An Introduction and Implementation of PLM in Aviation Industries

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ABSTRACT
In today's challenging global market, enterprises must innovate to survive. Business innovation must occur in all dimensions product, process, and organization to improve competitiveness and business performance.To differentiate themselves, enterprises must capture, manage, and leverage their intellectual assets. This can best be accomplished through proper application of a Product Lifecycle Management (PLM) approach that addresses the needs of the extended enterprise. PLM is a strategic business approach that helps enterprises achieve its business goals of reducing costs, improving quality, and shortening time to market, while innovating its products, services, and business operations.

Modern day enterprises are confronted by challenges arising from continuous innovations, global collaborations, and complex risk management. Intellectual assets in the form of product and process data must be accessible to anyone in the value chain. To address these issues, product lifecycle management (PLM) is proposed in recent years as a business approach integrating people, processes, business systems and information to manage the complete life cycle of a product across enterprises. PLM enables the collaborative creation,management, dissemination, and use of product definition and process operation information across the extended enterprise from market concept to product retirement. As the life span of an aircraft is over 30 years, opportunities abound for the application of PLM in aviation maintenance, repair and overhaul (MRO). Yet, the use of PLM in the support phase is not as widespread in the aviation industry as the design phase. The aim of this paper is to study the opportunities, advantages and caveats of implementing PLM in the aircraft industry.

1. PRODUCT LIFE CYCLE
A new product progresses through a sequence of stages from introduction to growth, maturity, and decline. This sequence is known as the **product life cycle** and is associated with changes in the marketing situation, thus impacting the marketing strategy and the marketing mix.

The product revenue and profits can be plotted as a function of the life-cycle stages as shown in the graph below

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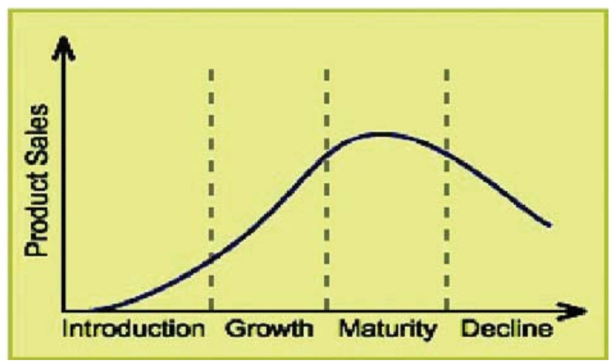

Fig.1 Product life cycle

1.1 Introduction Stage
In the introduction stage, the firm seeks to build product awareness and develop a market for the product.

1.2 Growth Stage
In the growth stage, the firm seeks to build brand preference and increase market share

1.3 Maturity Stage
At maturity, the strong growth in sales diminishes. Competition may appear with similar products. The primary objective at this point is to defend market share while maximizing profit

1.4 Decline Stage
As sales decline, the firm has several options:

- Maintain the product, possibly rejuvenating it by adding new features and finding new uses.
- Harvest the product - reduce costs and continue to offer it, possibly to a loyal niche segment.

- Discontinue the product, liquidating remaining inventory or selling it to another firm that is willing to continue the product.

2. What PLM entails ?

CIM data defines PLM as " a strategic business approach that applies a consistent set of business solutions in support of collaborative creation, management, dissemination, and use of product definition information across the extended enterprise, from concept to end-of-life, integrating people, processes, business systems, and information".

During the life of a product, a large amount of data is generated. This includes CAD data, specifications, quality documents, bill of materials, engineering simulations, etc., which are shared throughout the extended enterprise.PLM applications form the product information backbone for a company and its extended enterprise.CIMdata defines three major considerations in any product lifecycle: product definition, production definition, operational support.Product definition encompasses information about how the product is designed, manufactured,operated or used, serviced, and then retired. This data is continually updated throughout a product's lifecycle. Production definition focuses on all activities associated with the production and the distribution of a product. Operational support focuses on managing the enterprise's core resources, i.e., its people, finances, and other resources required.

