

PLM for Mechatronic Products

The success of PLM adoption in conventional mechanical product manufacturing industries gave inspiration to the PLM product vendors to focus on the combined electrical, electronics, mechanical and software product development, also known as, Mechatronics, which is a bigger challenge in the integrated product development scenario.

Typical mechatronic product development involves managing both hardware and software at various phases such as chip design with hardware specific language, Printed Circuit Board (PCB) layout design, mechanical and electrical design and software development. Usually this involves multiple environments which require synchronization at predetermined stages.

Major challenge is to integrate the life cycles of these different domains. Since these life cycle behavior are independent today including the systems which handle and support the life cycle management, it becomes a challenge to obtain an integrated product view and to manage the dynamics of changes across these domains. While there are changes to the design both at hardware and software level, lack of integrated PLM causes delay and also increases cost of the final product design.

Following are some of the other challenges:

- Keeping in sync with the different ECAD and MCAD systems.
- Maintaining short product cycles.
- Managing more variants.
- Utilizing manual prototyping methods which are expensive.
- Configuration management of mechanical, electrical and software product data.
- Managing rich electronic and software contents.

In addition, with the advent of globalization, managing the security and the Intellectual Property Rights (IPRs) from Original Equipment Manufacturers (OEMs) to suppliers, has added to the challenges faced by these industries.

Latest PLM solutions have to address these challenges effectively by giving an integrated secure environment for various work groups such as Electrical / Electronics, Mechanical and Software to simultaneously work on the product. Effective ECAD and MCAD integrations enable reduced use of transfer protocols which avoids the problem of stripping the essential design information during translation, Integrated prototyping in place of existing isolated prototype methods, Flexible work flow model to route the various activities and Effective supplier integration process which empowers the OEM to assign and review the supplier deliverables are the key benefits obtained.

This paper discusses these aspects in detail and suggests a suitable PLM environment to overcome the challenges in this growing field.

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Table of Contents

1. Introduction	3
2. Background	3
3. Current Industry Scenario	4
4. Challenges in Managing Product Data in Mechatronics	5
5. PLM Solution for Mechatronics	6
6. Benefits of an effective PLM Environment for Mechatronics	8
7. Conclusion	9
8. References	9

Introduction

A mechatronic system is defined as the synergistic integration of mechanical, electrical, electronics, and embedded firmware (software) technologies into electromechanical products. Mechatronic systems and subsystems appear across all industries [1], including automotive, aerospace, consumer electronics, machinery, equipment, and others, which are detailed in Table 1.

Product Categorizations	Examples
Electronic products	Cameras and audio equipment
Consumer Appliances	Refrigerators and Washing machines
Vehicle systems (Harnessing and wiring)	Automobiles, Aircraft and Trucks
Communication systems	Satellites, Radar equipment and Telephone switches
Onboard control systems	Aerospace, Marine, Weapons and Space systems
Biomedical instrumentation	MRI, CT scan, and Airport security systems
Office equipment	Computers, Printers, copiers, Fax machines
Industrial machinery and equipment	Turbines, Printing presses, Weapon systems
Large scale transportation equipment	Large aircrafts, Locomotives, Mass transit systems

Table 1. Mechatronic product categorizations

Background

The development of mechatronic products in the past, has been done in separate silos of electrical/electronics, mechanical, and software domain experts. In many cases, mechanical engineering work is completed and then the task is forwarded to the electronic/electrical design engineering group, and then forwarded to the software engineering group. Also the mechanical, electrical, and software features of the product were integrated through rounds of prototyping as shown in Figure 1. Since the disciplines worked in silos with their own individual design processes and non-integrated information system tools, engineers downstream in the development had little opportunity to provide valuable inputs early in the cycle. Hence design deficiencies were often discovered late in the process which resulted in increased cost and time for effecting design changes.

