Immersive Product Development

"An Evolving Product Development Approach that Maximizes Productivity and Leverages Knowledge"

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An Evolving Product Development Approach that Maximizes Productivity and Leverages Knowledge

Product design processes had not evolved significantly since the introduction of parametric design concepts in the late 1980s, but today, new and expanded capabilities to support product design are rapidly advancing so that designs can be developed much more quickly and to higher quality. This paper introduces some of these new concepts and capabilities.

It has been common practice for product designs to be developed in a highly iterative manner in which individual parts are designed, analyzed, assembled, checked, redesigned, etc., and only then added into the entire product context. This lack of visibility inevitably leads to product developers not understanding, until late in the design process, what is being developed and modified by other product developers. Designing in the context of complex products (see Figure 1) has been limited to a fairly simplified form of reusing data, mostly dimensions, from one part in the creation of another. While direct references of data, including non-geometric data, from part to part has been possible, this capability has not been fully adopted by many designers because of limitations with determining how a design was originally executed and difficulty discovering what issues might ripple throughout the product definition when a particular piece of data was modified. This lack of contextual product design resulted because the practices previously stated could lead to designs that are very difficult for someone other than the original designer to modify so some product development companies avoid the practices as a matter of policy. Tools have not been readily available that make it easy to completely develop whole, complex products (e.g., assemblies of assemblies including electronic, software, and mechanical components) within a context that allows designers to analyze, evaluate, and validate that their products are complete and operate in conformance to the product's specifications. Many individual capabilities have been available for some time, but typically not in a comprehensive, integrated product development environment.

Immersive Product Development (IPD) is an environment that supports a systems and process based approach to product development. In this approach, the complete systems view defines the product within its environment. This provides a much more holistic method for product development than the common component view of products often employed today. IPD is an evolving methodology combined with highly integrated supporting technologies that address the needs of complete product development. IPD must be deployed within highly integrated PLM environments that leverage tightly-coupled and synergistic solutions provided by data management, knowledge management, workflow and process management, computer-aided design, analysis and simulation, project management, visualization, collaboration, and other capabilities to support an extended enterprise's product development environment from concept through product end of life.

Since companies have been somewhat successful in developing new products in the past, the need for a concept like IPD may not be obvious. However, "An

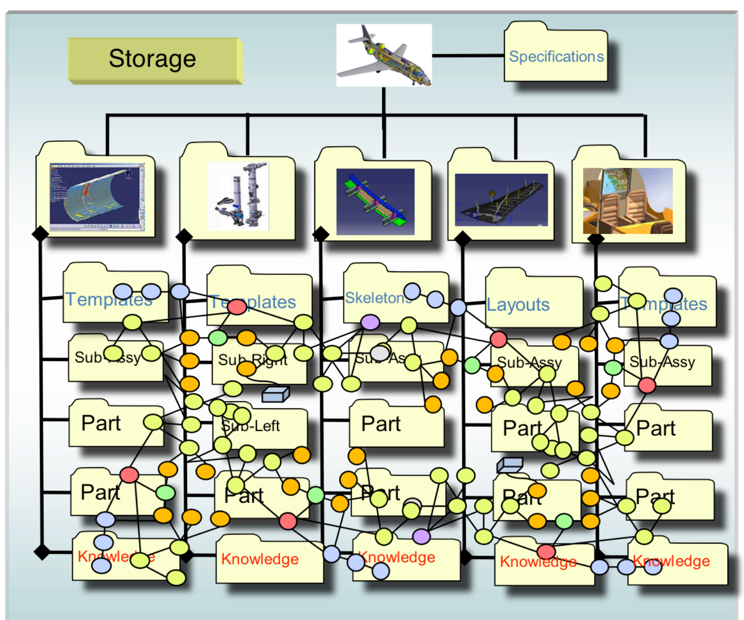

Figure 1—Product Definition Complexity Continues to Increase with Interrelationships Extending Well Beyond Geometric Models

