An Engineering Data Management Framework for Virtual Aircraft

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Abstract: Today, Concurrent Engineering activities during an Aircraft development programme are mainly organized around a static representation of the product: the Digital Mock-Up (DMU). The Engineering data related to this static representation are made of engineering objects such as CAD models and drawings, assembly drawings, space allocation models, bill of materials, etc.

To manage these data the Aeronautical Industry is currently moving to commercial Product Lifecycle Management Systems. This move is considered as a complex one as the aim is not only to support the product representation using configuration management methods but also to manage the related collaborative activities, modification and decision making processes.

Within the VIVACE European Commission 6th Framework Project, the step beyond addressed by EDM (Engineering Data Management) is to manage engineering data in a broader perspective. Indeed the static data currently managed in PLM systems is only one part of the whole engineering data. Engineering data can be split into three domains:
- requirements domain gathering requirements related to product capabilities, performance and behavior,
- product domain gathering product information,
- simulation domain gathering data related to product environment and enabling the analysis and validation of product definition regarding the set of identified requirements.

It is considered that the adoption of shared simulation data management capabilities by Aircraft development partners will lead to a significant enhancement of the development process.

In this context the objective is to develop an innovative EDM framework enabling extension of today's DMU-oriented data management methods to the management of a full distributed modeling and simulation environment lifecycle (Virtual Aircraft / Virtual Enterprise).

This paper focuses on the firsts EDM results. After the presentation of the VIVACE Project, the EDM Framework and concepts will be described and illustrated through a business Use Case from Engine and Aircraft Manufacturers that need to collaborate and to share requirements, product and simulation data throughout the life cycle starting from the early phases.

Keyword: Virtual Aircraft, Engineering Data Management, Product Lifecycle Management, Simulation Lifecycle Management, Domain Models, Product Context Management, Business Process

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**Introduction**

Collaborative design and data management processes from the early phases of a project have become crucial for faster, better product development. Within the context of the extended enterprise, the product is presently developed by several partners [5, 6, 9]. In this context, data exchanges and their management between the different partners and through the different activities have increased the need to create supporting “collaborative platforms”.

A collaborative platform appears now as a necessary element to enable data flow between applications used in enterprises [1, 3, 8]. The heterogeneity and diversity of software used during the different phases of a product development have increased the need for a “collaborative platform”. Their role is to enable the interoperability and the associativity of the different data to be created and managed. When considering PDM (Product Data Management) systems, these aspects are characterized by the fact that data created, exchanged and integrated must have exactly the same semantic objects (for PDM mainly considered as product meta-data and attributes). As the number of attributes attached to the product is also increasing with the evolution of data management requirements, data exchanges and management between partners need more complete interfaces. As a consequence, there is also an increasing need to provide control on data processed through these systems.

Data management systems and “collaborative interfaces” (such as middleware) are facing two major issues [2, 4]:

- The capability to enable the semantical parsing of data. This issue relies on the capability to define and extract the collaborative and semantic objects so as to re-export to partners and activities that need them.
- The ability to contextualize data. This issue relies on the capability to determine the context in which data has to be processed.

In a context of a proposed collection of middleware and collaborative hubs for data solutions, we propose the definition of a non-invasive architecture (means that “in house” configuration of the partners are not impacted) based on the modeling of context and data models of tools [1, 3]. This is based upon the work done within the 6th framework project called VIVACE (Value Improvement through a Virtual Aeronautical Collaborative Enterprise) that involves most of the large aeronautic enterprises in Europe. The approach used by the Work Package Engineering Data Management (EDM) of this project is motivated by the fact that data is not still well integrated and interoperable within the different partners’ systems. After the presentation of the VIVACE project, this paper focuses on the EDM Framework concepts developed to enable a multi-levels collaborative design and illustrates these concepts through a business Use Case for Aircraft and Engine integration.

**2 - The VIVACE Project**

Reducing time-to-market and lowering production costs are the key drivers for all successful manufacturing companies. These objectives lie behind the Airbus co-coordinated “Value Improvement through Virtual Aeronautical Collaborative Enterprise” (VIVACE) project [11].

This four-year project – co-funded by the European Commission – was launched in January 2004. It brings together 63 major partners (including 9 SMEs) forming a representative set of the European aeronautical industry. The overall objective is to achieve a 5% cost reduction in aircraft development and time reduction in the development phase of a new aircraft design, combined with a contribution to the 30% reduction in the lead time and to the 50% reduction in the development costs for a new or derivative gas turbine engine.

To achieve this, the work in VIVACE is organized around Use Cases, i.e. real industrial simulations of a part of the aircraft, the engine or a development process, reflecting both the Virtual Product and the Virtual Extended Enterprise. Both include requirements for early product simulation on the one hand and distributed working methods on the other hand.

VIVACE comprises three technical sub-projects as described below. Two of the projects represent the aircraft and engine manufacturers and the third project will ensure the integration of component frameworks developed by the first two into an advanced concurrent engineering design framework — the VIVACE Collaborative Engineering Environment. In the end, VIVACE will deliver a Virtual Product Design and Validation Platform based on a distributed concurrent engineering methodology supporting the Virtual Enterprise.
Virtual Aircraft Sub-Project (leader: Airbus)
The Virtual Aircraft Sub-Project revolves around the main components that constitute an aircraft and has six integrated technical work packages (System Simulation, Components, Global Aircraft, Flight Physics Simulation, Complex Sub-systems, Supportability Engineering). It is designed to cover the aircraft product throughout the development life cycle (design, modeling, interfacing and testing).