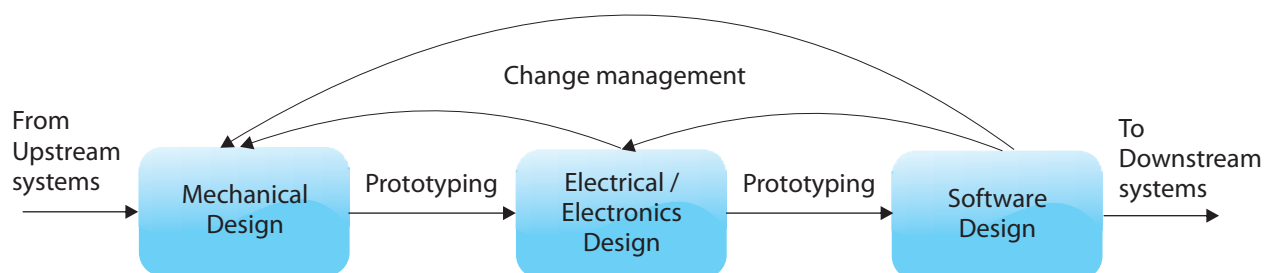


Figure 1. Sequential product development process

For example, PCBs used currently requires a much tighter integration between PCB design and mechanical engineering. Every PCB contains mechanical constraints primarily due to product packaging requirements that constrain the shape, size and position of PCBs. Based on these packaging constraints, the mechanical designer determines the board outline, size and the locations of mounting holes for the board. The mechanical designer also knows where to place certain critical components, such as connectors, displays, and switches, because these locations are determined by the product packaging itself. Often, the mechanical designer indicates areas on the board where components cannot be placed, or where placement is limited by other obstructions in the overall assembly.

On the other hand, the PCB layout designer uses initial information from MCAD as the basis for creating the board layout in ECAD. Often the layout designer adds additional placement and routing restriction areas, tooling holes, pads, and solders masks. With the pre-placed components as a start, the layout designer places additional components. The locations of the pre-placed components may have to be modified to accommodate board routing considerations. Typically, several revisions between MCAD and ECAD are required to stabilize the design, or to accommodate product packaging or functional changes. Due to the limited visibility to product information, respective disciplines will consider it as a fault with other disciplines.

Current Industry Scenario

Higher safety needs and faster serviceability have led to challenging new requirements for stylish, content-rich and price competitive products. In the electromechanical domain, latest product designs incorporate new intelligent mechatronic features with increasing complexity and the use of electronics and software as differentiators in the marketplace.

As depicted in Figure 2, there has been a fundamental shift in replacing the mechanical functions into electronic and software functions which is driving Mechatronics. Customers are demanding variety and options in products, which again is realized using Mechatronics. Competition is another factor which results in increased product features wherein these additional features turn out to be the basic features of the product [2]. The additional features require added electronics, increased embedded software, and smart manufacturing processes to drive the next level of operational efficiency and performance. Thus manufacturers must be ready and committed to continuously innovate in developing new mechatronic products with increasing complexity.

Also new regulations and an increasingly green-conscious customer have resulted in the demand for environment friendly products. Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) regulations in Europe are forcing high-tech manufacturers to rethink designing for product disposal. In automotive industry, fuel efficiency requirements have lead to new innovations in the engine design. This requires a clear communication of environmental requirements and support for unique design configurations according to the customers' location. Figure 2 depicts the various influencing factors for demanding improved electronic and software features in products.

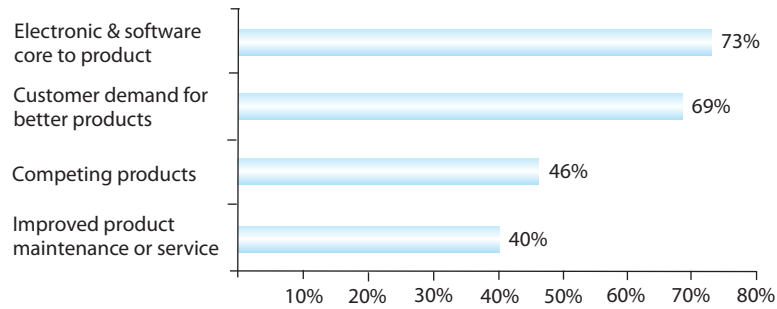


Figure 2. Influencing factors for increased electronics and software contents into products [2]

Challenges in Managing Product Data in Mechatronics

Given the industry scenario, following are some of the challenges [1] faced by manufacturers in the Mechatronics domain:

Lack of Integrated Data management

- There is no single legacy Product Data Management (PDM) system for capturing mechanical, electrical, and software design data, and are often handled in separate PDMs with no automated sharing of data between the systems.

Software Configuration Management

- Many different ECAD and MCAD tools are currently used by OEMs and by their supply chains. Keeping different versions of software in sync and maintaining interfaces is not cost effective.
- Companies are realizing embedded software is an area of competitive differentiation and are investigating on improving and streamlining their software processes. There are no commercially available systems for keeping the software version synchronized with the mechanical and electrical product data.

