A New Paradigm for Digital Design

Over the last 25 years, the need for solutions to help create and manage your intellectual assets – the engineering data that makes your products valuable – spawned an extended family of software offerings that have evolved into the product lifecycle management (PLM) solutions of today. While these PLM offerings have grown into enterprise-wide solutions providing extensive communication and collaboration features, the core need remains: how do we best empower our engineers and designers to build innovative, profitable products, and do it quickly? Dassault Systèmes designed the V5 architecture to do just that – to empower your most skilled technical staff with the tools and techniques to achieve true concurrent engineering, helping them design and build innovative products quickly and efficiently. ENOVIA, a leading PLM solution provider, offers a new paradigm for digital design through solutions that do more than just manage and share engineering data. ENOVIA is the only PLM solution provider that can harness the power of the V5 architecture to help your organization leverage your intellectual assets to maximize their value in the marketplace.

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Background

Products are the lifeblood of most companies, and product innovation is at the core of their ability to compete in the marketplace. The tools and techniques used to design these products have evolved over the last forty years, from producing blueprints on the drafting board to the digital design of today. As computer and graphics technology became more powerful and less expensive, computer-aided design (CAD) systems evolved to support the design of complex products. CAD and other related tools empower designers and engineers to create innovative products more quickly and efficiently. These designs embody the knowledge and experience of an organizations designers and engineers. They are the intellectual assets upon which innovative products can be developed, sold, and maintained.

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The design process using CAD systems and other tools results in a multitude of files that describe the elements of a product and how they all fit together. To manage the complexity of these configurations, software providers developed systems, often referred to as CAD data management (CDM) systems, focused on managing data within the workgroup. These systems helped engineers manage their evolving designs, and share them with their colleagues within the company. As design tools grew in capabilities, so too did the desire to support more of the engineering process using data management technologies. CDM systems began to add simple communication and collaboration technologies, such as workflow and notification, to let others know about changes in data of interest, or to include them in the development or engineering change process. With this increased emphasis on engineering process came the requirement to manage other types of intellectual assets, such as documents and other files that were part of the product development process but developed by tools other than CAD.

During the 1990's, the product data management (PDM) systems continued to expand in scope and scale to include more complex communication and collaboration technologies. Companies recognized that they could use these systems not just to design their products, but also to manage other related product data over their entire lifecycle from concept through deployment. This data includes requirements and specification documents related to product designs, design review results, engineering change documentation, test plans and results, and other documents related to the evolving product not developed using

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CAD authoring tools. With this recognition, and the solutions to support it, the move from PDM to product lifecycle management (PLM) was complete.

At the same time, CAD and computer-aided engineering (CAE) technologies grew in complexity and capabilities. Moore's Law rippled through high tech industries, leading to cheaper and more powerful computing and display technologies on the average engineer's desktop. Software suppliers capitalized on this new power, bring new design tools to the market. Cheaper, more powerful tools and less expensive hardware provided the tipping point for many companies to move from two dimension (2D) CAD to 3D, the prerequisite for many analysis techniques like finite element modeling (FEM). Once limited to mainframe and minicomputers, these powerful analysis tools also moved to the desktop, putting the full range of CAE at the engineer's fingertips. Using these new tools as an integral part of the product development process helped engineers answer many "what-if" questions that historically required prototypes, breadboards, or other physical mock-ups. Driven by the obvious cost benefits, this new product development process resulted in a proliferation of analysis data, data that is most valuable when it is linked to the evolving design accurately.