estimated 46 percent of all the resources allocated to product development and commercialization by U.S. firms is spent on products that are cancelled or fail to yield an adequate financial return."[1] Clearly, as innovation becomes more important to expanding companies' market shares and revenues, the product definition environment has to be more responsive to rapid iteration cycles and changes. It must provide support for more highly integrated, but distributed, design teams working in a collaborative environment. A recent survey by Boston Consulting Group shows that for 90 percent of manufacturing executives "…generating organic growth through innovation is essential for success." As globalization continues to take place, innovation for many companies has become a truly global activity. Thus, the need to support a network of innovation becomes critical for successful companies.

In addition, many companies face a "brain drain" as older knowledge workers retire and take their experience away with them. The only proven way to not lose the acquired knowledge of the people in an organization is to capture that knowledge through cross-training (e.g., in collaborative product development sessions) or by institutionalizing the knowledge by embedding it into the processes and technologies used to support product development (see Figure 2), or a combination of both. IPD can support all of these scenarios.

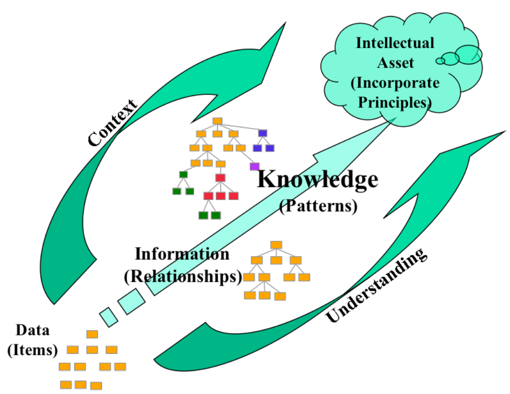

Figure 2—Knowledge Builds from Data, Context, and Understanding
(Adapted from Knowledge Management by Gene Bellinger, www.systems-thinking.org/kmgmt/kmgmt.htm, 2004)

This paper provides a high-level overview of the capabilities found in today's evolving Immersive Product Development environments as offered by the three leading comprehensive PLM solution providers: namely IBM/Dassault Systèmes, PTC, and UGS.

For IPD to be successful, it needs to embody three primary concepts. First, a tightly integrated, managed, and shared data environment that contains all of the information required to define a product. Second, an integrated set of product development processes across disciplines (e.g., design, analysis, test, manufacturing, services, etc.) that support the extended enterprise (including partners, suppliers, and customers) throughout the lifecycle of a product. Third, a set of technologies that support working in a distributed, but collaborative, product development process.

Solutions, technologies, and associated process-enabling capabilities that are **essential** to IPD include:

- Data and Process Management—Management of the IPD processes and the information used in IPD and its related processes makes these readily available to all people involved in an extended enterprise's product development processes. It also maintains versions and variations of data and synchronizes updates to information throughout the enterprise and supply chains and allows workers to navigate through variations of product information. Especially important is data management at a lower level than part items to include management of intra- and inter-part relationships, features, etc. This area also includes other important capabilities such as data visibility and traceability, managing data at the specification level, managing clash analysis and reconciliation, and evaluating the impact of changes to all product information as it is used within a product or across multiple products.
- Design in Context—Parts are designed in 3D within the context of the product's environment and as a complete assembly while referencing data from other parts of its assembly as well as mating assemblies. Associativity supports automated updates to reconcile data changes that affect multiple related parts and assemblies. Parts and components from multiple design (e.g., CAD) solutions, either in native CAD format or a viewable format, can be combined into a unified design.
- Relational Design—A relational environment allows designs to be related to and driven by many types of product definition information, both physical (e.g., dimensions, analysis results, mass, etc.) and attribute (e.g., manufacturer, weight, cost, color, etc.). Relationships may apply within features and within