Difficulty in reducing cost

- Since the PLM solutions for mechatronic product development are still in the evolving stage, many of the manufacturers are patching together homegrown systems that are expensive to develop and maintain.
- Due to the growing number of product variants and increasingly short lifecycles, costs for developing physical prototypes in iterations have become increasingly prohibitive.

Requirement of flexible integration techniques

- Interfacing with an incumbent PDM system requires more flexible application interfaces and data standards.
- Product design with integrated system simulation is yet another challenge.

Supplier Management

- Due to the increased electronic content, traditionally mechanical companies are sourcing the development of PCBs globally. Managing the supply chain and tying to as-shipped product structure is a growing challenge.
- IPRs are increasingly moving to suppliers, rather than OEMs, as the product behavior is moving to software. IP security related threats have to be taken care.

Compliance Management

- Compliance to RoHS and WEEE regulations require tracking of the material specifications right from the design stage. The related processes are still maturing in this area.

PLM Solution for Mechatronics

The futuristic PLM ecosystem for mechatronic development must have the following essential features:

ECAD/MCAD data exchange: It should adopt STEP AP210 and STEP AP212 [1]. STEP is the acronym for Standard for the Exchange of Product Model Data. STEP-AP210 (ISO 10303- 210:2001E) is a part of STEP on Electronic Assembly Interconnect and Packaging Design. STEP AP212 is for electro technical design and installation which enables electro technical exchange in a robust exchange format.

Currently, Intermediate Data Format (IDF) standard is typically used to communicate between MCAD and ECAD. Most MCAD application vendors do not support the IDF file format directly, but rely on third-parties. By implementing the STEP data model with a PDM system using XML schemas, the integration between ECAD and MCAD applications will be simplified. An MCAD and ECAD authoring tool will place design elements into the data model, and this information will be used by both the originating authoring tool for data management, and also other authoring tools for design validation and collaboration.

PLM data integration: To improve new product introduction through integration of mechanical, electrical, and software domains, the product data management (PDM) data model must support STEP standards for electrical and mechanical data, and must support an XML-based standard for robust interchange of data between applications. The core PDM mechatronic requirement is to provide a data model functional enough to represent fine grain level of functional requirement details and physical aspects of the electromechanical products and relationships between these representations. This include electrical and software domains in addition to mechanical.

Essential PLM solution components

In designing mechatronic products, manufacturers adopt a system decomposition approach to define the product. Top-level product systems are divided into subsystems that are further divided into components.

The natural place to bring all of these islands together is the enterprise PLM that maintains not only product Bill of Materials (BOMs), but also the relationships among the components that make up the mechatronic subsystems. In addition, an enterprise PLM already deals with the sophisticated concepts of effectivity, versioning, and configuration that are not completely dealt with by the isolated systems in an integrated way.

The enterprise PLM should essentially have the following components as mentioned in Figure 3.

Requirement Management: The typical mechatronic development process starts with customer requirements for a mechatronic subsystem that eventually flows down into a detailed set of constraining parameters to be met. In the process of flowing down the requirements, designers will allocate requirements to functions to be performed by the system, which in turn is partitioned and allocated to physical elements (mechanical, electrical, and software components) that perform the functions. The result is a set of requirements that flow down to each element that performs the task and act as input specifications for each component.

Document Management: The system should have the complete document repository with traceability right from idea generation for the product throughout the lifecycle of the product. It should have electronic signatures and full text search which will enable searching the contents of documents.

Supplier Management: Suppliers should be able to access through a secured network. Lightweight and secure forms of design collaboration such as design sharing and change notification for communication purposes, especially during design reviews and project status meetings should be used.

Compliance Management: PLM product vendors are offering solution components to achieve materials compliance by way of tracking part level material composition and regulatory compliance to be adhered during product development. For example, 21CFRPart 11 for Food and Medical device industries and ROHS compliance solutions for automotive & other electronic industries address the compliance requirements of mechatronic industries.

Integrated Prototyping Management: The prototype build events should be tightly integrated with engineering change management process and supplier management process to enable monitor impacts due to product changes and supplier quality evaluation process respectively.

Software configuration management: The ability to manage the embedded software can be achieved through PLM integrations with code configuration management applications like ClearCase, PVCS etc which has to be tightly integrated with the hardware lifecycle of the product.

Program Management: The whole product development for a customer has to be treated as one program. It should have phases and deliverables for each phase. Status monitoring and dash board reporting have to be periodically reviewed.