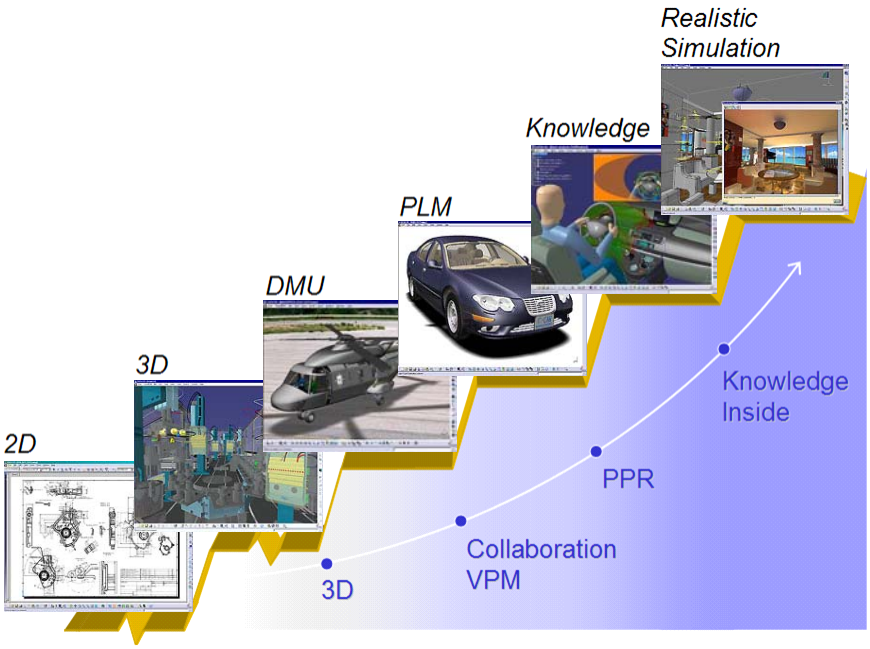

Figure 1 – Engineering tools evolved to enable virtual product development

In some ways, CAD/CAE and PLM evolved in different, conflicting directions... CAD/CAE to be more specialized…and…PLM … to be more generalized, providing more functions and general management capabilities for the extended enterprise.

In some ways, CAD/CAE and PLM evolved in different, conflicting directions. CAD/CAE evolved to be more specialized, providing more virtual product modeling capabilities with each passing year. At the same time, PLM solutions evolved to be more generalized, providing more functions and general management capabilities for the extended enterprise. While most PLM solutions can manage CAD files, and do it effectively, their approach to managing this data does not include the knowledge embodied in the relationships between the designs, their requirements, and the engineering analysis process used to reach the final design. Moreover, simply managing design data as files does not allow engineers and designers to directly access the knowledge embedded within their designs so that it can be reused effectively. Intellectual assets managed with a full understanding of this embedded knowledge enable organizations to leverage

this knowledge, providing value again and again in the development of new, innovative products.

Effectively leveraging the embedded product knowledge resulting from virtual product development requires PLM solutions that can manage the rich information product by CAD, CAE, and manufacturing process planning, while still supporting enterprise PLM requirements..

A New Paradigm for Digital Design

Virtual product development uses the power of computers and integrated 3D development, analysis, and data management tools to develop products and processes without costly physical prototypes and without capital investment in manufacturing equipment, tooling, and facilities until designs are nearly final. These tools help designers and engineers understand the full implications of a product's technical requirements, with these requirements elaborated in the design and associated analyses. Studies have shown that 80-90% of product cost is committed in the design phase. Using virtual product development, organizations can prove out designs, testing different product and process alternatives during this crucial product development phase, ensuring a smooth transition from engineering to manufacturing.

Dassault Systèmes V5 architecture provides the necessary foundation for virtual product development. CATIA V5, Dassault Systèmes' solution for digital product definition and simulation, enables users to tailor product development to meet industry-specific requirements. With CATIA, users can simulate the entire range of industrial design processes from marketing and initial concept to product design, analysis, assembly, and maintenance. ENOVIA, Dassault Systèmes' product lifecycle management solution, is the only PLM solution that provides integrated support for the V5 architecture. Figure 2 illustrates the elements of the Dassault Systèmes PLM solution.

To enable the exploratory nature of early design, ENOVIA provides a collaborative workspace, an interconnected environment in which all the