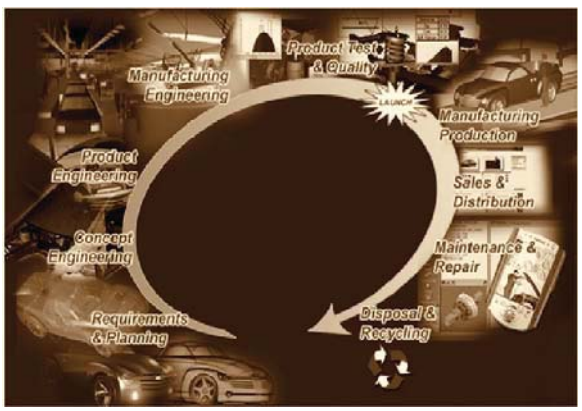

Fig.2 life of a product

From a manufacturer's point of view, the lifecycle of a product comprises five phases: imagination, definition, realization, support, and retirement.During the imagination phase, the market requirements are determined and a product design concept is realized. The definition phase consists of the detailed design of the product, the planning of the manufacturing process and the development of a prototype. The actual production and the subsequent warehousing take place in the realization phase. During the support phase the manufacturer is responsible for the maintenance of the product. When the product is retired, it is disposed or recycled.

The focus of PLM on engineering data and knowledge contrasts with enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM), which largely handle business process data. There is however, an increasing overlap between the systems and the distinctions are gradually blurring. In future, it is likely that the systems will have seamless connections and data exchanges with each other, and will provide access to any relevant data through a standard (but customisable) user interface.

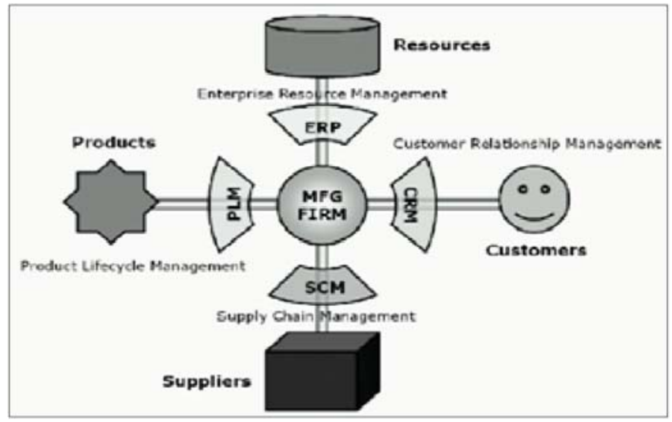

Fig.3 Relation of PLM with other systems

PLM has three fundamental concepts:

- A universal, secure, managed access and use of product definition information.
- A persistent integrity of product definitions and related information throughout the life of the product.
- The management and maintenance of business processes that create, manage, disseminate, share and use product information.

3. Features of PLM system used in aviation industries

3.1 Item management

one of the basic functions of a PLM system is the management of items. The system controls the information on the item and the status of the item as well as processes related to the creation and maintenance of items.

3.2 Product structure management and maintenance

The PLM system identifies individual information and its connections to other pieces of information with the help of the product structure, which consists of items hierarchically connected together.

3.3 User privilege management

The PLM system is used to define information access and maintenance rights. The PLM system defines the people who can create new information or make, check and accept changes, and those who are allowed only to view the information or documents in the system.

3.4 Maintenance of the state or status of documents and items

The system maintains information about the state and version (e.g. sketch, draft, accepted, distributed, obsolete) of each document and item, and about changes made to them: what, when, and by whom.

3.5 Information retrieval

One of the main tasks of a PLM system is information retrieval. PLM systems intensify and facilitate the retrieval of information so that It is possible to utilize existing information better than before when creating new information. All the existing information on a given subject, such as a particular product, can be easily accessed: documents, components, perhaps a design solution of proven quality. It is easy to find out how a given piece of information is related to other information, for example to find out where else a given design solution, part or component is used. (This is very important for change management-when implementing changes in this piece of information)

3.6 Change management

Is a tool with which the latest valid information about changes, such as version changes to a product or component, are recorded in documents or items, which are then made available in the right place and at the right time.

3.7 Configuration management

Varying the physical properties of similar products and switching interchangeable assemblages or components. Configuration management allows products to be customized according to customer wishes.

3.8 The management of tasks

(messages), also known as workflow management, is one of the basic properties of a PLM system. The communication and division of tasks is carried out through graphical illustration of the chain of tasks and by e-mail or a task list. The management of tasks makes possible the radical intensification of communication in the organization, especially in a decentralized even worldwide environment.

3.9 File/document management

Involves index information on files contained in the system. In other words, it is a question of metadata – information about what information is located where.

3.10 Information loss

During updating is avoided. The PLM system controls the copying of files and ensures that the master copy is preserved until the files have been successfully updated.

3.11 Backup management

The system automatically logs backup copies. l) History / System log – a database of events which ensures that that all measures – such as updating documents or changing component items – made within the sphere of PLM management can be tracked, if necessary (Product process traceability).