[1] Robert G. Cooper, Product Leadership, pathways to Profitable Innovation, 2nd Ed., Perseus, NY, 2005, pp 17, 18.

parts and between parts or features of the same assembly or other assemblies within a product configuration. Impact analysis is critical so that precisely what is affected by a change to any relational or parametric data element can be quickly and reliably determined, including impacts on other products.
- Collaborative Development—Provides support for product development teams to work collaboratively together through shared data access, shared development processes, and, possibly, shared work sessions, regardless of the team members' geographic locations or organizational affiliations (e.g., suppliers and customers), to create virtual configurations of products. Both synchronous and asynchronous collaboration capabilities support team working among distributed partners (e.g., suppliers) in the development process. Data is managed to support collaborative sharing and "global" information access.
- Mechatronics—Integrated mechanical, electrical, and software development requires integrating data for a product into a total design that can be used to validate system level interactions among these three domains that make up a product. Routed systems design (e.g., wiring, hydraulics) is also part of fully defined mechatronics systems.
- Virtual Testing and Simulation—Various types of digital analysis and simulation (virtual testing) are integrated into the product development process, including digital mockup, visualization, and multi-discipline analysis. These support overall product validation.
- Product Production—Supports the use of integrated Product and Manufacturing Information (PMI) and other product definition information to drive the production planning, NC, and other manufacturing processes, closing the gap between design and production.
- Knowledge Management and Information Reuse—Reusable components such as previous products, product parts and features, engineering calculations, specifications and other textual data, design rules, analysis results, manufacturing processes, best practices, accumulated experience, and other information helps leverage past experiences, avoid past failures, and streamline the product development processes. Knowledge reuse software provides both knowledge capture and its application to streamline all phases of product development through the use of wizards, rules, knowledge databases, and optimization capabilities.
- Process Change—Product development processes will need to evolve so that they encourage the use of and support the activities required for IPD.

Within these capabilities there are a number of additional precepts that are required to support a complete IPD environment. Some of these are:

- Process method templates—Templates allow organizations to control processes better, to streamline processes for specific types of products, and to embed knowledge into their product development processes.
- Feedback loops—Provide essential interaction among product development processes (e.g., between design and analysis) to facilitate collaborative work, reduce data reentry, and reduce development time.
- Data reuse—Provide standard data formats across processes and technologies to promote data reuse (decrease data redevelopment), decrease data translation errors, and improve the accuracy of data throughout the product development process. However, data from multiple CAD environments must also be supported, especially for larger enterprises and companies in supply chains.
- Multiple data representations—Within the standard data formats, managed variations of the data (e.g., simplified representations) support activities such as analysis and visualization where the data needs to be modified to support specific processes.

Benefits of IPD

A number of business benefits accrue from the use of an IPD methodology. Foremost among these is streamlining the entire product development process from conception, through manufacturing and service, to product retirement. Within the broader context of product development there are many component benefits. Some of these are:

- Reduce product development iteration time thus either allowing more iterations early in the product development cycle when they are less expensive or reducing the number of iterations, e.g., "doing it right the first time," by leveraging product knowledge throughout the product development process and sharing design information more broadly.
- Decrease the time it takes to design complex products through the use of an integrated

product development process, supporting tool set, and integrated and controlled data environment.

- Achieve early detection and resolution of interferences and operational issues by leveraging design data with all players in the product development and aligning designs to operational issues early in a collaborative product development process.
- Reduce the cost of correcting errors during the design process, and more importantly, during production by validating designs through digital mockup, simulation, and requirements validation early in the product development process.
- Improve ability to consistently maintain compliance through simulation and validation of processes and product designs.
- Reduce change propagation impacts from cascading engineering changes by reducing the number of errors that cause changes, resolving changes earlier, being able to evaluate the impacts of changes, and by validating that designs match requirements.
- Reduce the number of physical prototypes and tests by using more virtual product definition validations and digital mockups.
- Meet schedules and delivery dates through a more controlled product development process that converges more rapidly to a valid design that meets requirements.
- Reduce manufacturing and tooling costs through the use of correct, stable product definitions during manufacturing engineering.
- Deliver products to market more quickly by reducing change cycles and product development cycles.
- Create products that meet or exceed customer needs through improved quality and product designs that are validated against requirements.
- Achieve project and program business goals more effectively by streamlining the overall product development process and reusing previously developed knowledge and experiences.
- Support global operations through a collaborative design process in an environment that protects intellectual property.