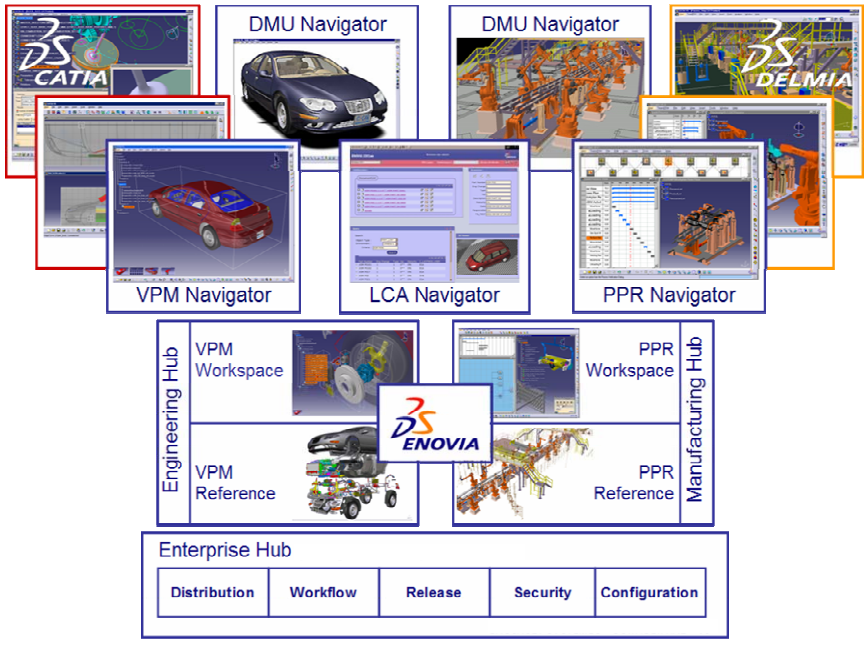

Figure 2 – ENOVIA provides integrated support for the V5 architecture

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participants in the product lifecycle – design, marketing, sales, manufacturing, OEMs, suppliers, and customers – can access and work on each other's "In-Work" designs. ENOVIA provides company-wide 3D collaborative workspaces that connect suppliers, OEMs, and customers via the Internet. These workspaces enable the rapid exchange, direct use, simulation, and validation of 3D data, significantly enhancing communication. Dassault Systèmes' Collaborative Workspaces break down the barriers between engineering design functions, both accelerating the product development process and bringing a new level of decision support, innovation, and collaboration.

The key to V5's support for virtual product development is relational design, a product development approach based on the relationships between objects in a design. These relationships, referred to as "links," are built either manually or automatically as product definition progresses. These links help capture and manage the original design intent, or design knowledge and intelligence, used to plan and execute the design. This can include the original specifications and other information. Relational design supports the co-evolution of related parts within a design. It also helps ensure consideration of the original design intent or specifications during engineering changes.

ENOVIA stores and manages the part information, related analyses, simulation, process planning, and other knowledge developed using authoring tools during product development. In this case, management includes configuration management of all of the relationships and analyses. For example, suppose two parts must be a specific distance apart. If one part changes, the other part can change automatically, without intervention by a designer. Figure 3 illustrates this concept. ENOVIA manages assemblies, including all of the relational links, in the ENOVIA repository. When a part changes, ENOVIA highlights the affected parts and processes in the configuration (the tree structure in Figure 3.) ENOVIA keeps track of these changes and notifies the designers of affected