3.12 File vault

The system also includes a file vault, or storage place for files. It is the place where files – the actual data – or file attachments are recorded. The file vault is usually located near the group of persons who create, update and administer the files. In practice, the vault is a file server on the same LAN (Local Area Network). The files on the PLM system file server are managed by the system so that correct and controlled revisioning principles, user privileges and information maintenance are maintained.

4. PLM SYSTEM ARCHITECTURE

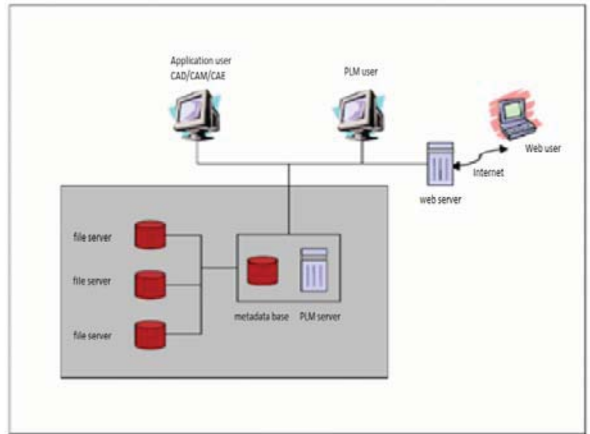

Fig.4 PLM System architecture

The file vault is a centralized filing system for information files or, in practice, a concentrated databank, usually a file server or set of file servers (Electronic vault, file vault, central filing system). In another words, it is a warehouse for information data, stored in files, which meets certain,set demands. This kind of information consists of documents at various stages of their life cycle, such as CAD drawings that have been accepted and are ready to be released for distribution, or other kinds of documents such as Microsoft Word files.

The metadata base (Metadata base) is needed to maintain the structure of the whole system. The task of the metadata base is to handle relationships between individual pieces of product data, the structure of the information

The application carries out the PLM functions of information and metadata base management and appears to the user as a variety of different user interfaces. The task of the software is to make possible all the PLM functions, data transfers, and conversions in accordance with the principles of PLM. The PLM application usually also acts as a link between different applications and systems within the sphere of PLM and makes the connections between the separate databanks possible.

5. PLM in the aviation industry

As mentioned earlier, the automotive and aerospace industries are the biggest adopters of PLM. The high degree of penetration of PLM in the aerospace industry is due to the fact that their products have long lifecycles, are very complex and have nearly no possibility of physical prototyping. In general, PLM has a major positive impact on business: IBM-Dassault's PLM Solution, ENOVIA VPM, enabled Dassault Aviation and its 27 partners in North America and Europe to collaboratively design the Falcon 7X business jet. Furthermore, 7 months were sufficient to assemble the aircraft instead the usual 16 for comparable aircrafts. UGS PLM solution's was deployed in the development of the Boeing 7X7 series of commercial aircraft and the F-35 Joint Strike Fighter (JSF). A Lockheed Martin-led coalition of military aircraft manufacturers and suppliers around the world designed as many as 5000 aircraft using TeamcenterTM with just three design variants to satisfy the operational needs of the USAF and RAF at the lowest cost of sustainment for a 30-year life of fleet. Lockheed Martin reported a 35 percent cycle time reduction and anticipates the manufacturing time to be reduced by 66 percent. Lockheed has two primary partners, Northrop Grumman and BAE Systems, plus up to 1000 suppliers in 30 countries. Pratt & Whitney used Tecnomatix solutions in order to limit the development of its engines to within 3 years which was considered competitive. Besides that, the design is service friendly and minimizes downtimes by making maintenance operations as simple as possible. The engines were designed such that no other components need to be removed for a line-replicable component to be replaced. During development, maintainability issues were addressed via 3D visualization and since there was no need for a physical mock-up development time and costs were significantly reduced. In the aviation industry, capital equipment and products with long service lives and complex configurations are a challenge.

