Product Lifecycle Management (PLM) to support Product Development processes

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ABSTRACT

Today manufacturing companies are more and more characterized by a growing product and processes complexity. Projects needs the participation of a pool of companies that have to collaborate in a multidisciplinary and integrated way following a defined PLM strategy.

These challenges are meant to introduce a new way of working, based on innovation and global collaboration, both internally among different disciplines and externally between operations, administration, and maintenance and its suppliers. One of the main leverages to achieve this aim is enabling a new business paradigm through pervasive 3D (three dimensions) to support activities from engineering, manufacturing, operations, and in-service domains.

Nowadays, products can be designed, simulated, and validated directly in the virtual domain with the help of computer-aided design (CAD), computer-aided engineering (CAE), and Digital manufacturing software using 3D interaction and simulation. This new approach adds to traditional product data management (PDM) systems new functionalities to explicitly manage products, processes, and resource objects, as well as the relationships between them, according to configuration and effectiveness. This paper will illustrate methods and tools deployed within **Alenia Aeronautica** and **Ansaldo Energia** projects, companies of **Finmeccanica**.

Categories and Subject Descriptors

J.6 [**Computer_Aided Engineering**]: *Computer_aided design (CAD), Computer_aided manufacturing (CAM).*

General Terms

Algorithms, Management, Design, Standardization.

Keywords

Collaborative Engineering, Multidisciplinary Process, Data Management, Process Management, Optimization.

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1. INTRODUCTION

The centrality of innovation to Finmeccanica is truly depicted by the numbers which indicate the importance held by Research and Development within the Group: 1.982 billion Euros invested in 2009 (a 11% share of revenue), about 15,600 employees involved in design and engineering activities, and 5,200 company staff participating in R&D activities.

How to better use these resources? How to identify and create new synergies? How to spread the know-how that exists in our companies and share, increase, give new value and reapply the wealth of people, passion, knowledge, processes and existing technologies? How to transform the diversification and richness of technological competencies into a competitive advantage for the Group? How to put people in contact so as to work cooperatively?

It is to these and other questions that the MindSh@re project has sought to find answers. Created in 2003 within the Technological Development Function of Finmeccanica, MindSh@re and the technical Communities, which make up its basic entity, have the mission to be the unconventional engine for value innovation by directing their efforts towards cooperation, technologies and people.

The connection among personnel in this heterogeneous network allows MindSh@re to be a multiplying factor in the generation of new ideas, products and talents while the Communities create a transversal organizational model aimed at focusing and sharing research activities in areas considered of primary importance in industrial terms.

The objectives and the results achieved since 2003 give testimony to how MindSh@re is seeking to achieve its main mission: to be the hub of a cooperative network that involves Group's partners, institutional customers, universities and research centers.

Among those activities created at the knowledge-sharing level, which help leverage the intangible assets within the Group, sharing of technologies, institution of inter- and extra-company contacts which support and increase the effectiveness of daily work activities and diffusion of "best practice" procedures must be mentioned. The latter has been achieved through (but not only) the publication of guidelines and thematic position papers and the preparation of market surveys or technology appraisals required for defining our position in relation to market and our competitors. Furthermore, information is passed on by the Communities which are quite active in organizing seminars and workshops involving high-level technology, often together with university professors, partners, suppliers and clients. By mapping competencies, we have been able to define the technological roadmaps both in terms of product level and processes. Quite often the results of these analyses are evaluated, tested and validated by collaborating laboratories within the Group. To maintain this thrust for innovation, Finmeccanica financially supports several projects every year that are considered of corporate importance. To be approved, the projects must involve the participation of two or more Group companies, as well as some Universities, shall have the support of customers and/or end-users and, obviously, shall demonstrate a highly innovative character.

The heterogeneity of the Finmeccanica world is well represented in the Product Lifecycle Management (PLM) field. The FNM companies are changing their role in the industrial V-curve moving towards the system and/or platform integrators with a major integration with all the stakeholders belonging to their supply chain. This key role needs a better support of all the functionalities and performance associated with the PLM. However tools, methodologies and processes are significantly different in every FNM company in which best practice as well as weakness are present. The IE4EC (Integrated Environment for Engineering Capabilities) is the MindSh@re Community dedicated to engineering processes, environments and tools, with the aim to support the spread and the leverage the best practices implemented in different companies. In this paper two case studies are presented, one from Alenia Aeronautica and one from Ansaldo Energia. They are a practical example of how common key elements in a PLM strategy, are implemented and of how synergies are reached among the Finmeccanica companies. A further support to the companies is provided thanks to an intra companies laboratory (the System Mechanical Design Lab), located c/o Alenia Aeronautica, where new tools and functionalities can be tested and evaluated.

2. THE PLM ALENIA PROJECT

Alenia Aeronautica is one of the major European players in aerospace, with full system development and integration capabilities in the most advanced fields, such as: high performance combat aircraft, military and commercial transport aircraft, unmanned air systems, mission systems aircraft and modern aerostructures for airlines.
Alenia Aeronautica is subjected to many factors that push toward new competitive positions and toward a reorganization of the company value chain. The main are: the global collaborative Environment as constraint, the growing competition from emerging countries, the project team more and more de-located, the Alenia Aeronautica multiplicity role according to the various programs, significant increasing of activity plan, …

To answer to the above factors Alenia Aeronautica, on the 2007, started a PLM Project named AleNET.
AleNET is a turnaround project focused on designing and implementing an extended enterprise operating model, that enforces Alenia Aeronautica as “global player”, with the aim to:

- Increase of productivity with an enlargement of products portfolio and manufacturing volumes
- Reduce Time to market
- Develop costs reduction
- Develop risks control and mitigation
- Increase of efficiency and revenue margins
- Improve competitiveness
- Improve quality and stakeholders satisfaction
- Improve supply chain management

Other benefits, less tangible, but even stronger affect improvements of strategic competences, management and capitalization of the knowledge.

The PLM exploit leverages and drivers to modify processes, methodologies, organization, competences and infrastructure through the following elements:

- *extended enterprise* –establishing since the early stage of the product lifecycle (conceiving phase), an open environment to supply chain (partners, suppliers and customers) in which the resources involved can share information and develop integrated solutions with multi-disciplinary approach. In this way, any choice will be defined by considering all relevant aspects of the product, the performance characteristics, the implications of construction, operation and maintenance;
- *concurrence* – by defining the degree of anticipation of the processed information and the associated type of activity authorized to valley; in particular it is important to define the operational modalities to early release the components in the long lead time procurement;
- *collaboration* - in analogy to the concept of extended enterprise, the open environment will include ways of working and involvement of internal resources in cross-functional view;
- *digitization of information* – by developing methodologies, applications and infrastructure to enable the acquisition and sharing of the company information;
- *multi-disciplinary integration* - in order to cover the entire product lifecycle, from exploration of needs, requirements analysis, implementation to operational use, in a view of the integrated system, including human interfaces machinery, infrastructure and environmental issues;
- *virtualization (and simulation) of the product* - across the board overseeing the entire product lifecycle, through a structured process (such as through the modeling CAD / CAE and Manufacturing Engineering);
- *virtual and physical prototyping* – by ensuring that the virtual prototyping is covered in synergy with the

experimental activity and providing integration and correlation, reducing risks and costs of development. In the trend, virtual and physical prototyping approach composes a single, integrated platform for the validation and certification of the product;
- *knowledge management* - providing the necessary operating procedures and applications to enable the capitalization and sharing of know-how in cross view on programs and functions;
- *lifecycle management* - to allow the timely and effective measurement of benefits throughout the lifecycle of the product.

