments.

Without the support of explicit abstraction levels, the risk arises of drowning everyone in ever-increasing detail. Abstraction and filtering must be applied. Moreover, establishing agreement at a higher level supports the freedom and flexibility for each domain to pursue the detailed objectives dictated by their own area expertise, with their own framework and language, in parallel. The higher level then ties the product definition together.