

## From Engineering Information Management (EIM) to Product Lifecycle Management (PLM)

This Special Issue is dedicated to the memory of Dr. Robert Fulton, Professor of Mechanical Engineering at Georgia Tech and the founder of the Engineering Information Management Committee of the ASME CIE Division.

The field of *engineering information and product lifecycle management* (PLM) takes a systems perspective to facilitate the efficient use, dissemination, creation and change of product related information through representations that efficiently capture engineering semantics. This semantics-oriented approach to product representation is important to the optimization of business processes and system integrations spanning multiple phases of the product lifecycle. Over the years we have witnessed leaps in task automation through advances in CAD, CAM, CAE, and practices such as DFM and related concurrent engineering approaches (DFX). However, product development organizations now see task automation as a local optimization, and are looking to PLM as the systemic infrastructure to achieve product excellence and realize business goals. Concomitantly, analysts, vendors, system integrators and researchers have been pursuing this area with significant investment.

Early advances in engineering database management (circa 1980s) dealt with building databases to support relatively static elements such as materials databases, catalog parts, and databases to support standards-based schemas. These initial engineering databases facilitated sharing and data exchange. In the early 1990s, this evolved into information management for design processes, and we saw product data management (PDM) tools and technologies to support collaboration and process automation—such as vaulting (archiving) of design files and workflow to route these files for approval, release, and change management. This evolution towards process automation enabled workgroup collaboration, but many industry implementations limited themselves to organizational silos. Starting from the mid-90s, early industry adopters began employing finer grain representations to facilitate intelligent handling of design processes—streamlining tasks such as platform management for mass customization, change impact analysis, distributed design and manufacturing operations, and configuration management, often across business process silos. The current emphasis in product lifecycle management (PLM) adopts a more holistic perspective that ties information management and system integration with business strategy, thereby exploring system effects across the full product realization process.

In the mid-1980s, ASME had the foresight to launch the Engineering Database Program [under the leadership of Prof. Robert (Bob) E. Fulton from the Georgia Institute of Technology] to address the broader scope of information in product development organizations, and today the CIE Division, through the Enterprise Information Management committee, continues to contribute significantly to this multi-disciplinary area of research and practice. In recognition of his contributions to the field, we would like to take this opportunity to dedicate this Special Issue to the memory of Dr. Bob Fulton who passed away in February 2004. Bob was instrumental in ASME's thrust into the field of Engineering Infor-

mation Management and PLM, and graduated several Ph.D. and M.S. level students who are currently active researchers and practitioners in the field. In his final days, Bob was actively working towards establishing a PLM Center at Georgia Tech, and responded to our call for papers with: "A special issue publication is certainly in order now!"

This special issue brings together an excellent array of application and research papers that address the many facets of PLM.

In a paper on Collaborative Product Development (CPD), T. Wu, N. Xie, and J. Blackhurst review existing research related to CPD and focus on developing a suitable information/knowledge-sharing platform as the basis for distributed decision support relative to CPD processes such as design negotiation. The suitability of different distributed information frameworks is assessed relative to CPD requirements. The authors go on to propose an information framework termed VE4PD to manage the CPD process across the product lifecycle. A prototype implementation is used to assess different operating scenarios and underscores the benefits of this framework through its ability to automate the synchronization process between the client and server, thereby facilitate collaborative processes.

Enterprise application integration (EAI) is addressed in the paper by T. Madhusudan through an approach based on an intelligent mediator-based framework. In this framework, Web Services are used to expose intraorganizational information sources. A domain-specific ontology is used to standardize data and methods with organization and industry-specific semantics. An artificial intelligence planning mechanism, known as Hierarchical Task Network planning, is used to dynamically compose processes into a service plan for responding to service requests, where dynamic processes integrate information gathering with transactional activities. Well-defined mapping rules are used to transform a declarative service plan into an execution sequence. The mediator-based framework described in this paper is capable of flexible integration at the knowledge level and at the implementation architecture level, facilitating knowledge reuse and providing an incremental approach to application integration based on product life cycle management.

Addressing PLM for Performance Management, D. Pham, S. Dimov, R. Setchi, B. Peat, A. Soroka, E. Brousseau, A. Huneiti, N. Lagos, A. Noyvirt, C. Pasantonopoulos, and D. Tsaneva target the in-service phase of the product lifecycle with use cases to address business processes related to in-service and product support. The authors explore the product support lifecycle phase and introduce key relationships between business objects related to product definition and the technical support documentation, both of which exhibit hierarchical structures that relate to each other reflecting the interactions between product designers and support engineers. The authors introduce data retrieval and navigation use cases based on observations involving actors performing product support scenarios, and describe prototype system implementations using knowledge based technologies.

C. Romanowski and R. Nagi address the use of data mining for

the creation of generic bills of materials (GBOMs) in variant design. Given that numerous bills of materials (BOMs) can complicate the reuse of a BOM design in a new design activity, the results presented in this paper describe an approach for unifying similar BOM designs into a single entity. Text and tree mining are used for generalizing information about parts and subassemblies. A new tree union algorithm is also presented for unifying similar BOM trees into GBOMs. Association mining is used to extract design and configuration rules from a BOM. The paper describes the manner in which the resulting GBOM design is represented using constrained XML. The paper also illustrates how data mining can be used to reduce the search space for retrieving past designs and to aid in the configuration of new variant designs.