2.1 Main environments considered

Requirements management

The product requirements are managed by reproducing the hierarchical structure and ensuring the traceability along the deployment and through evolution.

In addition, the requirements are related to parts of the product (interoperability between requirements management and configuration management) and related validation activities. In this way, all the impact diagnostics analyze the result of a requirement change and/or a modification of the product. The requirements cover all the implications of the product, from the performance, realization, operations and maintenance points of view, in correlation to the functional view, to flow down to the technical choices. The requirements management crosses the entire product lifecycle, starting from the exploration stage of need and product design, following the development of work-packages and changes. In this way, the data implementation (e.g. costs and time) allow you to build the knowledge base to support the budgeting and acquisition of successive contracts. As a reference characteristic, the V-Model is applied in terms of development along two main directions of requirements decomposition and product integration, crossed by the conformity verification at each evolution stage of aggregation.

Early release and management of the concurrence

The design phase is a crucial moment in the lifecycle of the product, since this stage foresees the choices that deeply mark later on the degree of industrial success. In this stage the changes are easy because the product is not yet defined, but then they become hopelessly expensive in advanced stage of maturity, if necessary to compensate for a bad choice. The design phase is supported by an environment of collaboration in cross-functional and extended enterprise view, open to the supply chain. The involved resources, therefore, will share information in accordance with their respective security access rights and develop integrated solutions with multi-disciplinary approach. In this way, each choice will be defined by considering all relevant aspects of the product, the performance characteristics, the implications of construction, operation and maintenance. In coherence with the collaboration, the concurrence is developed, defining the degree of anticipation and the associated type of actions enabled downstream. In particular, the operational modalities are defined for the early release of the components in the long lead time procurement. The following benefits are perceived throughout the lifecycle of the product:

- the various design disciplines have visibility on the defined parts and the associated operations authorized to the actions downstream;
- The industrialization receives and processes the parts defined by the design;
- The procurement have visibility of parts and, depending on the level of maturity, develops the actions authorized downstream.

Testing

The PLM approach covers all aspects of the testing of the product, focusing on the following main aspects:

- ***Lab and production testing management :*** The test article is managed with the associated experimental infrastructure (instrumentation and equipment acquisition) and relevant documents to support the activity (e.g. test plans, test procedures, test reports). The physical testing is increasingly linked and integrated with the virtual platform, to maximize consistency and minimize the commitment of the experimental activities, coming to the development of virtual testing.

- ***Ground and flight testing management:*** The PLM approach covers the management of the prototype with the associated experimental infrastructure (instrumentation and equipment acquisition) and relevant documents to support the activity (e.g. test plans, test procedures, test reports). The experimental activity is developed in correlation and consistency to the virtualization techniques. Finally, the integration and acceptance tests are managed, including all compliance testing of the product.

- ***Configuration and management of test environment:*** The PLM approach covers the configuration management of test rigs, test equipment, test articles and prototypes with the associated instrumentation integrated for experimental activities. It will include not flyable products (e.g. flight simulators), relevant to the purpose.

Configuration management of simulators to be delivered

The PLM approach covers the configuration management of flight simulators that are to be delivered to the customer.

Schedule, budget and spending

The activities are tracked in terms of planning up to the spending, in order to gradually build up an asset of information to support subsequent budgets. In particular, it ensured the connection between change, planning, budget and spending throughout the process of evolution.

Digital Mock Up

The DMU becomes a carrier for the activities of design and is used as a support tool:

- for design (e.g. DMU is configured for the analysis of the clash);

- for design review (such as checking the interfaces between components developed by different suppliers);
- for concurrent engineering between design, manufacturing, production, operational support and logistics;
- for the analysis of accessibility, safety and human interface.

In the DMU perspective, the following aspects are considered:

- The DMU is developed and used in a way that represents all the components of the aircraft (structures and systems) with impacts on integrated hardware and software;
- The DMU is directly related to configuration management to follow the product in all its stages of development;
- The DMU is usable by the business functions and supply chain, allowing the sharing of information according to security access rights and encouraging collaboration in multi-disciplinary environment.

Fig. 1 – Design review process

Model Based Definition

MBD methodologies are based on the CAD system in order to fully define the product information in the 3D model. This context, therefore, includes both the general design rules consistent with the model of concurrent engineering and the strong interdependence between the simulation and CAD modeling, and specific rules to be adopted in different technologies (sheet metal, machined parts, wiring, etc.)

Simulation

Virtualization and simulation of the product cover the whole lifecycle, through a structured process to manage the following main aspects:

- ***Multi-disciplinary simulation:*** Virtual prototyping reproduce the characteristics of the product, in terms of behavior, performance and implications for development through an integrated multi-disciplinary environment. The scope covers the entire product lifecycle from exploration of the needs, requirements analysis, implementation to operational use, in a view of the integrated system, including the human-machine, infrastructural and environmental interfaces. The virtual prototype is developed in synergy with experimental activities, ensuring correlation and integration, reducing risks and costs of development. In the rend, virtual and physical prototyping composes a single, integrated platform for the validation and certification.
- ***Systems simulation:*** The simulation reproduces the behavior of an integrated system, representing the mechanical, electrical and software characteristics. The virtual platform is modular and open to the supply chain, allocating the contributions throughout the hierarchy chain from the component up to the complete system. The simulation also cover more specific needs, with particular attention to the development and traceability of the software. Nowadays the exploration looks at the compatibility and the trend towards the tools/ methods/ formats/process (e.g. SysML, Systems Engineering) new standards, pursuing an integrated approach with the other aspects of the system simulation in general, up to the concept of systems of systems.

- ***Operation simulation:*** The simulation reproduces the main operational aspects of the product, considering implications of service and maintenance. In particular, in this context, the integration verification among products, people and infrastructure are important for the business commitment.

- ***Simulation Data Management:*** The simulation data are managed, including CAD models, CAE and CAPP, in correlation to the DMU and configuration, along the entire lifecycle. The govern of the development process is ensured through a scenario of collaboration in the enterprise network extended to the supply chain.

- ***Multi-disciplinary integration:*** The process of multi-disciplinary simulation is one of the most innovative areas with significant implications on business through the following main operational impacts:
    - Management of simulation data (virtual and physical) in the product structure, consistent with the parts/systems to which they are associated;
    - Multi-disciplinary simulation of a configured product;
    - Management of requirements and performance demonstrated through virtual and/or physical testing;
    - Management of the correlation between modification of the requirements, change in performance expectations and tuning of CAD/CAE/CAPP platform, relying on the parametric-associative logic;

RMTS management
The impact of PLM approach is also significant on aspects of product support that is becoming increasingly important within the business. It ensures the management of the defect report through a process extended to the supply chain, until the closure of the investigation. The aspects of maintainability and testability of the product are covered since the stage of conceiving. The integration test results, the quality checks, the waivers, certificates of conformity are also managed, ensuring the traceability of data. Finally, the context covers the activities of troubleshooting, fault isolation, and functional performance degradation resulting from the failure. Finally the associated information feed the knowledge management and enable continuous improvement.

Product concepts and prototypes
The PLM approach requires management of prototypes, technical studies and preliminary design to support the conceiving phase which has a significant impact on product development:

- Simplified configuration management in order to avoid excessive phasing of the development process which is dominated by the flexibility and reactivity, not having immediate impacts on production processes;
- Structured management of information developed in the upstream stages of product development in order to capitalize the knowledge, even with regard to technical solutions that do not result in a development;
- Management of the link between detailed and preliminary design, in order to not allow duplication, inconsistency and inefficiency.