Leading IPD Solutions

As mentioned above, three companies currently offer solutions that are capable of supporting many of the requirements of IPD. These three provide a broad set of integrated PLM solutions from CAD through digital manufacturing with essential support from product data management tools. These three vendors also have large suites of additional capabilities that are provided by third-party developers and, while they may be applicable to IPD, are not considered in this description. Their solutions are outlined below.

IBM and Dassault Systèmes:

Their IPD solution is based on three groups of components: PLM technologies from Dassault Systèmes include CATIA V5 (for product authoring, including Knowledgeware and engineering analysis), ENOVIA V5 VPM (with VPM Navigator and DMU for collaboration, visualization, optimization, and validation), and DELMIA (for digital manufacturing); middleware from IBM (Websphere, WBI Server, technology adapters, etc.) and a set of methodologies for the application of these technologies within a process-oriented framework to support product developments. They call this Relational Product Development (RPD). RPD is used to help customers create product solutions specific to their industry and business situations. Frameworks for automotive and aerospace have been developed in RPD. RPD is currently in various stages of deployment at a number of customers.

The RPD method embodies many of the requirements for supporting an IPD environment from concept through manufacturing. IBM uses a PLM capability benchmark methodology to help determine how companies should approach RPD as illustrated in Figure 3. RPD is implemented by IBM services in a phased approach that assures the methodology fits the organization's needs and supports its ongoing operations. Typical phases include:

- Education and evaluation through executive workshops
- Capability and needs assessment
- Strategy roadmap
- Technology roadmap
- Implementation and training

Central to the RPD approach is that product designs should include all aspects of the product definition from requirements to operating instructions. This strategy does not limit people to defining only the geometric model of products, but captures essential manufacturing and operational information as well. ENOVIA LCA (Web-enabled ENOVIA V5) provides data management of all of this information. In addition, with access controlled by VPM Navigator and LCA Navigator, ENOVIA V5 supports in-context relational design by managing data related not only to part mod-