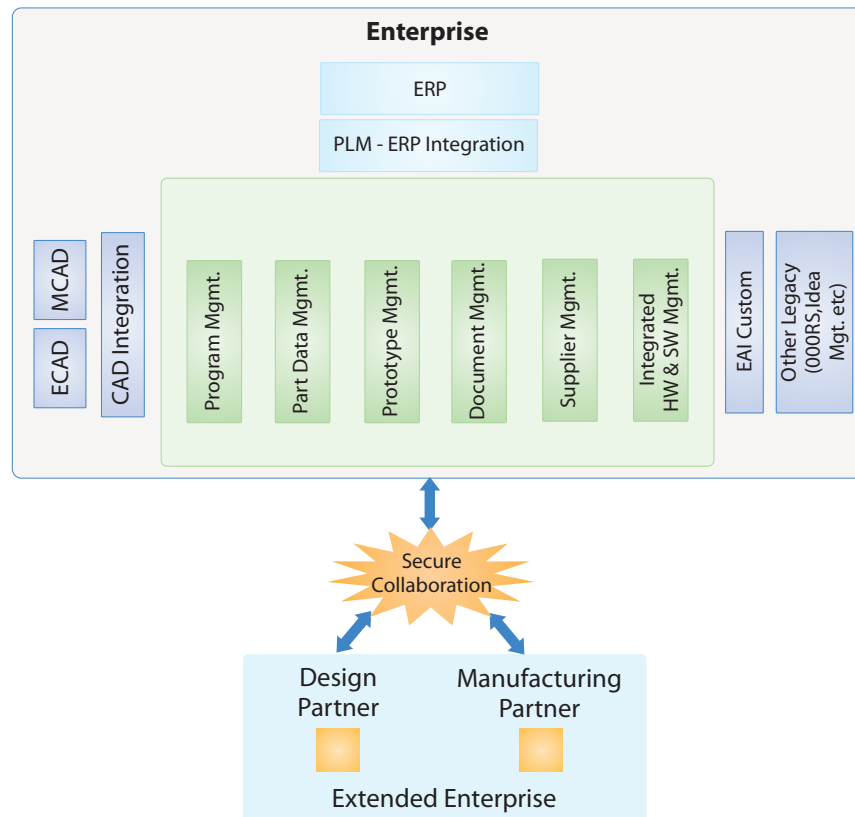


Figure 3. Integrated PLM ecosystem

Idea Management: Considering the development processes of high-tech electronic equipment, the ability to assess the end customer demands through various innovative ideas and capturing them in a system will help the industry to stay ahead of competition.

After market support: Connecting product development processes with service applications also enables design engineers to see which parts and services are being actively deployed in the field and thereby lower future warranty activities and costs through redesign. These capabilities will be highly useful in the development of mass production components, by avoiding product recalls and increased customer satisfaction [3].

Benefits of an effective PLM Environment for Mechatronics

Following are some of the benefits of an effective PLM environment:

Enables postponement: Postponement is a supply chain term. It refers to the practice of postponing the features that are closest to the customer to the last stage of product delivery. The configurable characteristics of the mechatronic product can be easily identified and managed in a better way. Using this, the same product can be delivered at different places by still meeting the local regulatory and end user requirements [4]

Enables avoiding loss of design information: Efficient transfer protocols between MCAD and ECAD applications help in avoiding stripping of design information during translation process.

Limited organizational changes: Challenges in technology integration are substituted by integrated organizational structure across disciplines, which is not a good method for multi disciplinary product development. Industry statistics reveal that discipline specific engineering teams are highly productive than integrated structure teams [5].

Reduces the inventory of different applications software: Companies working with multiple OEMs can reduce their software inventory, since multi CAD and PLM integration will be possible through effective protocol methods.

Reduction in prototyping expenses: Integrated prototyping and system simulation will reduce the cost of prototyping in mechatronic product development.

Enable cost effective globalization: Optimum product development processes with better way of supplier management will enable effective globalization which can be cost effective for the organizations.

Enable compliance to regulations: When there are changes in the regulatory compliance policies or new regulations introduced with respect to product development processes, organizations can easily implement them.

Conclusion

Mechatronic industries exist for a long time, but this industry is growing considerably due to the increasing market requirements. The issues these industries are facing can be well addressed with recommended enterprise PLM ecosystem, which will help the companies to get appreciable benefits when compared to the conventional product development processes.

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