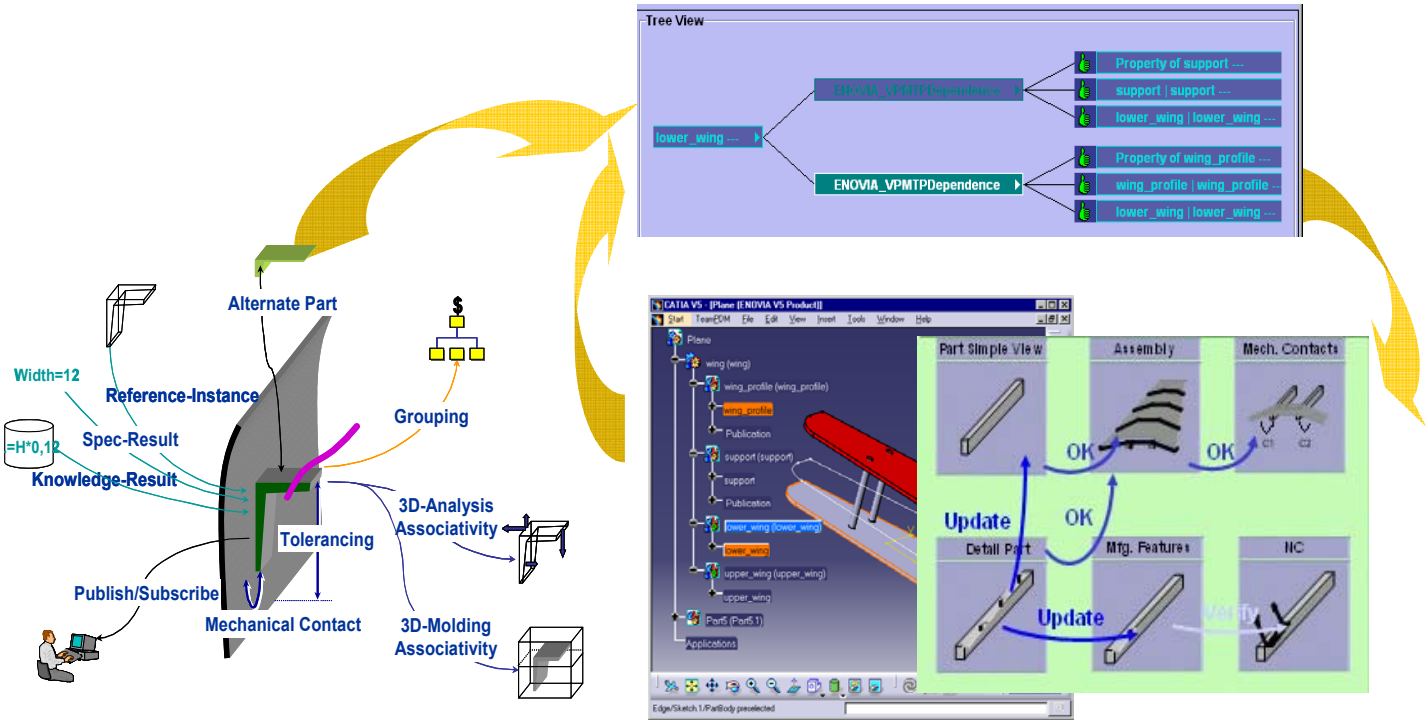

Figure 3 – Relational design empowers knowledge workers

parts, and can initiate workflows to ensure that the necessary parties make their contribution. Most PLM systems, including ENOVIA, support pre-planned workflows for common functions like engineering change or product information release. However, unlike other systems, ENOVIA can automatically initiate ad hoc workflows resulting from relational design. These ad hoc workflows help ensure that the cascading impacts of changes are truly understood and resolved. Once all the necessary changes are completed and resaved in ENOVIA, the change impact changes status to resolved. This functionality helps engineers optimize their designs as early as possible in the lifecycle, when the cost of change is still low.

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In its most advanced form, relational design can propagate changes automatically from business goals to object definitions. For instance, an aircraft mission specification (maximum flight time) could be linked to a design specification (fuel capacity), which itself is related to the wing dimension. A change in flight time or fuel capacity could update the wingspan dimension and in turn the number of wing ribs and stringers and their geometry. This approach provides significant advantages in an engineer-to-order environment, as well as for companies that must modify designs by year or model.

Relational design extends to CAE and manufacturing process analysis. Any change in a part can require that a certain engineering analysis be re-performed before that part is considered up to date. Part changes usually also require changes in manufacturing processes. ENOVIA includes functionality that helps ensure that the impacts of these design changes are reflected in manufacturing processes for that design. DELMIA, Dassault Systèmes' PLM solution for engineering lean manufacturing processes, enables manufacturers to digitally plan, create, monitor, and control production and maintenance processes. If there are existing manufacturing process plans and simulations, these too are flagged and require updates. Using these techniques, the V5 architecture and integrated tools enable true concurrent engineering and provide opportunities to reduce the overall product development cycle time and cost significantly. ENOVIA is the only PLM system that fully supports this knowledge management function.

Enabling this virtual product development vision required a unique approach to data management. Dassault Systèmes' PLM solution focuses on managing all virtual product development knowledge in a central, integrated repository. The Product, Process, Resource (PPR) Hub is the core of the V5 architecture and a fundamental building block of Dassault Systèmes' PLM strategy. The integrated PPR model links representations of the Product, the manufacturing Resources (tooling, factory, and operators) and the production Process. The technology underlying the PPR hub is the primary enabler for implementing relational design. Our Hub strategy helps organizations realize the value of virtual product development.

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During the product lifecycle, different user classes have very different requirements for developing, accessing, and using product data. Usage classes form a pyramid, with the smallest user classes at the top, and other classes growing as you move down. At the top of the pyramid are engineers and designers. They develop CAD models and other technical data using specialized authoring tools that are often expensive and require extensive training. At the next level are larger numbers of managers and other staff who support the development process. They may be performing technical tasks requiring access to the technical data, but do not have access to or training in using those authoring tools. At the lowest level, the largest user class includes higher-level managers and workers from other disciplines, like marketing and purchasing, who need access to technical data. They do not have access to authoring tools, and often need the data summarized at a higher level to perform their tasks. To support these different user requirements, Dassault Systèmes is developing

"Navigators," specialized gateways to classes of product information focused on the specific requirements of those users. The VPM Navigator focuses on requirements for engineers and designers to support their virtual product development tasks more effectively. The Lifecycle Applications (LCA) Navigator will focus on providing access to most ENOVIA managed data and processes using a standard Web browser. Integrated viewer technology will allow users without access to authoring tools to see and manipulate complex 2D and 3D data. Similarly, the PPR Navigator will allow users to access data from the Manufacturing Hub.

Within the PPR, the Engineering Hub is the secure collaborative workspace that enables engineers and designers to develop and share their ideas, managed by ENOVIA. The VPM Workspace provides a secure environment for engineering work-in-process (WIP), the information that an engineer develops while evolving their ideas through design and analysis.

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The Manufacturing Hub provides a parallel structure for manufacturing process development. Engineers manage manufacturing process work-in-process in the PPR Workspace, maintaining linkages to the product data in the Engineering Hub. When this information is ready for broader release, ENOVIA pushes the data to the PPR Reference area. The Enterprise Hub provides enterprise PDM functionality. It provides secure access to information ready for enterprise