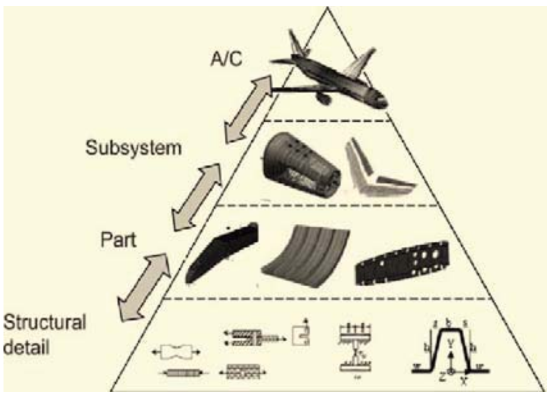

Fig.5 structural detail of an aircraft

The profitability of the industry is not from the sale of aircraft, but from maintaining them for an anticipated thirty-plus year lifespan. Aviation MRO companies, with assets in service for many years, need to focus on persistent product performance. Today, the global commercial aviation fleet includes more than 17,000 active aircraft. The 2005 operating budget for MRO exceeded US$38 billion and an inventory of spare parts is estimated at US$50 billion.Furthermore, analysts expect a growth in operating budgets to nearly US$46 billion in 2010, exceeding US$54 billion by 2015. The main stakeholders in the use phase of an aircraft are: the operator of the aircraft, the aircraft manufacturer, part manufacturers, and the company that maintains, repairs and overhauls the aircraft. The objective of the aircraft operator is to ensure safe operation at minimal operating costs. Confining service to only those parts of the aircraft that require it, as opposed to servicing all units, increases profitability. In particular, PLM application goals are reducing the time that an aircraft is under maintenance, curbing actual maintenance costs, and lengthening the time between service. Aircraft manufacturers and part manufacturers want products that are easy to maintain. MRO companies strive to minimize maintenance costs and turn-around time to maximize revenue for the owner. Maintenance can be defined as the process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety. There are two types of maintenance: scheduled maintenance and unscheduled maintenance.The former is a preventive form of maintenance conducted at pre-set intervals to ensure that the aircraft is air-worthy. Unscheduled maintenance is needed in the event of a breakdown. Such maintenance actions are more definitive, requiring extensive testing, adjusting and often a replacement or overhaul of parts or subsystems.

Scheduled maintenance and inspections consists of a battery of checks, depending on the number of flight hours elapsed: transit, 48 h, ''A,'' ''B,'' ''C,'' and ''D'' checks. The transit check is performed at each transit stop of the aircraft. 48 h checks are performed once every 48 h, and are more detailed than transit checks. The intervals for a Boeing 747–400 of ''A'',''B'', ''C'' and ''D'' checks are 600, 1200, 5000 and 25,000 flight hours, respectively.Maintenance is further classified as on- or off-aircraft.On-aircraft maintenance is performed on or in the aircraft itself. On-aircraft maintenance can be done with or without taking the aircraft out of service. The former is called line maintenance and the latter hanger maintenance. Line maintenance entails work associated with, for example, transit, 48-h, ''A,'' and ''B'' checks. Examples of such inspections include checking the brakes, oil levels, the condition of cargo door seals and the wing surfaces for obvious damage or oil leakage. Hanger maintenance entails scheduled checks, modifications of the aircraft or aircraft systems by an airworthiness directive or engineering order, special inspections mandated by the airline, the FAA or other regulations, painting of the aircraft and aircraft interior modifications. During hangar maintenance, the aircraft is out-of-service. Off-aircraft maintenance entails the overhaul of systems removed from the aircraft which can be temporarily put out of service if substitute systems are not deployed. Aircraft availability can be measured as (MTBF/(MTBF+MTTR)).where MTBF denotes mean time between failures and MTTR denotes mean time to repair. To increase aircraft availability either the MTBF needs to be increased or the MTTR decreased.These issues can be addressed in the product design phase.By improving the quality of the maintenance, the MTBF can be increased, and an improved turn-around-time equals a decrease of MTTR. More recently, due to high fuel cost, aviation operators have shifted the MRO responsibility to MRO companies, such as Honeywell, for integrated service solutions and asset availability.PLM and aviation MRO In order to ascertain the opportunities for PLM applications in a particular sector, its objectives need first to be identified.

The objectives of aviation MRO are:

- To ensure or restore safety and reliability of the equipment
- To obtain the product and process information necessary to optimize maintenance when these inherent safety and reliability levels are not met.
- To obtain the information necessary for component repair and tooling design for those items to be fully repaired or replaced during the overhaul process.
- To accomplish these objectives within the required time limits and at a minimum total cost, including the costs of maintenance and the cost of residual failures.

The first objective can be realized by scheduled and unscheduled maintenance. The key technical information for any maintenance job is the component maintenance manual (CMM), which is supplied by the original equipment manufacturer (OEM), such as Boeing. Due to the complexity of the system, automated information retrieval, associative inspection and maintenance procedures and tools, product structure information, fault detection and isolation tools, and even 3D viewing and mark-up tools should be provided by a PLM system. Currently, the processes are independent and largely manual. Further more, the ideal PLM system should be able to record, check and manage inspection and maintenance records, such as the replacement of certain parts after repair. Fig. 6 shows a typical highpressure blade before and after repair.