Industrialization
The PLM approach pursues the industrialization objectives through the coverage of the following aspects:

- ***Manufacturing processes and verification management: t***he definition of the cycle of production/assembly, its use in the factory are based on the 3D CAD model. This context will avoid duplication and ensure consistency between product configuration and the manufacturing process. They innovation also simplifies the procedures for description of the cycle, relying on three-dimensional models and movies that make faster the path on the learning curve for the workers involved in the assembly line.

- ***Tooling management:*** Similarly to the working cycles management, the link with the valid configuration increases both the effectiveness and the efficiency of the process of defining and modifying the tools in concurrent engineering and with the contribution of the supply chain.

- ***Digital manufacturing:*** The definition of the production process are developed in concurrence with the design of the product and focused on the following main aspects:
    - o The definition of optimal layout;
    - o The definition of the assembly sequence;
    - o The optimal flows of the materials;
    - o Simulation of the assembly sequence.

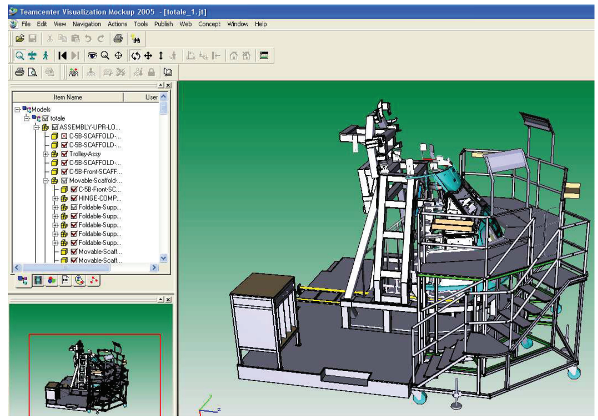

Fig. 2 – Tooling design management

Management of indicators for process/program and metrics
The revision of the model of the product lifecycle takes into account the definition of process indicators that allow to control the progress, crossing the information of development with the progress of the project timeline.

Document management
The context covers all the activities related to the product documentation, such as naming, template, type, classification and workflow for the issue and change. However, the new process of product lifecycle management assumes that there is close correlation between the product structure and associated documentation.
The implementation considers the needs of longevity date since the documents must be available and searchable, regardless of the tool of generation, even for the duration of a program that normally spans several decades.

Knowledge management
The PLM approach through the integration of aspects of strategy, technology, process and change management reinforces the capability of knowledge management, increasing the explicit knowledge within the company.

Configuration management
The PLM approach allows to manage the configuration of the product throughout its lifecycle and define its evolutionary stages through the coverage of the following representations: Functional Allocation or As Conceived, As Designed, As Planned, As Built and As Maintained

Configuration management integrates parts of the structure, systems and avionics onboard systems including electrical and software aspects, covering the following areas:

- Management of the configuration links to data and documents, such as technical notes, project

specifications, models, procurement information, evidence of qualification, test procedures;
- Management of materials, standards and equipment;
- Management of product information, combined with the configuration views;
- Integrated management of individual parts or branches of product structure assigned to external suppliers;
- Correspondence between requirements management, product configuration and evidence of compliance;
- Change management in their development and in cross-functional approach and with the contributions of the supply chain;
- Management of the change boards and DMU reviews;
- Management of data for certification and delivery to the customer;
- Management of AGE (Aircraft Ground Equipment), ASTA (Aircrew Synthetic Training Aids) and Ground Test Equipment, LRU (Line Replaceable Unit).

2.2 Benefits

The PLM approach leads to significant benefits in the tangible and intangible assets. The main targets for improvement identified quantitative parameters affecting the efficiency and effectiveness in the following areas: Times, Costs, Quality and Information Technology. In this view, there are the benefits associated with managing off-load and supply chain that will become even more substantial to affect hugely the business performance.

Time

The reduction is considered in the context of the processes "end to end" and compared to the reduction of "time to market" considering the overall permanence of the product in its production flow. In this context, the benefits reported a reduction of at least 15%.

Costs

Costs are grouped into the following categories: Costs of design and development and Costs of industrialization and production

- ***Cost of design and development:*** The cost benefits of planning and development are assessed as impact on hours in the comparison between budget and final accounts. The following effects are estimated:
    - Reduction of activities related to the revision process are about **-10%** on hours for Programs with HIGH impact and **-5%** on hours for Program with LOW impact
    - Reduction of non-recurring activities are about **-15%** on hours for Programs with HIGH impact and **-5%** on hours for Program with LOW impact

Additional benefits that are not measurable benefits, but can induce a huge impact on the business refer to the intangible assets: improvement of the culture, improvement of the capability, certification of processes (e.g. CMMI), capitalization of the knowledge and Change Management.

3. THE PLM ANSALDO PROJECT

Ansaldo Energia (AEN), company of Finmeccanica Group, is the Italy's leading producer of thermoelectric power plants including process, mechanical, civil, installation and start-up engineering. The production centre is split into three product lines: gas turbines, steam turbines and generators.

The Product Lifecycle Management is a strategic approach aimed to the management of the information, processes and resources in order to support the product life cycle, beginning from its conception, through the design, manufacturing, until sales and service.

Through the years AEN has implemented a complete PLM Solution starting from design, to configuration management, classification and product configuration, document management with the future goal of extension of PLM platform on MRO and In-Service management. All applications and business areas are based on a single platform with many benefits in terms of economic and organizational efficiency. AEN today operates on a single PLM platform managing 3D CAD data with related product structure and product configuration, integrated with change and configuration management. CAM data are completed integrated with engineering data bringing to the production area all relevant information to operators through "totem" data visualization 2D, 3D, notes, production information etc.

One of the most important phase of the PLM Project has been the recent implementation of the manufacturing data management and the integration with ERP.

Ansaldo Energia had the issue of having to cope with manufacturing technical data spread in non-integrated multiple systems resulting in difficulty in the reuse of data and lack of structured validation processes. After the implementation a controlled and structured management system for data and related processes has been delivered to Manufacturing: Routing cycles, Methods, Documents, Tapes, Tools, Tool assemblies, Equipments, Work Places, Specs are now all integrated and interrelated into a single source of managed knowledge.

The last major development has been the recent implementation of a project to manage simulation data and analysis results in the same unique PLM platform.

With this in place AEN has now a truly collaborative managed environment to control and distribute knowledge across the entire enterprise.

Then this involves an integrated approach based on a methodology of collaborative work and team organization starting from the engineering processes definition.

The role of the Development Engineering during the conception phase of a new product is crucial to achieve success over the whole lifecycle process.

In general, the know-how of the people involved in the Development Engineering is available in the form of models, algorithms and data of different key-disciplines as aerodynamics, heat transfer, mechanical integrity, combustion, materials, etc. For this reason the use of these topics in the multi-disciplinary processes is often difficult due to the incompatibility of the concepts, differences in notation, in informatics languages and in IT platforms.

Here-hence the need in the defining and in the managing of the processes and simulation data so that they can always be tracked, traced, referred to the product requirements and available by all the users operating in network on different disciplines involved in the product design.

The target of introducing the Product Lifecycle Management in the Development Engineering is to manage, improve and accelerate the multidisciplinary simulation processes in field of product innovation, since its design conception, in order to obtain the best product in terms of upgrade, performance and quality.

The Ansaldo PLM project is started in Development Engineering Dpt. since it has gone from the engineering's organization structured in disciplines, e,g. Centres of Excellence, to one where the teams operate in a multidisciplinary context and the turbomachinery components are the focus of the process design.

In general, there are two aspects that characterize the engineering's:

- the know-how in the form of models, algorithms, tools for the simulations, data coming from the various disciplines: aerodynamic, heat transfer, materials, mechanical integrity, combustion, etc.Often, the exchange of data is not agile because of the incompatibility of the concepts, differences in notations, implementation languages, platforms and sometimes the conflicts among the operators
- the processes: generating a large amount of information/data/simulations and for this reason there is the need to improve and accelerate the exchange of data, that is able to operate in an environment of Collaborative Engineering.