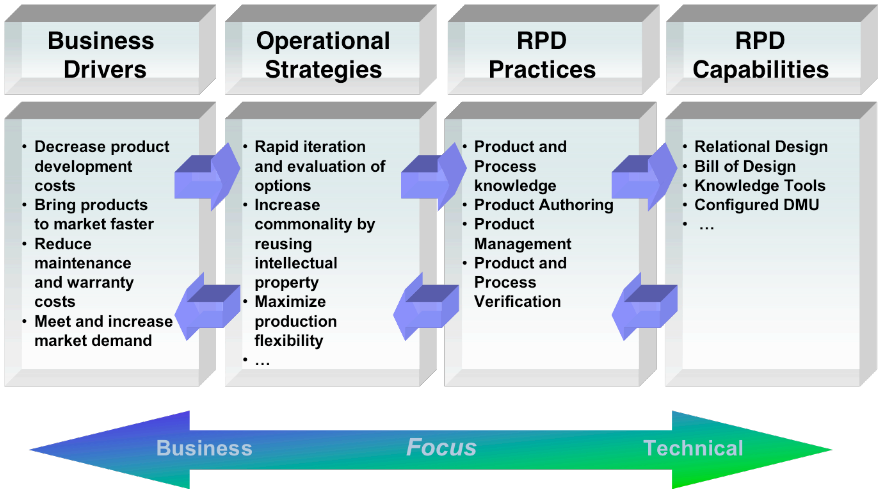

Figure 3—RPD Business Value

els, but also to the feature and attribute level. In ENOVIA V5, the attributes that drive the derivation of a design can be at any level of the product's hierarchy so that a parameter at the assembly level can impact features that are located in many different components of that assembly. This also means that attributes of parts in one assembly can affect parts in related assemblies. Taking this one step further, attributes of the designed product's components can be leveraged throughout the product development process. For instance, data associated with a part can be used to help define how that part is to be treated in analysis or simulation or manufacturing operations. This all provides the ability to design within the configured context of the product.

Knowledgeware integrated into RPD allows designers to capture best practices and provides methods for automating many design tasks so other designers can readily repeat them. Knowledgeware works within the PDM environment to help users to perform impact analyses on and validate their design decisions against best practices. Validation scenarios are created within the Knowledgeware framework and can be applied to many different types of product development information.

Mechatronics is supported through support for combined mechanical component designs from MCAD and ECAD as well as routed systems. Software is not fully integrated into the design today such that the interactions of software controls, electronic components, and mechanical components can be verified. The IBM middleware components allow links to multiple PDM environments to support heterogeneous data sources.

When CAD data other than that from CATIA is brought into the RPD environment it can be inserted into the design environment as an un-featured solid so that its geometry can be referenced and modified. Data from other CAD environments can also be viewed along with CATIA data in VPM Navigator.

A complimentary offering to RPD is PLM Engineering Desktop (PED), which is a Dassault Systèmes initiative that provides templates for various activities within product development such as structural analysis. Solution packages have been developed for automotive and aerospace use. PED supports a number of IPD concepts for companies that exclusively use CATIA V5 as their design tool.

There are a few areas where RPD does not yet completely fulfill all of the concepts of IPD. First, the integration with DELMIA digital manufacturing tools is not yet complete; however, it does support the use of the RPD tools to help identify manufacturing engineering needs. Second, systems engineering is a separate initiative that needs eventually to become part of RPD. Third, ECAD is not yet fully integrated with the mechanical CAD portions of designs. Overall, we give RPD quite high marks for fulfilling many IPD ideals with very good capabilities to validate product developments.

Mr. Mike Bair, vice-president and general manager, 787 Program, Boeing Commercial Aircraft stated, "*The 787 project incorporates numerous technological innovations and represents a major advance in aircraft design. The Dassault Systèmes' PLM solution is not only helping us push the technological envelope, but it will allow us to capitalize on the knowledge and IP assets we are creating during this process.*" This statement clearly recognizes the value of RPD concepts.

Noting the importance of overall support for the product development process, Mr. Arnie Moore, Vice President of Engineering, Northrop Grumman Ship Systems, commented, "*In shipbuilding, all things positive begin with predictable business. We needed new processes and a Product Lifecycle Management (PLM)* *solution to help us minimize costs from the early bidding process to the servicing phase 25 years down the road.*"

PTC:

PTC supports IPD concepts through the integration of its PLM technologies, in particular Pro/ENGINEER (for CAD/CAM/CAE), Windchill (for content and process management, including collaboration), Arbortext (for dynamic authoring and publication of technical documents), ProductView (for interactive visualization), and Mathcad (for authoring and documenting engineering calculations). PTC calls their IPD initiative Product Development System (PDS).

PTC uses an extensive set of process maturity models to assess the readiness of a company to undertake various stages of PDS implementation and to help plan for how their solution transition should take place within their process framework (Figure 4). The maturity models are based on data from a substantial number of PTC customers.

Data management, via Windchill, is integrated throughout the PDS environment from products to components to parts to features to parameters and attributes. All levels of items can be managed and shared throughout a product development team. A "Sandbox" supports work with partners within PDS without requiring formal control restrictions that are typically part of a design process. Configurations of the design including baselines and revisions are managed.