Fig.6 A high pressure blade before and after rejuvenation repair

At Tinker Air Force Base in Oklahoma City, staff members use portable devices developed by UGS and Intel for wireless access to maintenance records and technical manuals where and when these are needed. Each item that needs repair is displayed as an image or 3D CAD model. This reduces the time personnel spend searching paper files, fill out (paper) forms and search through maintenance manuals. The system can also search for historic data on similar maintenance issues and their resolution. Aside from maintenance, another way to reduce costs is to minimize waste in the value chain.With PLM, paperwork is reduced, thus allowing staff more time to perform value-adding tasks. Clearly, every airline operator seeks cost-effective and reliable MRO vendors for their regular maintenance contracts. An evaluation of maintenance tasks including whether to repair or to replace items is the common task of both the operator and the vendors. Here, detailed product engineering knowledge and procedures involved in any repair are necessary. Future PLM systems should be able to offer more than the current hard copy standard service bulletins or rough experience-based estimations. Fig. shows the inner skin of an outer carbon cover after removal from the honeycomb core, the damaged honeycombmcore on the inner skin, and the repaired panel. Integrated product and process information play an important role in timely and efficient repair. Furthermore, OEM and MRO companies have to exchange information such as the bid price, part numbers, references to standard service bulletins, procedures, the repair schedule, inspection results, and the final agreed repair plan. Clearly, collaborative information sharing reduces overall maintenance costs and time. The impact of PLM also lies in the feedback, either within an enterprise, an extended enterprise, or across lifecycle stages of the product. The PLM collaborative management function is especially helpful for service quality assurance. Vendor service quality can be evaluated by an investigation into why safety and reliability levels are inadequate. Reasons may include maintenance or parts of low quality, inadequate maintenance processes and procedures, or unsuitable maintenance intervals. Immediate improvement measures should be implemented and, if necessary, new vendors should be appointed. Through such feedback, the maintenance schedule can be revised and optimized, realizing the third objective of maintenance. Research revealed that 40% of the replacements of enginedriven air compressors on the Navy P-3 Maritime Patrol aircraft were unnecessary. PLM can potentially lower maintenance to a level that meets safety and reliability standards. For example, a European airline achieved a 15% drop in unscheduled downtime and a 25% reduction in overall MRO costs by using PLM. An Asian airline even reported a 40% decrease in unplanned maintenance. Such feedback to the OEMs potentially improves the design of aircraft of the same or different model, thereby realizing the close loop of design for maintenance and service. Because PLM can be pervasive throughout the extended enterprise, such systems will lead to not only an active change in the design and manufacturing phases but also in business activities like ERP and SCM. In the case of off-aircraft repair or overhaul, a PLM solution can really be deployed in a pervasive manner in order to achieve the third and fourth objectives given at the beginning of this section. Feature-based information integration on product and process models is one such approach as illustrated in the case study of the next section. Last but not least, PLM can play a role in the optimization of inventory. By having the right part at the right place at the right time, there is no need for expensive back-order. Carrying costs can be minimized and turn-around time for an overhaul project can be reduced. Shorter turn-around time means increased revenue for the airline operator. Thus, it can be seen that the impact of PLM on aviation MRO is considerable.

6. BENEFITS OF PLM

Generally, many benefits accrue from the adoption of PLM. It

- helps to deliver more innovative products and services in a shorter time.
- is able to shorten time-to-market.
- establishes a more comprehensive and collaborative relationship with customers, suppliers, and business partners.
- improves communication among departments.
- improves the success rate of newly introduced products and reduces costs by taking advantage of the efficiencies and effectiveness that come from improved market intelligence and business collaboration

7. CONCLUSION

Presently, PLM is mainly adopted in the design phase of aircrafts with impressive results. However, in comparison with the design of aircraft, PLM is used nearly 10 times less frequently in maintenance, repair and overhaul. Because of the long lifespan of aircrafts, this means that the potential of PLM in aviation MRO activities has not been realized.

However, much research is still needed in data and constraint management although a few successful initiatives have been reported. Ideally, PLM provides reliable and accurate feedback among partners in an extended enterprise and among the various lifecycle stages of a product; it could optimize inventory levels and improve the efficiency of scheduled or unscheduled maintenance by cutting down on non-value add tasks.

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