Hence the need to define and to manage the processes and the design data so that they can always be reachable, secure, accessible to all the users operating in the network on various disciplines.

To define this new methodology three pilot projects on the data and processes management have been carried out.This project aimed to extend the PLM in the Development Engineering, consists of introducing:

- A **process management** system, that will allow to all the multidisciplinary team experts to work using shared design procedures, following an established design activities flow, applying shared tools and simulation database. It makes also possible the automation of the design processes and, subsequently, carrying out *multidisciplinary & multi-objective optimization*.
- A **simulation data management** system, that will allow to ensure the basic properties, such as:
  - *Uniqueness*: data are reliable, unique and officially issued
  - *Traceability*: data are located in the simulation process. Every user knows anytime the data road map bottom-up or top-down, who produced the data, the creation date, the used software tools and the issued release.
  - *Sharing in real time*: data are available in the last version at anytime.

3.1 Project Description

The introduction of the PLM allows the Development Engineering to gather and manage reliable simulation data and processes of all the key disciplines in the design activities and to use them in best way.

Thereby, this methodology enables to improve the effectiveness in the whole design process as well as to ease the knowledge communication in the work teams among who have issued the data and who have to use them.

The aim of the proposal is to bring in Development Engineering a high degree of innovation through the PLM in order, on the one hand, to manage, upgrade and speed-up the multidisciplinary design processes focused on the product innovation while, on the other hand, to make the best use of the synergies amongst the team works, the experiences and the skills of the users.

So, in order to achieve the previous results the following few specific requirements have been specified:
- the capitalization of the technical know-how and know-why on the key-disciplines
- the development of an ICT environment for the collaborative engineering processes
- the simulation data management
- the management and automation of the process flows
- the mono- and multi-objective optimization of the design solutions

3.2 Status

The introduction of the PLM in Development Engineering must be considered useful in order to meet the competitive marketing in the energy field.

To do it in the energy industry, and in particular in **Ansaldo Energia**, three pilot projects have been launched on the gas turbine product development, each of which committed to a multidisciplinary team and focused to a benchmark of the design in collaborative environment.

The outline of the three pilot projects is shown in Fig.3.

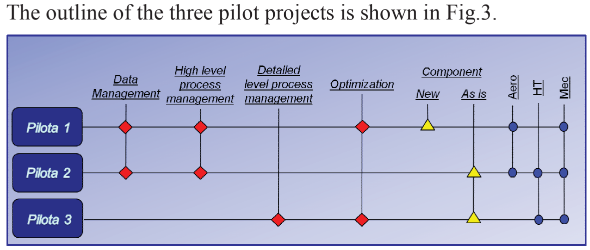

Fig. 3 – Outline of the Pilot Projects

The pilot projects are planned in order to cover all the topics of interest, in terms of data and process management, optimization, and to include both the existing components (*as is*), on which the *re-engineering* is performed, and new design components *(new)*. The involved components are compressor and turbine blades.

The pilot projects are:

– **Pilot 1**: data management and optimization process on airfoil of a 'new design' of a compressor blade

Involved disciplines: aerodynamics and mechanical integrity
Target: process and data management of a compressor blade

– **Pilot 2**: data management of an existing turbine blade 'as is'(CAD 3D models already available in the repository area)
Involved disciplines: aerodynamics, heat transfer and mechanical integrity
Target: data management of a gas turbine cooled blade

– **Pilot 3**: optimization of an existing turbine blade 'as is'
Involved disciplines: heat transfer and mechanical integrity
Target: optimization of the internal cooling design

On the current stage the main phases of this iniziative are here below listed:

- investigation in literature and analysis of proposed methods
- capitalization of the knowledge through the drafting of the Design Practices
- design software tools census and their interaction
- installation of a high performance hardware environment
- acquisition and installation of commercial software tools for the collaborative engineering
- training on the job of the multidisciplinary working teams
- development of design real cases in the collaborative engineering environment (pilot projects)
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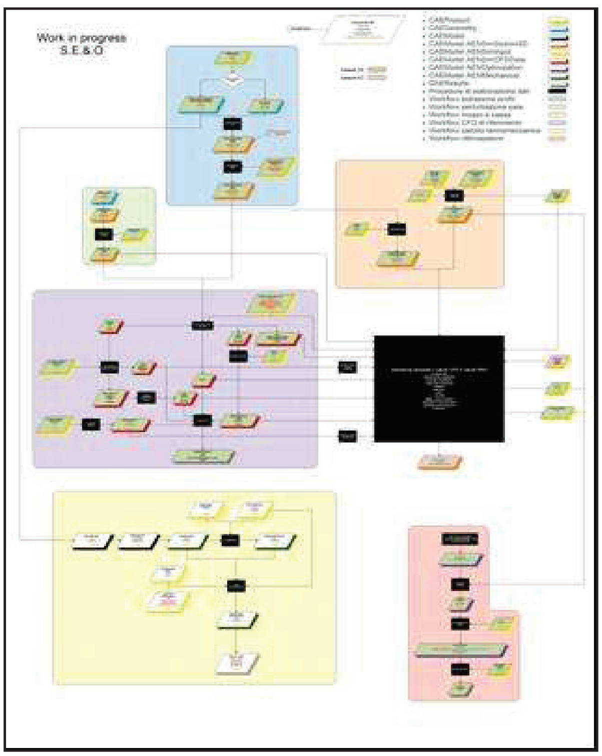

Fig. 4 – Example of process carried out

3.3 Results obtained/obtainable

The introduction of PLM approach in Development Engineering leads to remarkable benefits in tangible and intangible assets.

The most observable profits of the PLM in Development Engineering are hereinafter listed:

- **Sharing of the Company Know-how:** This outcome is not easily measurable in terms of return of investment, even though it is definitely a key factor in a Company ever-growing. In particular, in the Development Engineering the know-how spreading is a crucial point in order to release rapidly new optimized design solutions.

- **Data Generation, Management, Traceability:** Be able to gather easily and clearly the information concerning analysis and reports previously carried out gives undoubtedly a relevant profit in terms of times reduction even in the future works. Essentially this benefit involves the adopted practices by the reusing both the design processes already implemented and the results already obtained.

- **Design Processes Standardization:** The generation of standard processes, made official and shared amongst the users, gives a profit in terms of time reduction due to their repeatability by the side of the users operating in network.

- **Optimization of the Design Process:** Tangible reduction in the computing times of the design processes is achieved by the improvement of the hardware platform, through a computing cluster driven by the standard processes, and by the implementation of optimization tools, based on the most updated optimization techniques.

Starting from the experience of the pilot projects and taking into account the different types of application (data and processes management, optimization) a time reduction in the engineering design processes is estimated approximately around **10-15%,** which are consistent with the valuations available in open literature.

In fact, the hereinafter Table 1 shows the estimation of asset improvements coming from the application of the PLM in Development Engineering and confirmed by sources in open literature.

Table 1- Estimation of asset improvements

Task	*Benefit*
Time to Market reduction	Time reduction: 10-35%
Product cost reduction	Cost reduction: 15%
Improvement of quality	10-25%
Components re-use	Increase contents of re-use: 20-40%
Documents management Archiving and search	Effort reduction: 20%
Signatures and Approval procedures	Effort reduction: 5%
Checks of progress and Design Review	Effort reduction: 5%
Standardization	Effort reduction: 15%
Data exchange	Effort reduction: 20%
Implementation changes	Time reduction: 15%

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Product Lifecycle Management (PLM) to support Product Development processes

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ABSTRACT

Today manufacturing companies are more and more characterized by a growing product and processes complexity. Projects needs the participation of a pool of companies that have to collaborate in a multidisciplinary and integrated way following a defined PLM strategy.