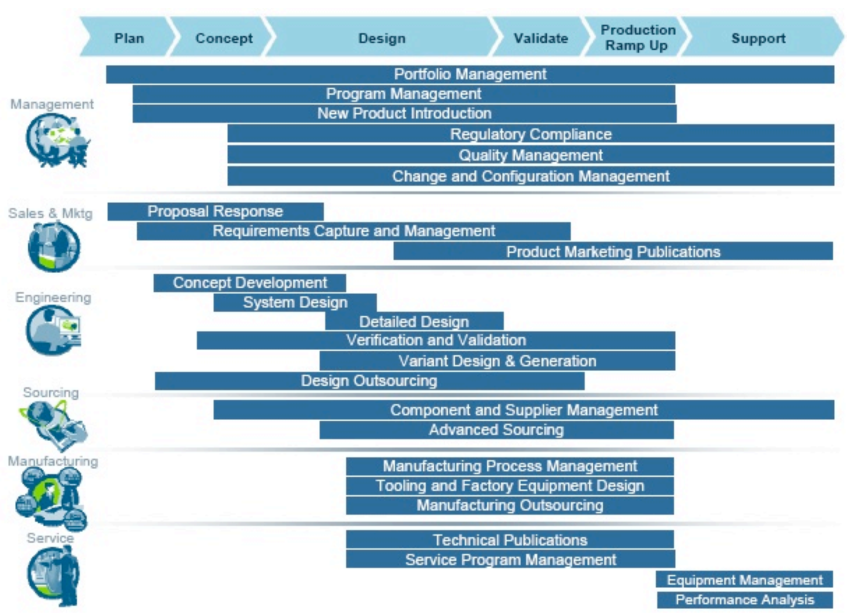

Figure 4—The PDS Process Framework

Within processes, wizards help users step through various tasks and can be modified as needed. Models contain embedded drawing, PMI, and assembly information in addition to geometry and other attributes. PDS uses a top-down modeling process within this managed environment to assure that the process remains under control and to support the flow of data from one process to others. However, users need to be using either Pro/INTRALINK 8 or PDMLink to access the full capabilities of PDS; notably design collaboration.

Requirements (handled via DOORS integration) can be linked to components and parts so they are available to be validated against the product design.

Integrated physics-based simulations are used to validate the physical product. The managed test environment can be used to drive and store data for both physical and virtual tests. As-tested configurations are maintained so users can go back to any previous test. Validation is also supported by visualization and digital mockup tools for MCAD data.

Validation criteria are tied to project plans which can be automatically executed (based on workflows). Third-party analysis tools can be integrated via APIs. In addition, knowledge reuse software, called Behavioral Modeling, is well integrated with Pro/ENGINEER and allows users to program repeated tasks, but does require engineers to have some familiarity with programming concepts.

Mechatronics support includes data from mechanical, electrical, software (via a Clearcase integration), routed systems and design documentation all within a configured environment. EBOMs can be reconfigured into MBOMs so that complete product BOMs can be transferred into ERP applications. Software is not fully integrated into the design today such that the interactions of software controls, electronic components, and mechanical components can be verified.

Technical publications support is provided by the Arbortext products (which are now integrated with the other PDS capabilities) and superior to the offerings of the other vendors. The capabilities in this part of the PTC product suite extend well beyond document templates to include generation of compound documents with reusable components and embedded 3D content. Multiple formats (e.g., PDF, print, web, drawing) of output are generated automatically from multiple sources of data including CAD and other databases. Publications are managed as part of product configurations.

A Web-based project portal provides support for supply chains and includes an integrated 3D visualization package. Outsourced design is also supported by built-in, real time design collaboration in which multiple collaborative meeting attendees can modify CAD models if they have Pro/ENGINEER.

PTC's support for digital manufacturing is in a very early stage and limited to supporting process planning, resource plans, work instructions, CAM, CMM, and tooling designs. Polyplan supports process planning, resource planning, and work instructions. Integration of Polyplan into PDS is planned for a future release.