The paper by C. McMahon, A. Lowe, S. Culley, M. Corderoy, R. Crossland, T. Shah, and D. Stewart describes a system known as Waypoint, which provides an integrated search and retrieval system for engineering information. Initially developed as a university/industry cooperative research project in the aerospace industry, Waypoint is now a commercial system used in engineering environments to organize and access documents that are needed by engineers in various stages of the design process. Waypoint provides uniform access to multiple information collections, such as product data management systems and company intranets, supporting keyword searches and browsing of classification schemes. The browsing interface provides feedback to users about how to refine the results of a search. The system also provides a feature for the automatic classification of documents according to a predefined classification schema. The paper describes the architecture of Waypoint, with a specific focus on the faceted classification scheme that forms the basis of the system.

In step with commercial CAD systems' ability to capture design intent, M. Pratt introduces recent developments in STEP's ability to exchange parametrization and constraints, which allow explicit geometric models to be modified following data exchange between systems. The new resource schema, ISO 10303-108, designed to be upward compatible with existing standards, is presented in detail, along with its relationship to existing STEP parts, and emerging parts needed to implement these concepts. The exchange of rich parameters and constraints in CAD models adds considerable semantic richness across data exchange transactions and may be applied to 2D sketches, interfeature relationships and interpart relationships in 3D assembly models.

In a Technical Note describing an information integration framework for PLM, H. Morris, S. Lee, E. Shan, and S. Zang present a federation architecture that aggregates information and services user requests from multiple PLM and PDM systems distributed over the network. Using typical use cases from the automotive and aerospace industry, the authors discuss the details of HEDWIG, a real-world IT solution developed as a proof-of-concept system. Using commercial application components and middleware, the authors present key design considerations including details of the federation architecture, connector design to ensure insulation from PLM system changes, the use of a Content Management system for intermediate data management and the management of relationships between PLM domain objects such as a bill-of-material structure. Industry specific use cases and lessons learned from the HEDWIG project are detailed along with a list of issues that must be addressed for additional robustness and overall performance.

H. Lockett, P. Bartholomew, and J. Gallop report on data management considerations relative to the capture and exchange of product and analysis data in an integrated aircraft analysis environment for multi-disciplinary optimization. Part of a EU Framework V funded project, this effort required the integration of many analysis tools developed and deployed across multiple countries.

In their implementation, a Computational Design Engine provides a platform for a range of numerical simulation and design tools employed to create an effective design for Blended Wing-Body (BWB) aircraft. Two standards-based product database approaches were investigated: one using a project-specific EXPRESS schema, and, the second using a generic approach based upon the STEP PDM Schema. The authors conclude with a discussion of the pros and cons of each approach relative to the analysis/optimization domain.

K. Kao, C. Seeley, S. Yin, R. Kolonay T. Rus, and M. Paradis introduce various enabling technologies required for real-time design/analysis collaboration across company boundaries, and demonstrate its application in the design of a combustor subsystem of an aircraft engine. Using an intelligent master model to capture product data semantics, OGM's CAD Services as an application interface, FIPER as their collaborative infrastructure and standard Internet and Web protocols, the authors present a case study where GE establishes the nozzle definition in the form of key interfaces, and envelopes before delegating the nozzle design and vibration/clearance analysis activities to Parker Hannifin. Following the nozzle design, GE assumes aerodynamics analysis within the overall engine context. Results include improvements in product quality and performance and reduction in design cycle times. To realize the full potential of such solutions, the authors argue that such tools should be used in conjunction with well-defined business processes with clear responsibilities and hand-off practices.

M. Jennings and R. Rangan provide an application brief that describes a model-management system for vehicle system simulation piloted at Ford Motor Company. Model-based prototypes can reduce the time and cost associated with the creation of physical prototypes. This paper presents a case study in which a model management system was used to support collaboration and model reuse in the context of product architectures. Using a generic model structure, subsystem models are produced with reduced development time. The generic model structure also facilitates model sharing with suppliers, which increases the benefit of model-based simulation in the vehicle product development process. The paper also describes important lessons learned from the pilot study with respect to organizational and user support and also with respect to the use of reference models versus instance models in the repository data model.

In a Technology Review on STEP, XML, and UML, J. Lubell, R. Peak, V. Srinivasan, and S. Waterbury discuss how we can effectively leverage these complementary technologies and benefit from the vast investments made in STEP and its rich set of product models, through XML toolkits and UML techniques for modeling and analysis. The authors argue that the STEP community's synergistic efforts to generate XML schemas and datasets, and UML models from EXPRESS schemas, will preserve and proliferate the adoption of STEP, given the popularity of XML and UML. The interoperability between these technologies leads to interesting application architectures, and the authors offer ideas on how to make sense out of the seeming similarities and unique perspective offered by each of these technologies.

We would like to thank the many anonymous reviewers who worked hard to meet our demands on their time. Without their help, this special issue would most certainly not be where it is today.

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