These challenges are meant to introduce a new way of working, based on innovation and global collaboration, both internally among different disciplines and externally between operations, administration, and maintenance and its suppliers. One of the main leverages to achieve this aim is enabling a new business paradigm through pervasive 3D (three dimensions) to support activities from engineering, manufacturing, operations, and in-service domains.

Nowadays, products can be designed, simulated, and validated directly in the virtual domain with the help of computer-aided design (CAD), computer-aided engineering (CAE), and Digital manufacturing software using 3D interaction and simulation. This new approach adds to traditional product data management (PDM) systems new functionalities to explicitly manage products, processes, and resource objects, as well as the relationships between them, according to configuration and effectiveness. This paper will illustrate methods and tools deployed within **Alenia Aeronautica** and **Ansaldo Energia** projects, companies of **Finmeccanica**.

Categories and Subject Descriptors

J.6 [**Computer_Aided Engineering**]: *Computer_aided design (CAD), Computer_aided manufacturing (CAM).*

General Terms

Algorithms, Management, Design, Standardization.

Keywords

Collaborative Engineering, Multidisciplinary Process, Data Management, Process Management, Optimization.

1. INTRODUCTION

The centrality of innovation to Finmeccanica is truly depicted by the numbers which indicate the importance held by Research and Development within the Group: 1.982 billion Euros invested in 2009 (a 11% share of revenue), about 15,600 employees involved in design and engineering activities, and 5,200 company staff participating in R&D activities.

How to better use these resources? How to identify and create new synergies? How to spread the know-how that exists in our companies and share, increase, give new value and reapply the wealth of people, passion, knowledge, processes and existing technologies? How to transform the diversification and richness of technological competencies into a competitive advantage for the Group? How to put people in contact so as to work cooperatively?

It is to these and other questions that the MindSh@re project has sought to find answers. Created in 2003 within the Technological Development Function of Finmeccanica, MindSh@re and the technical Communities, which make up its basic entity, have the mission to be the unconventional engine for value innovation by directing their efforts towards cooperation, technologies and people.

The connection among personnel in this heterogeneous network allows MindSh@re to be a multiplying factor in the generation of new ideas, products and talents while the Communities create a transversal organizational model aimed at focusing and sharing research activities in areas considered of primary importance in industrial terms.

The objectives and the results achieved since 2003 give testimony to how MindSh@re is seeking to achieve its main mission: to be the hub of a cooperative network that involves Group's partners, institutional customers, universities and research centers.

Among those activities created at the knowledge-sharing level, which help leverage the intangible assets within the Group, sharing of technologies, institution of inter- and extra-company contacts which support and increase the effectiveness of daily work activities and diffusion of "best practice" procedures must

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be mentioned. The latter has been achieved through (but not only) the publication of guidelines and thematic position papers and the preparation of market surveys or technology appraisals required for defining our position in relation to market and our competitors. Furthermore, information is passed on by the Communities which are quite active in organizing seminars and workshops involving high-level technology, often together with university professors, partners, suppliers and clients. By mapping competencies, we have been able to define the technological roadmaps both in terms of product level and processes. Quite often the results of these analyses are evaluated, tested and validated by collaborating laboratories within the Group. To maintain this thrust for innovation, Finmeccanica financially supports several projects every year that are considered of corporate importance. To be approved, the projects must involve the participation of two or more Group companies, as well as some Universities, shall have the support of customers and/or end-users and, obviously, shall demonstrate a highly innovative character.

The heterogeneity of the Finmeccanica world is well represented in the Product Lifecycle Management (PLM) field. The FNM companies are changing their role in the industrial V-curve moving towards the system and/or platform integrators with a major integration with all the stakeholders belonging to their supply chain. This key role needs a better support of all the functionalities and performance associated with the PLM. However tools, methodologies and processes are significantly different in every FNM company in which best practice as well as weakness are present. The IE4EC (Integrated Environment for Engineering Capabilities) is the MindSh@re Community dedicated to engineering processes, environments and tools, with the aim to support the spread and the leverage the best practices implemented in different companies. In this paper two case studies are presented, one from Alenia Aeronautica and one from Ansaldo Energia. They are a practical example of how common key elements in a PLM strategy, are implemented and of how synergies are reached among the Finmeccanica companies. A further support to the companies is provided thanks to an intra companies laboratory (the System Mechanical Design Lab), located c/o Alenia Aeronautica, where new tools and functionalities can be tested and evaluated.

2. THE PLM ALENIA PROJECT

Alenia Aeronautica is one of the major European players in aerospace, with full system development and integration capabilities in the most advanced fields, such as: high performance combat aircraft, military and commercial transport aircraft, unmanned air systems, mission systems aircraft and modern aerostructures for airlines.
Alenia Aeronautica is subjected to many factors that push toward new competitive positions and toward a reorganization of the company value chain. The main are: the global collaborative Environment as constraint, the growing competition from emerging countries, the project team more and more de-located, the Alenia Aeronautica multiplicity role according to the various programs, significant increasing of activity plan, …

To answer to the above factors Alenia Aeronautica, on the 2007, started a PLM Project named AleNET.
AleNET is a turnaround project focused on designing and implementing an extended enterprise operating model, that enforces Alenia Aeronautica as "global player", with the aim to:

- Increase of productivity with an enlargement of products portfolio and manufacturing volumes
- Reduce Time to market
- Develop costs reduction
- Develop risks control and mitigation
- Increase of efficiency and revenue margins
- Improve competitiveness
- Improve quality and stakeholders satisfaction
- Improve supply chain management

Other benefits, less tangible, but even stronger affect improvements of strategic competences, management and capitalization of the knowledge.

The PLM exploit leverages and drivers to modify processes, methodologies, organization, competences and infrastructure through the following elements:

- *extended enterprise* –establishing since the early stage of the product lifecycle (conceiving phase), an open environment to supply chain (partners, suppliers and customers) in which the resources involved can share information and develop integrated solutions with multi-disciplinary approach. In this way, any choice will be defined by considering all relevant aspects of the product, the performance characteristics, the implications of construction, operation and maintenance;
- *concurrence* – by defining the degree of anticipation of the processed information and the associated type of activity authorized to valley; in particular it is important to define the operational modalities to early release the components in the long lead time procurement;
- *collaboration* - in analogy to the concept of extended enterprise, the open environment will include ways of working and involvement of internal resources in cross-functional view;
- *digitization of information* – by developing methodologies, applications and infrastructure to enable the acquisition and sharing of the company information;
- *multi-disciplinary integration* - in order to cover the entire product lifecycle, from exploration of needs, requirements analysis, implementation to operational use, in a view of the integrated system, including human interfaces machinery, infrastructure and environmental issues;
- *virtualization (and simulation) of the product* - across the board overseeing the entire product lifecycle, through a structured process (such as through the modeling CAD / CAE and Manufacturing Engineering);
- *virtual and physical prototyping* – by ensuring that the virtual prototyping is covered in synergy with the

experimental activity and providing integration and correlation, reducing risks and costs of development. In the trend, virtual and physical prototyping approach composes a single, integrated platform for the validation and certification of the product;
- *knowledge management* - providing the necessary operating procedures and applications to enable the capitalization and sharing of know-how in cross view on programs and functions;
- *lifecycle management* - to allow the timely and effective measurement of benefits throughout the lifecycle of the product.