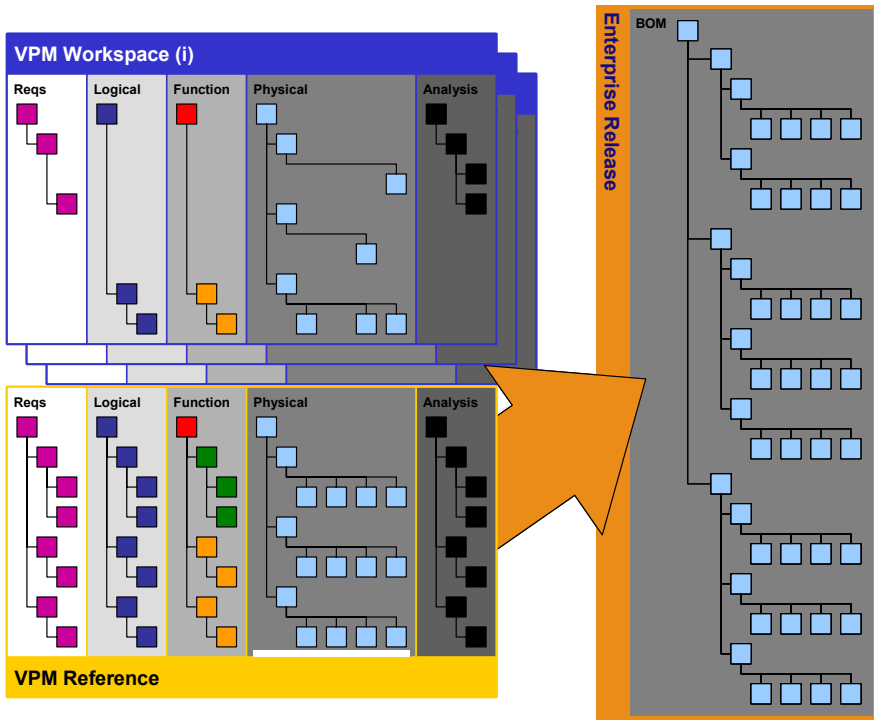

Figure 4 – Multiple workspaces support virtual product development

release, notification, workflow, and configuration management capabilities. Used in combination, these three Hubs provide unsurpassed support for virtual product modeling.

The VPM Navigator provides an engineering gateway to ENOVIA functionality from within the CATIA interface. VPM Navigator allows designers to work within a single, integrated environment as shown in Figure 5. This single interface provides quick, easy, and convenient access to central product data and lifecycle management functions. Its integration with the CATIA environment will speed systems deployment and lower overall software maintenance cost. Using one interface for both CAD and PLM functionality will require less training, and will increase the productivity of your key designers and engineers. It will also help reduce errors often introduced when switching between CAD and PLM applications. Providing designers with access to product data management functions from within the CATIA environment will simplify relational design, bringing this powerful technique into reach for more designers. Data access in VPM Navigator is subject to all of the same security and lifecycle management restrictions defined in ENOVIA, increasing your product data accuracy and quality. Enhanced data access will also significantly increase the opportunities for part and data reuse, saving both time and cost.

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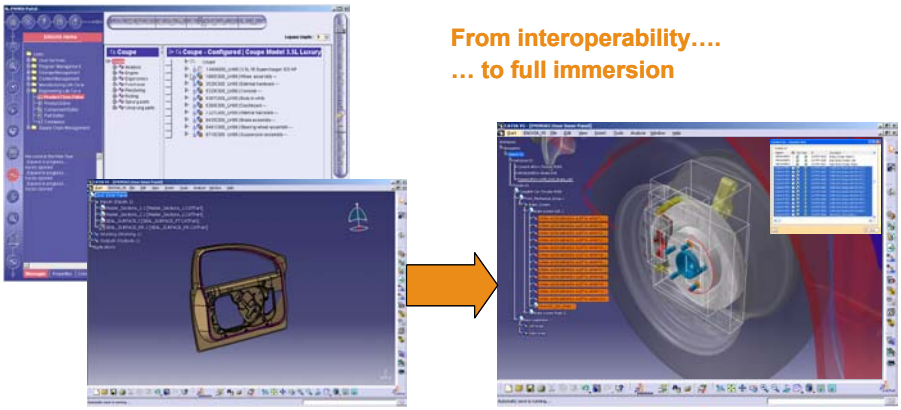

Figure 5 – The VPM Navigator, a gateway to ENOVIA functionality

The VPM Navigator helps engineers and designers access ENOVIA's VPM functionality, as shown in Figure 6. Our *Product Definition and Configuration* functions help companies manage corporate product definition. This capability supports breaking down complex structures into manageable, relevant views, such as work assignment or organization, subsystems or functions, or areas/zones. Companies can define generic component objects for use within multiple products with a similar product structure, helping to integrate marketing and technical product definition. These functions support defining and managing product variants, different models built off a common platform to meet market requirements. Designers can define option packages for each model and rules for their application, supporting the use of product configurators.