Requirements are managed only via integration to DOORS, a third-party tool. Thus, the validation of requirements against the product definition is not fluid as it could be with an internal requirements management capability.

Currently, ECAD Workgroup Managers provide integration of ECAD data through the InterComm visualization engine. Unfortunately, InterComm is not capable of concurrently viewing mechanical design data as well as electrical data, nor is ProductView (the mechanical design viewer) capable of viewing ECAD data. Therefore, examining mechatronics assemblies is rather difficult in PDS today. Combined mechanical and electrical viewing is planned for the future.

PTC's current IPD solution is fairly broad with many high points. Areas for improvement are to better integrate all parts of the solution set, especially the Polyplan manufacturing planning capabilities and requirements management. Polyplan has fewer digital manufacturing capabilities than the other vendors' solutions, but this is by design and users should look at third-party solutions to add capabilities in this area. In addition, PTC needs a more robust validation capability that extends beyond test planning and execution (which are very well supported) to also look at multi-discipline impacts across all aspects of the product design.

"*The PTC PDS maps to our corporate goals of increased innovation, operational excellence and global collaboration,*" commented Barry Libenson, chief information officer, Ingersoll Rand. "*The single unified PDS architecture simplifies product development while also providing the power and scalability to support our continued growth.*"

"*PTC Pro/ENGINEER has added a lot of value to our development efforts by reducing the development time for our different racing cars for many years now. ... Windchill PDMLink proved to be tremendously helpful to better manage our product development data. Providing collaborative access to data and product structures, it allowed the teams to work in parallel and save valuable time in the development process,*" said Dr. Wolfgang Ullrich, head of the sports and special developments division at Audi.

UGS:

A recent initiative called Knowledge Driven Digital Product Development (DPD) is based on UGS' NX CAD (for data authoring and analysis), Teamcenter Engineering (data and process management), NX Knowledge Fusion (knowledge reuse software), engineering analysis, Tecnomatix digital manufacturing, visualization and digital mockup (PLM Vis), and other

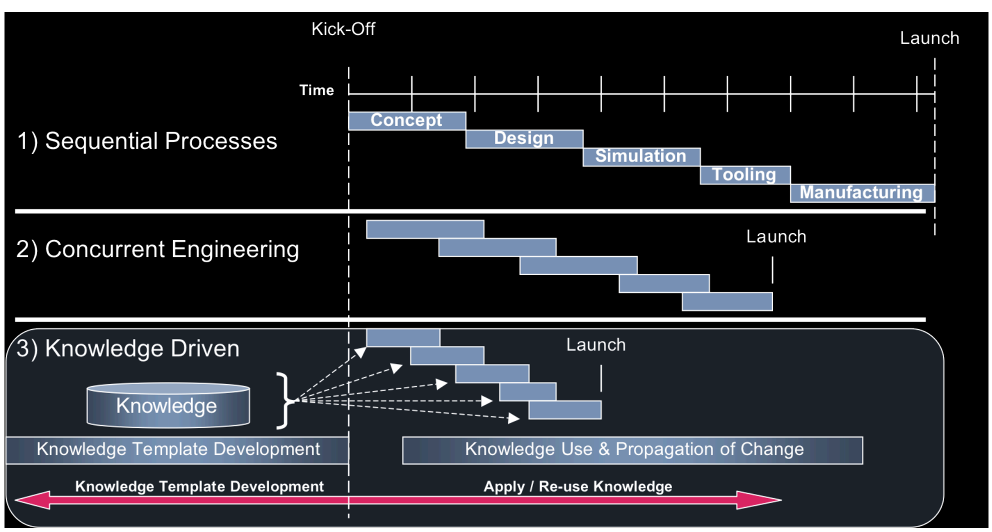

Figure 5—Impacts of Knowledge Driven DPD

technologies. Most of the capabilities represented in these are managed within the Teamcenter environment that coordinates the overall Knowledge Drive DPD activities. The use of a knowledge-driven approach can lead to substantial reductions in product development duration as illustrated below.