2.1 Main environments considered

Requirements management

The product requirements are managed by reproducing the hierarchical structure and ensuring the traceability along the deployment and through evolution.
In addition, the requirements are related to parts of the product (interoperability between requirements management and configuration management) and related validation activities. In this way, all the impact diagnostics analyze the result of a requirement change and/or a modification of the product. The requirements cover all the implications of the product, from the performance, realization, operations and maintenance points of view, in correlation to the functional view, to flow down to the technical choices. The requirements management crosses the entire product lifecycle, starting from the exploration stage of need and product design, following the development of work-packages and changes. In this way, the data implementation (e.g. costs and time) allow you to build the knowledge base to support the budgeting and acquisition of successive contracts. As a reference characteristic, the V-Model is applied in terms of development along two main directions of requirements decomposition and product integration, crossed by the conformity verification at each evolution stage of aggregation.

Early release and management of the concurrence

The design phase is a crucial moment in the lifecycle of the product, since this stage foresees the choices that deeply mark later on the degree of industrial success. In this stage the changes are easy because the product is not yet defined, but then they become hopelessly expensive in advanced stage of maturity, if necessary to compensate for a bad choice. The design phase is supported by an environment of collaboration in cross-functional and extended enterprise view, open to the supply chain. The involved resources, therefore, will share information in accordance with their respective security access rights and develop integrated solutions with multi-disciplinary approach. In this way, each choice will be defined by considering all relevant aspects of the product, the performance characteristics, the implications of construction, operation and maintenance. In coherence with the collaboration, the concurrence is developed, defining the degree of anticipation and the associated type of actions enabled downstream. In particular, the operational modalities are defined for the early release of the components in the long lead time procurement. The following benefits are perceived throughout the lifecycle of the product:
- the various design disciplines have visibility on the defined parts and the associated operations authorized to the actions downstream;
- The industrialization receives and processes the parts defined by the design;
- The procurement have visibility of parts and, depending on the level of maturity, develops the actions authorized downstream.

Testing

The PLM approach covers all aspects of the testing of the product, focusing on the following main aspects:

- ***Lab and production testing management :*** The test article is managed with the associated experimental infrastructure (instrumentation and equipment acquisition) and relevant documents to support the activity (e.g. test plans, test procedures, test reports). The physical testing is increasingly linked and integrated with the virtual platform, to maximize consistency and minimize the commitment of the experimental activities, coming to the development of virtual testing.

- ***Ground and flight testing management:*** The PLM approach covers the management of the prototype with the associated experimental infrastructure (instrumentation and equipment acquisition) and relevant documents to support the activity (e.g. test plans, test procedures, test reports). The experimental activity is developed in correlation and consistency to the virtualization techniques. Finally, the integration and acceptance tests are managed, including all compliance testing of the product.

- ***Configuration and management of test environment:*** The PLM approach covers the configuration management of test rigs, test equipment, test articles and prototypes with the associated instrumentation integrated for experimental activities. It will include not flyable products (e.g. flight simulators), relevant to the purpose.

Configuration management of simulators to be delivered

The PLM approach covers the configuration management of flight simulators that are to be delivered to the customer.

Schedule, budget and spending

The activities are tracked in terms of planning up to the spending, in order to gradually build up an asset of information to support subsequent budgets. In particular, it ensured the connection between change, planning, budget and spending throughout the process of evolution.

Digital Mock Up

The DMU becomes a carrier for the activities of design and is used as a support tool:
- for design (e.g. DMU is configured for the analysis of the clash);

- for design review (such as checking the interfaces between components developed by different suppliers);
- for concurrent engineering between design, manufacturing, production, operational support and logistics;
- for the analysis of accessibility, safety and human interface.

In the DMU perspective, the following aspects are considered:

- The DMU is developed and used in a way that represents all the components of the aircraft (structures and systems) with impacts on integrated hardware and software;
- The DMU is directly related to configuration management to follow the product in all its stages of development;
- The DMU is usable by the business functions and supply chain, allowing the sharing of information according to security access rights and encouraging collaboration in multi-disciplinary environment.

Fig. 1 – Design review process

Model Based Definition

MBD methodologies are based on the CAD system in order to fully define the product information in the 3D model. This context, therefore, includes both the general design rules consistent with the model of concurrent engineering and the strong interdependence between the simulation and CAD modeling, and specific rules to be adopted in different technologies (sheet metal, machined parts, wiring, etc.)

Simulation

Virtualization and simulation of the product cover the whole lifecycle, through a structured process to manage the following main aspects:

- ***Multi-disciplinary simulation:*** Virtual prototyping reproduce the characteristics of the product, in terms of behavior, performance and implications for development through an integrated multi-disciplinary environment. The scope covers the entire product lifecycle from exploration of the needs, requirements analysis, implementation to operational use, in a view of the integrated system, including the human-machine, infrastructural and environmental interfaces. The virtual prototype is developed in synergy with experimental activities, ensuring correlation and integration, reducing risks and costs of development. In the rend, virtual and physical prototyping composes a single, integrated platform for the validation and certification.
- ***Systems simulation:*** The simulation reproduces the behavior of an integrated system, representing the mechanical, electrical and software characteristics. The virtual platform is modular and open to the supply chain, allocating the contributions throughout the hierarchy chain from the component up to the complete system. The simulation also cover more specific needs, with particular attention to the development and traceability of the software. Nowadays the exploration looks at the compatibility and the trend towards the tools/ methods/ formats/process (e.g. SysML, Systems Engineering) new standards, pursuing an integrated approach with the other aspects of the system simulation in general, up to the concept of systems of systems.

- ***Operation simulation:*** The simulation reproduces the main operational aspects of the product, considering implications of service and maintenance. In particular, in this context, the integration verification among products, people and infrastructure are important for the business commitment.

- ***Simulation Data Management:*** The simulation data are managed, including CAD models, CAE and CAPP, in correlation to the DMU and configuration, along the entire lifecycle. The govern of the development process is ensured through a scenario of collaboration in the enterprise network extended to the supply chain.

- ***Multi-disciplinary integration:*** The process of multi-disciplinary simulation is one of the most innovative areas with significant implications on business through the following main operational impacts:
  - o Management of simulation data (virtual and physical) in the product structure, consistent with the parts/systems to which they are associated;
  - o Multi-disciplinary simulation of a configured product;
  - o Management of requirements and performance demonstrated through virtual and/or physical testing;
  - o Management of the correlation between modification of the requirements, change in performance expectations and tuning of CAD/CAE/CAPP platform, relying on the parametric-associative logic;

RMTS management
The impact of PLM approach is also significant on aspects of product support that is becoming increasingly important within the business. It ensures the management of the defect report through a process extended to the supply chain, until the closure of the investigation. The aspects of maintainability and testability of the product are covered since the stage of conceiving. The integration test results, the quality checks, the waivers, certificates of conformity are also managed, ensuring the traceability of data. Finally, the context covers the activities of troubleshooting, fault isolation, and functional performance degradation resulting from the failure. Finally the associated information feed the knowledge management and enable continuous improvement.

Product concepts and prototypes
The PLM approach requires management of prototypes, technical studies and preliminary design to support the conceiving phase which has a significant impact on product development:

- Simplified configuration management in order to avoid excessive phasing of the development process which is dominated by the flexibility and reactivity, not having immediate impacts on production processes;
- Structured management of information developed in the upstream stages of product development in order to capitalize the knowledge, even with regard to technical solutions that do not result in a development;
- Management of the link between detailed and preliminary design, in order to not allow duplication, inconsistency and inefficiency.