Assembly Detailing helps engineers define part and assembly structures, drawing from objects managed in the Engineering Hub. ENOVIA goes beyond the effectivity functions supported by most PLM systems. Using the power of relational design, engineers can navigate impact graphs to understand the affects of a part change on other parts, drawings, analysis results, specifications, operating parameters, and manufacturing processes and resources. A tight integration with computer-aided engineering (CAE) and digital mockup (DMU) tools helps engineers visualize change impacts and resolve them effectively.

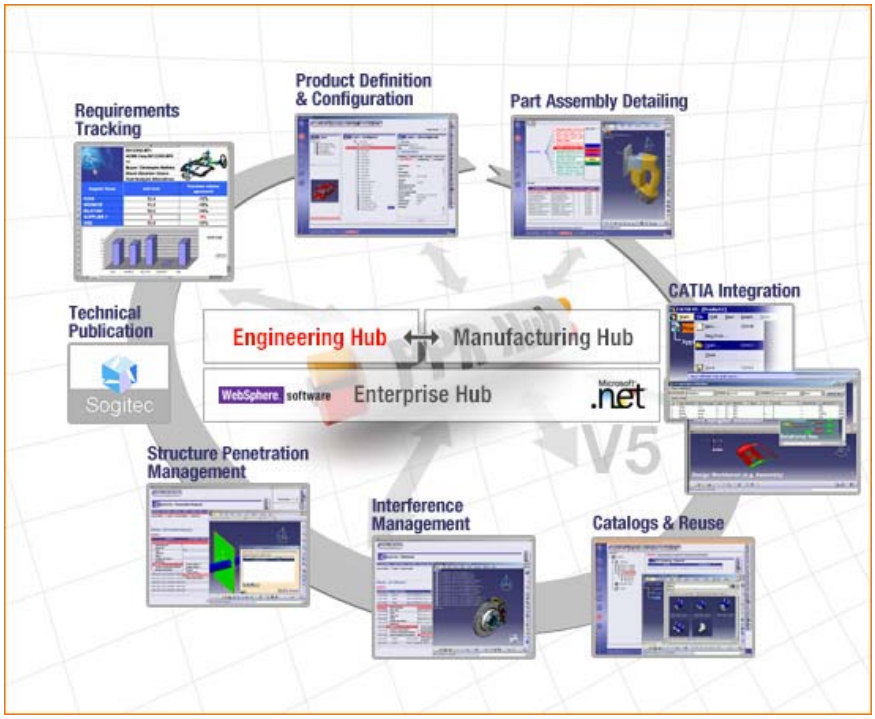

Figure 6 – The Engineering Hub supports powerful VPM capabilities

ENOVIA offers the only CATIA Integration in the PLM industry that fully leverages the V5 architecture.

Our DMU solution provides strong multi-CAD support. Most complex products include parts designed with different CAD systems, either within your organization or from your supply chain. DMU supports the virtual 3D design and simulation of a product and all of its components, regardless of the native CAD system. The mock-up includes precise measurements and other data taken directly from the CAD models. Manufacturers can design a product mock-up in full detail, simulating all functions and interactions among the different components. In most cases, DMU can eliminate the need for expensive physical mock-up, saving significant time and money in the product development process.

Of course, ENOVIA offers the only *CATIA Integration* in the PLM industry that fully leverages the V5 architecture. Dassault Systèmes extends the reach of our PLM solution with integrated V5 tools developed by our software development partners. The Component Application Architecture (CAA), a comprehensive, open development platform, enables independent software vendors to develop, sell, and support CAE solutions integrated with the Dassault Systèmes' PLM portfolio. The CAA V5 Software Community Program results in CAA V5-based applications that significantly expands Dassault Systèmes' PLM offering, giving customers solutions targeted to their specific industrial needs. Around the globe, over 30 CAA software partners offer over 130 applications that enhance the virtual product development process.

The Component Application Architecture (CAA), CAA V5 Software Community Program results in CAA V5-based applications that significantly expands Dassault Systèmes' PLM offering.

Catalog Management provides tools enabling end users to define, catalog, and manage standard parts, documents, and other resources for effective reuse. Complex search functionality helps engineers quickly find existing knowledge to enhance their designs, which they cad drag-and-drop onto their evolving product structures. ENOVIA's catalog management functions interoperate with both i2 and the CATIA V5 catalog.

With our focus on supporting virtual product development, ENOVIA provides integrated support for common design problems. For example, in designing

complex products, engineers have to be concerned about the physical relationships between those parts. A design may require that parts touch, or have a define contact, or may have to be a specified distance apart. In relational design, this information is an inherent part of the design. If a part changes, ENOVIA can readily identify other parts that may now interfere with one another, or may be out of specification. While most CAD systems provide some functionality to find interferences, they generally just report interferences when they occur. ENOVIA goes well beyond simple reporting to *Interference Management*. When a part causes one or more interferences, ENOVIA documents each interference as a separate ENOVIA-managed object. ENOVIA can notify the responsible engineers automatically, with ENOVIA initiating workflows and change processes to ensure that each interference is addressed to its resolution. The real power of this approach is that it extends beyond just the current CAD objects or files loaded in memory. An engineer working in the VPM Navigator can extend this analysis across entire product structures managed in ENOVIA, ensuring that the complete identification of change impacts quickly and effectively.