UGS' IPD solution is based on a managed knowledge environment that supports best practices, parts reuse, reusing historical data, reuse of processes, and reuse of other types of data. Designs contain embedded drawing, PMI, and assembly information. Manufacturing information is stored with the design at the feature level. Features are managed as well as parts, components and products. All of these elements can be shared among product developers and across products. Teamcenter is the management and workflow control engine. Roles based workflows and workflow driven design operations reduce complexity in this environment. A capability called Process Studio captures best practices and previous knowledge through a visual workflow process that captures by example, as users develop a product. These can then be used on future products. Rules-driven design templates help drive valid design processes and can be modified by users to adapt them to new processes. Engineering rules can be embedded directly in the product definition and are validated continuously throughout the design process. Design parameters can be associated with measurements taken from other components as well as with formulas.

Tecnomatix provides a broad set of capabilities supporting most aspects of digital manufacturing. These products are integrated into UGS's IPD suite through Teamcenter such that they can share data with the other product development capabilities (e.g., CAD, requirements management, validation, etc.) and be used to validate manufacturability during design and change processes.

UGS NX family of products (CAD, PDM, CAM, digital manufacturing, analysis, etc.) provides a common API throughout to facilitate integration with third-party products that support a company's product development process.

Validation of engineering rules, requirements, and manufacturability (limited to plastic parts, castings, and automotive dies and their tooling today) supports what-if analysis of alternative designs. Validation is carried out on the fly during design, and can be driven by workflows. The visualization and DMU tools support evaluations of a large number of MCAD formats. DMU includes interference detection as well as mechanism analysis.

A specialized tool manages requirements that are linked to the design information so that their proper incorporation into the design can be validated. In addition, UGS provides a very complete suite of engineering analysis tools that can be used to validate the physical product. Tolerance analysis can be performed on parts and assemblies.

Mechatronics is supported with routed systems, flexible PC boards, and mechanical data from multiple MCAD and ECAD sources. Software is not fully integrated into the design today such that the interactions of software controls, electronic components, and mechanical components can be verified.

3D documentation including PMI, tolerances, and dimensions is provided within document designs without producing drawings.

ECAD is not integrated with MCAD beyond being able to load boards and component height information so mechatronics evaluations are not as valuable as they could be.

"*An important side effect is that design and the traditional analysis grow closer together and a mutual understanding is fostered*," OPEL AG, Germany.

"*Security DBS is not only able to work faster, but also has the ability to improve processes and increase quality by making knowledge available to the organization*," Ides De Vos, Security DBS.

Overall, UGS's IPD capabilities are broad and fairly complete. UGS provides very good integration of third-party CAD data. Their solution is broad and well integrated today, although integration will continue for some time. They have an established program to resolve their issues with ECAD integration to support mechatronics.

Summary

IPD embodies a new, more productive direction within the broader PLM space. It provides major advantages over previous product development initiatives and will help companies create higher quality products that, in the first instance meet customer needs. It will also streamline and speed up the creation of those products. Three of the major PLM vendors have embraced this concept, with IBM and Dassault Systèmes leading the charge with a well conceived program and a methodology to help companies understand how to take advantage of IPD's value. However, PTC and UGS have good technologies as well and clearly embrace IPD as a value for their clients.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of PLM. CIMdata works with both industrial organizations and suppliers of technologies and services seeking competitive advantage in the global economy by providing world-class knowledge, expertise, and best-practice methods on PLM solutions.

CIMdata helps industrial organizations establish effective PLM strategies, identify requirements, and select PLM technologies, optimize their operational structure and processes to implement solutions, and deploy these solutions.

For PLM solution suppliers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through international conferences in North America, Europe, and the Pacific region.

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