Industrialization
The PLM approach pursues the industrialization objectives through the coverage of the following aspects:

- ***Manufacturing processes and verification management: t***he definition of the cycle of production/assembly, its use in the factory are based on the 3D CAD model. This context will avoid duplication and ensure consistency between product configuration and the manufacturing process. They innovation also simplifies the procedures for description of the cycle, relying on three-dimensional models and movies that make faster the path on the learning curve for the workers involved in the assembly line.

- ***Tooling management:*** Similarly to the working cycles management, the link with the valid configuration increases both the effectiveness and the efficiency of the process of defining and modifying the tools in concurrent engineering and with the contribution of the supply chain.

- ***Digital manufacturing:*** The definition of the production process are developed in concurrence with the design of the product and focused on the following main aspects:
  - The definition of optimal layout;
  - The definition of the assembly sequence;
  - The optimal flows of the materials;
  - Simulation of the assembly sequence.

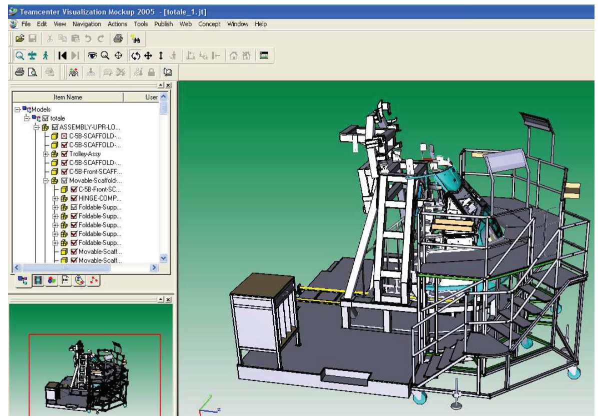

Fig. 2 – Tooling design management

Management of indicators for process/program and metrics
The revision of the model of the product lifecycle takes into account the definition of process indicators that allow to control the progress, crossing the information of development with the progress of the project timeline.

Document management
The context covers all the activities related to the product documentation, such as naming, template, type, classification and workflow for the issue and change. However, the new process of product lifecycle management assumes that there is close correlation between the product structure and associated documentation.
The implementation considers the needs of longevity date since the documents must be available and searchable, regardless of the tool of generation, even for the duration of a program that normally spans several decades.

Knowledge management
The PLM approach through the integration of aspects of strategy, technology, process and change management reinforces the capability of knowledge management, increasing the explicit knowledge within the company.

Configuration management
The PLM approach allows to manage the configuration of the product throughout its lifecycle and define its evolutionary stages through the coverage of the following representations: Functional Allocation or As Conceived, As Designed, As Planned, As Built and As Maintained

Configuration management integrates parts of the structure, systems and avionics onboard systems including electrical and software aspects, covering the following areas:

- Management of the configuration links to data and documents, such as technical notes, project

specifications, models, procurement information, evidence of qualification, test procedures;
- Management of materials, standards and equipment;
- Management of product information, combined with the configuration views;
- Integrated management of individual parts or branches of product structure assigned to external suppliers;
- Correspondence between requirements management, product configuration and evidence of compliance;
- Change management in their development and in cross-functional approach and with the contributions of the supply chain;
- Management of the change boards and DMU reviews;
- Management of data for certification and delivery to the customer;
- Management of AGE (Aircraft Ground Equipment), ASTA (Aircrew Synthetic Training Aids) and Ground Test Equipment, LRU (Line Replaceable Unit).

2.2 Benefits

The PLM approach leads to significant benefits in the tangible and intangible assets. The main targets for improvement identified quantitative parameters affecting the efficiency and effectiveness in the following areas: Times, Costs, Quality and Information Technology. In this view, there are the benefits associated with managing off-load and supply chain that will become even more substantial to affect hugely the business performance.

Time
The reduction is considered in the context of the processes “end to end” and compared to the reduction of “time to market” considering the overall permanence of the product in its production flow. In this context, the benefits reported a reduction of at least 15%.

Costs
Costs are grouped into the following categories: Costs of design and development and Costs of industrialization and production

- ***Cost of design and development:*** The cost benefits of planning and development are assessed as impact on hours in the comparison between budget and final accounts. The following effects are estimated:
  - Reduction of activities related to the revision process are about **-10%** on hours for Programs with HIGH impact and **-5%** on hours for Program with LOW impact

  - Reduction of non-recurring activities are about **-15%** on hours for Programs with HIGH impact and **-5%** on hours for Program with LOW impact

Additional benefits that are not measurable benefits, but can induce a huge impact on the business refer to the intangible assets: improvement of the culture, improvement of the capability, certification of processes (e.g. CMMI), capitalization of the knowledge and Change Management.

3. THE PLM ANSALDO PROJECT

Ansaldo Energia (AEN), company of Finmeccanica Group, is the Italy's leading producer of thermoelectric power plants including process, mechanical, civil, installation and start-up engineering. The production centre is split into three product lines: gas turbines, steam turbines and generators.

The Product Lifecycle Management is a strategic approach aimed to the management of the information, processes and resources in order to support the product life cycle, beginning from its conception, through the design, manufacturing, until sales and service.

Through the years AEN has implemented a complete PLM Solution starting from design, to configuration management, classification and product configuration, document management with the future goal of extension of PLM platform on MRO and In-Service management. All applications and business areas are based on a single platform with many benefits in terms of economic and organizational efficiency. AEN today operates on a single PLM platform managing 3D CAD data with related product structure and product configuration, integrated with change and configuration management. CAM data are completed integrated with engineering data bringing to the production area all relevant information to operators through “totem” data visualization 2D, 3D, notes, production information etc.

One of the most important phase of the PLM Project has been the recent implementation of the manufacturing data management and the integration with ERP.

Ansaldo Energia had the issue of having to cope with manufacturing technical data spread in non-integrated multiple systems resulting in difficulty in the reuse of data and lack of structured validation processes. After the implementation a controlled and structured management system for data and related processes has been delivered to Manufacturing: Routing cycles, Methods, Documents, Tapes, Tools, Tool assemblies, Equipments, Work Places, Specs are now all integrated and interrelated into a single source of managed knowledge.

The last major development has been the recent implementation of a project to manage simulation data and analysis results in the same unique PLM platform.

With this in place AEN has now a truly collaborative managed environment to control and distribute knowledge across the entire enterprise.

Then this involves an integrated approach based on a methodology of collaborative work and team organization starting from the engineering processes definition.

The role of the Development Engineering during the conception phase of a new product is crucial to achieve success over the whole lifecycle process.

In general, the know-how of the people involved in the Development Engineering is available in the form of models, algorithms and data of different key-disciplines as aerodynamics, heat transfer, mechanical integrity, combustion, materials, etc. For this reason the use of these topics in the multi-disciplinary processes is often difficult due to the incompatibility of the concepts, differences in notation, in informatics languages and in IT platforms.

Here-hence the need in the defining and in the managing of the processes and simulation data so that they can always be tracked, traced, referred to the product requirements and available by all the users operating in network on different disciplines involved in the product design.

The target of introducing the Product Lifecycle Management in the Development Engineering is to manage, improve and accelerate the multidisciplinary simulation processes in field of product innovation, since its design conception, in order to obtain the best product in terms of upgrade, performance and quality.

The Ansaldo PLM project is started in Development Engineering Dpt. since it has gone from the engineering's organization structured in disciplines, e,g. Centres of Excellence, to one where the teams operate in a multidisciplinary context and the turbomachinery components are the focus of the process design.

In general, there are two aspects that characterize the engineering's:

- the know-how in the form of models, algorithms, tools for the simulations, data coming from the various disciplines: aerodynamic, heat transfer, materials, mechanical integrity, combustion, etc.Often, the exchange of data is not agile because of the incompatibility of the concepts, differences in notations, implementation languages, platforms and sometimes the conflicts among the operators
- the processes: generating a large amount of information/data/simulations and for this reason there is the need to improve and accelerate the exchange of data, that is able to operate in an environment of Collaborative Engineering.