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In designing complex products, there are times where parts should intersect. For example, a heating duct should carry heat from the engine compartment through the dashboard. ENOVIA's *Structure Penetration Management* functionality helps identify and manage these instances. This is most common when designing wiring or piping components in a product. When this type of "clash" is detected, the designer can choose to address the clash using a specific action, such as drilling a hole in a structure. Structure penetration management allows users to declare this intent, and to associate clashes with this penetration. By declaring this design intent, ENOVIA will stop reporting these clashes, even before the penetration solution is designed, while still ensuring that this design change does indeed occur. This helps maximize the creativity and productivity of your designers, letting them identify solutions and move on to the next problem.

Some of the world's leading companies use ENOVIA and the V5 architecture to empower their engineers and designers to create innovative, competitive products. Let's see how.

What Our Customers Are Saying?

Embraer (Empresa Brasileira de Aeronautica S.A. (NYSE: ERJ - News; Bovespa: EMBR3 EMBR4) is a major aerospace company with 34 years of experience in designing, developing, manufacturing, selling and providing after sales support to aircraft for the global airline, defense and corporate markets. With headquarters in Sao Jose dos Campos, state of Sao Paulo, the Company has offices and customer service bases in Australia, China, France, Singapore and the United States. Embraer is among Brazil's leading exporting companies. As of September 30, 2003 Embraer had a total workforce of 12,607 people, and its firm order backlog totaled US$ 10.4 billion.

To support its integrated product development (IPD) processes, Embraer needed an environment for product lifecycle management that could support worldwide, extended enterprise collaboration, with strong capabilities in configuration management, digital mockup, and digital manufacturing. CATIA and ENOVIA are an excellent fit for their requirements.

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Embraer uses ENOVIA-VPM and CATIA (V4 for design as well as other major activities, and V5 for some technical publications functionality) to support IPD for their latest line of twin-engine jet airliners, the EMBRAER 170/190. Commonality between the four aircraft in the EMBRAER 170/190 product line is high: 89% between the EMBRAER 170/175 and the EMBRAER 190/195 and

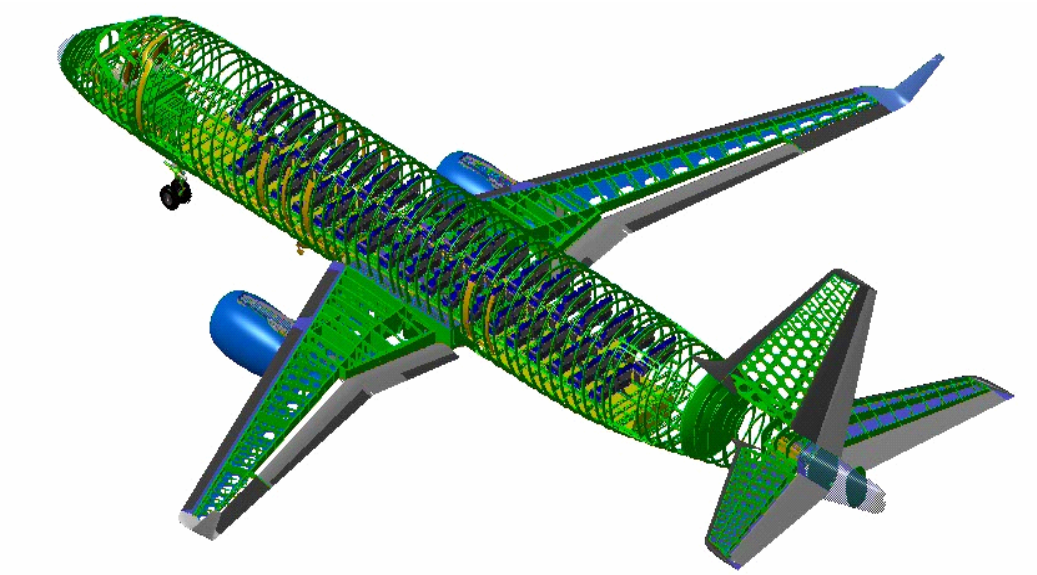

Figure 7 – CATIA model of EMBRAER 170

95% between the EMBRAER 170 and the EMBRAER 175 as well as between the EMBRAER 190 and the EMBRAER 195. Just the job for the product variant/options, relational design, and data management capabilities that are ENOVIA's strengths.