Hence the need to define and to manage the processes and the design data so that they can always be reachable, secure, accessible to all the users operating in the network on various disciplines.

To define this new methodology three pilot projects on the data and processes management have been carried out.This project aimed to extend the PLM in the Development Engineering, consists of introducing:

- A **process management** system, that will allow to all the multidisciplinary team experts to work using shared design procedures, following an established design activities flow, applying shared tools and simulation database. It makes also possible the automation of the design processes and, subsequently, carrying out *multidisciplinary & multi-objective optimization*.
- A **simulation data management** system, that will allow to ensure the basic properties, such as:
  - *Uniqueness*: data are reliable, unique and officially issued
  - *Traceability*: data are located in the simulation process. Every user knows anytime the data road map bottom-up or top-down, who produced the data, the creation date, the used software tools and the issued release.
  - *Sharing in real time*: data are available in the last version at anytime.

3.1 Project Description

The introduction of the PLM allows the Development Engineering to gather and manage reliable simulation data and processes of all the key disciplines in the design activities and to use them in best way.

Thereby, this methodology enables to improve the effectiveness in the whole design process as well as to ease the knowledge communication in the work teams among who have issued the data and who have to use them.

The aim of the proposal is to bring in Development Engineering a high degree of innovation through the PLM in order, on the one hand, to manage, upgrade and speed-up the multidisciplinary design processes focused on the product innovation while, on the other hand, to make the best use of the synergies amongst the team works, the experiences and the skills of the users.

So, in order to achieve the previous results the following few specific requirements have been specified:
- the capitalization of the technical know-how and know-why on the key-disciplines
- the development of an ICT environment for the collaborative engineering processes
- the simulation data management
- the management and automation of the process flows
- the mono- and multi-objective optimization of the design solutions

3.2 Status

The introduction of the PLM in Development Engineering must be considered useful in order to meet the competitive marketing in the energy field.

To do it in the energy industry, and in particular in **Ansaldo Energia**, three pilot projects have been launched on the gas turbine product development, each of which committed to a multidisciplinary team and focused to a benchmark of the design in collaborative environment.

The outline of the three pilot projects is shown in Fig.3.

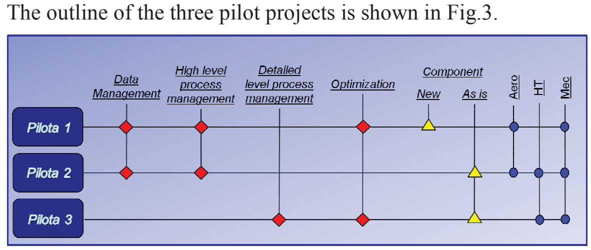

Fig. 3 – Outline of the Pilot Projects

The pilot projects are planned in order to cover all the topics of interest, in terms of data and process management, optimization, and to include both the existing components (*as is*), on which the *re-engineering* is performed, and new design components *(new)*. The involved components are compressor and turbine blades.

The pilot projects are:

– **Pilot 1**: data management and optimization process on airfoil of a 'new design' of a compressor blade

Involved disciplines: aerodynamics and mechanical integrity
Target: process and data management of a compressor blade

– **Pilot 2**: data management of an existing turbine blade 'as is'(CAD 3D models already available in the repository area)
Involved disciplines: aerodynamics, heat transfer and mechanical integrity
Target: data management of a gas turbine cooled blade

– **Pilot 3**: optimization of an existing turbine blade 'as is'
Involved disciplines: heat transfer and mechanical integrity
Target: optimization of the internal cooling design

On the current stage the main phases of this iniziative are here below listed:

- investigation in literature and analysis of proposed methods
- capitalization of the knowledge through the drafting of the Design Practices
- design software tools census and their interaction
- installation of a high performance hardware environment
- acquisition and installation of commercial software tools for the collaborative engineering
- training on the job of the multidisciplinary working teams
- development of design real cases in the collaborative engineering environment (pilot projects)
-

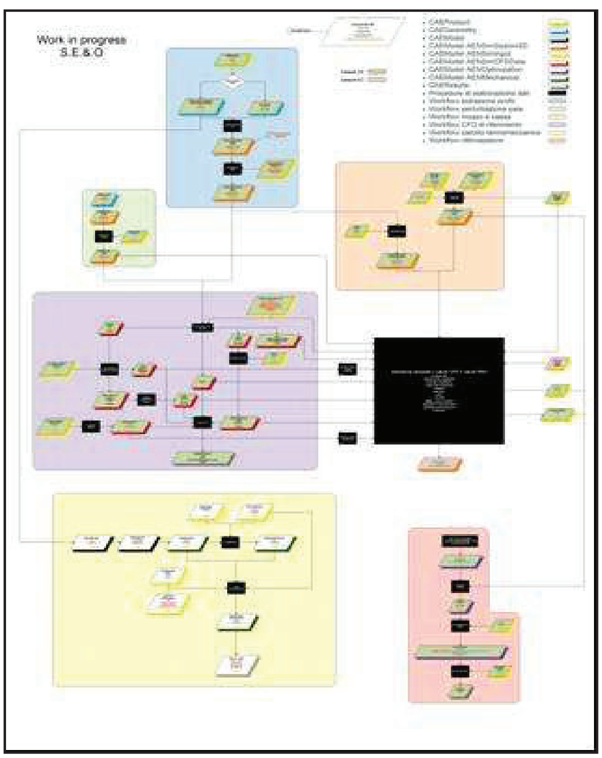

Fig. 4 – Example of process carried out

3.3 Results obtained/obtainable

The introduction of PLM approach in Development Engineering leads to remarkable benefits in tangible and intangible assets.

The most observable profits of the PLM in Development Engineering are hereinafter listed:

- **Sharing of the Company Know-how:** This outcome is not easily measurable in terms of return of investment, even though it is definitely a key factor in a Company ever-growing. In particular, in the Development Engineering the know-how spreading is a crucial point in order to release rapidly new optimized design solutions.

- **Data Generation, Management, Traceability:** Be able to gather easily and clearly the information concerning analysis and reports previously carried out gives undoubtedly a relevant profit in terms of times reduction even in the future works. Essentially this benefit involves the adopted practices by the reusing both the design processes already implemented and the results already obtained.

- **Design Processes Standardization:** The generation of standard processes, made official and shared amongst the users, gives a profit in terms of time reduction due to their repeatability by the side of the users operating in network.

- **Optimization of the Design Process:** Tangible reduction in the computing times of the design processes is achieved by the improvement of the hardware platform, through a computing cluster driven by the standard processes, and by the implementation of optimization tools, based on the most updated optimization techniques.

Starting from the experience of the pilot projects and taking into account the different types of application (data and processes management, optimization) a time reduction in the engineering design processes is estimated approximately around **10-15%,** which are consistent with the valuations available in open literature.

In fact, the hereinafter Table 1 shows the estimation of asset improvements coming from the application of the PLM in Development Engineering and confirmed by sources in open literature.

Table 1- Estimation of asset improvements

Task	*Benefit*
Time to Market reduction	Time reduction: 10-35%
Product cost reduction	Cost reduction: 15%
Improvement of quality	10-25%
Components re-use	Increase contents of re-use: 20-40%
Documents management Archiving and search	Effort reduction: 20%
Signatures and Approval procedures	Effort reduction: 5%
Checks of progress and Design Review	Effort reduction: 5%
Standardization	Effort reduction: 15%
Data exchange	Effort reduction: 20%
Implementation changes	Time reduction: 15%

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