By integrating Dassault Systèmes tools into their develop processes, Embraer has experienced an overall improvement in design quality. They now create 100% of their geometry data in 3D, two steps ahead of past practices. Exchanging geometric data with their supply chain is easy using the CATIA format, a de facto standard in the aerospace industry. ENOVIA-VPM has proven invaluable in keeping a highly complex and dynamic product structure synchronized with geometrical data (CATIA), allowing Embraer to employ DMU across the entire product lifecycle, not just in the conceptual phase as in the past. ENOVIA-VPM improved analysis in several areas, specifically interference and change impact. Embraer's backlog for this new product line demonstrates their ability to drive innovation in these product using CATIA and ENOVIA.

Honeywell is a diversified technology and manufacturing company. Lines of business include aerospace products and services; control technologies for buildings, homes and industry; automotive products; power generation systems; specialty chemicals; fibers; and plastics and advanced materials. Headquartered in Morris Township, N.J., Honeywell employs approximately 100,000 people in 95 countries, and reported 2002 revenues of $22.3 billion.

Honeywell needed a PLM solution that could support their existing CAD suite (and future DS solutions), could easily be adapted to fit their existing processes, and could enable and simplify collaboration with their supply chain partners. Honeywell selected ENOVIA as the best solution meeting these requirement.

The Propulsion System Enterprise of Honeywell Aerospace is a leading provider of gas turbine engines for a diverse range of applications, including fixed wing aircraft, helicopters, trainers, marine systems, tanks and armored vehicles, and for use as auxiliary power units. Honeywell already used CATIA for mechanical design and relied on their supply chain to design and supply key engine components. Honeywell needed a PLM solution that could support their existing CAD suite (and future DS solutions), could easily be adapted to fit their existing processes, and could enable and simplify collaboration with their supply chain partners. Honeywell selected ENOVIA as the solution best meeting these requirements and began implementation in 2000.

Honeywell found it easy to adapt ENOVIA to support their design processes and practices. Adding Honeywell-specific attributes, like master flag and target

estimated weight, to ENOVIA's standard set was straightforward. ENOVIA's product structure functions allowed Honeywell to define their product structure around their desired engine modules, such as the speed reduction gearbox or low-pressure turbine. Since many such modules are the responsibility of one functional group or an outside supplier, partitioning the evolving design this way can improve Honeywell's ability to manage the process. It provides all their users with a synchronized, graphical view of a configured bill of material (BOM). Honeywell defined products and queries so that the engine development team could access all necessary CATIA models so they can design in the context of a complete assembly or product.

Designers can also synchronize their design with offsite partners, and use ENOVIA to build synchronization reports that identify which modules have been modified. Designers now have one centralized database to identify design problems, resolve part clashes, and store change. They can track and promote maturity of a part all the way through final release.

The security administration features built into ENOVIA help Honeywell provide controlled access to their product information. Honeywell works with many suppliers and partners, and must control data access to ensure that collaboration partners can only access data appropriate to their role and assigned tasks. "ENOVIA controls and streamlines security and lifecycle processes," according to Tom Rook, Senior Principal Engineer, Integrated Design Systems, "ENOVIA's security features are an essential tool for maximizing the integrity of our designs." Each ENOVIA user receives a role that determines their privileges in the system. For example, a design lead has privileges for release and data export to partners. Certain roles can be prohibited from accessing proprietary data. These features help Honeywell protect both its intellectual property and that of its suppliers and partners.

According to Keith Zobot, Senior Manager, Integrated Design Systems, Honeywell achieved gains in design productivity through spatial management and configuration control. ENOVIA helped them streamline the release and change process lifecycles. It enabled development engineers to work off the same engineering BOM, eliminating inconsistencies and rework. They now have the capability to meet the aggressive engine program milestones using a multi-PDM synchronization program with their risk-sharing partners.

"As we look forward," Zobot continued, "we will continue to leverage the collaborative capabilities of ENOVIA lifecycle tools throughout the product delivery process with our customers, partners, and suppliers.

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Conclusion

Product lifecycle management (PLM) solutions evolved from the need to support designers and engineers in their quest to develop new, innovative products. Of course, supporting the extended enterprise is important. However, providing in-depth support for the product development process will most empower your technical staff to achieve true concurrent engineering, helping them design and build innovative products quickly and efficiently. Your chosen solutions must understand the knowledge embedded in your product data so that you can leverage that knowledge for the good of the enterprise.

Dassault Systèmes developed the V5 architecture to help engineers and designers bring this knowledge to life in their designs created with CATIA and other authoring tools. ENOVIA is the only PLM solution provider that can harness the power of the V5 architecture to help your organization leverage your intellectual assets to maximize their value in the marketplace.

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Companies discussed in this document: Honeywell, Embraer, and Renault, are referenced with their permission.

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