Virtual Engine Sub-Project (leader: Rolls-Royce plc)
The Virtual Engine Sub-Project consists of five integrated technical work packages performing fundamental research to provide for a competitive European jet engine industry, working across extended enterprises (Extended Jet Engine Enterprise Scenario, Life Cycle Modeling within the Virtual Engine Enterprise, Whole Engine Development, European Cycle Programme, Supply Chain Manufacturing Workflow Simulation). It will develop the different engine modules of the aircraft propulsion system and key areas of multi-disciplinary optimization, knowledge management and collaborative enterprises.

Advanced Capabilities Sub-Project (leader: EADS CCR)
The Advanced Capabilities Sub-Project is a key integrating work area that will develop common tools, methodologies and guidelines. Its six technical work packages provide cohesion between the first two sub-projects through activities that are generic and common to both (Knowledge Enabled Engineering, Multi-Disciplinary Design and Optimization, Design to Decision Objectives, Engineering Data Management, Distributed Information Systems Infrastructure for Large Enterprise, Collaboration Hub for Heterogeneous Enterprises).

The critical size of VIVACE and its integrated platform structure are helping its deployment of results toward the European aeronautical supply chain and in particular toward the small and medium suppliers.
EDM Framework

The EDM (Engineering Data Management) Work Package is part of the Advanced Capabilities Sub-Project. The major goals targeted by EDM framework activities are to provide:

- **A non-invasive framework**: Enterprises have already an “in-house” environment running with their processes. The objective of such a framework is not to replace existing environments but, to provide an interoperable “middleware” that should be able to integrate the existing tools and methods. EDM framework proposes an add-on based solution to complete user environment features provided by PLM & SLM (Product Lifecycle Management & Simulation Lifecycle Management) COTS and legacy tools. This approach leads to define, from the different environments involved, accurate domain models to enable a scalable interoperable environment, at multi-partner, enterprise or discipline levels.

- **A standard based ontology**: This is the major topic to set an interoperable environment. Heterogeneity of semantic and format makes that business concepts described in domain models are not exploited in the same way from one environment to another. EDM framework targets enabling domain interoperability by using a semantic reference based on standards. XML and STEP provide mechanism to describe and to exchange the information involved in collaborative activities.

- **Services to provide information in context**: Within the interoperable environment, in order to use efficiently any kind of data exchanged or shared, the associated context must be known at each moment. The context identifies the data and provides a way to localize all the information associated to this data: Product, Process and Resources. EDM framework proposes an Information Model that provides the context of usage for each data involved in an activity.

In order to reach those goals EDM proposes innovative concepts that will enable:

- Management in context of heterogeneous data (Design & Simulation data)
- Persistence of accurate information for exchange & sharing
- Management of business process between partners, domains and disciplines

### 3.1 - EDM framework concepts

#### 3.1.1 - Interoperabilities at four levels

Four levels of interoperability needs were identified during the analysis phase of the different VIVACE use cases:

- The first obvious need of interoperability in VIVACE concerns the link between Design discipline from one side and Simulation and Test disciplines on the other side. EDM framework tries to create a bridge between heterogeneous Design and Simulation (and Tests) environments: that means services to integrate existing tools and services to support business processes. Actually Engineering Data Management creates a bridge between Product Life Cycle Management and Simulation Life Cycle Management.

- The second need of interoperability is between product and process. This interoperability is strongly linked to the context of information. EDM framework tries to manage a product context above any information published by a user. This context provides on any information a link between product, process and also resources associated to this information.
The third need of interoperability concerns multi-domain links (mechanical, aerodynamic, thermal, system...). EDM framework provides the interoperable environment to publish the necessary sub-set of Domain Models for multi-domain activities. EDM framework proposes within this interoperable environment the mechanism to consolidate (fully or partially) the different Domain Model in a Standard Consolidated Repository. In the case of a partially consolidated Domain Model, the Standard Consolidated Repository is seen as a dictionary of common references.

The fourth need of interoperability concerns multi-partner links in the context of Extended Enterprise. Typically in the VIVACE project the multi-partner interoperability need is common to all the use cases dealing with the collaboration around the Engine program, and also in all the use cases dealing with collaboration around Engine-Aircraft integration. EDM framework must provide interoperability mechanisms that facilitate exchange between heterogeneous environments in terms of size and solution and must also provide a solution compatible with confidentiality issues between partners.

3.1.2 - Product Context Management

In order to ensure the different levels of interoperability, the Product Context Management was developed and provides a set of concepts:

- The Information Model,
- The Domain Model,
- The Consolidated Repository.
The **Information Model** represents the key point of the framework. Its major role is to provide navigation services and persistence services to manage the context of the information and its related usage. The context defines implicit and explicit links between Product, Process and Resources involved in the engineering activities [10].

The **Domain Model** represents the published sub-set of a complete skill Data Model. The Domain Model represents the Information to exchange or share when performing collaborative engineering activities. It enables the interoperability between disciplines (design, simulation, test), between domains (mechanical, aerodynamic, thermal, system) and between organizations (within or without enterprise).

The **Consolidated Repository** represents the whole collaborative product data repository for a project. Domain Models are consolidated in a common Consolidated Model expressed in standard format (identified as STEP and using description from PLCS). This consolidation can be partially achieved; in this case the common Consolidated Model is seen as a common references source for the Domain Model. The consolidation can also be fully achieved; in this case the Domain Models share a common standard format and semantic, global services such as check and optimization can be perform at the whole project level.

Traceability of Process in the context of the Product Life Cycle is managed by the Product Context Management component of the EDM architecture. The Product Context Management takes into account the “static” management of the Process by recording the activities log performed on a product with the resources involved in it. The “dynamic” part of the Process Management is provided by a Process Management component, typically this role is assumed by a workflow engine.

The Product Context Management component offers interoperability services to enable the integration of “in house” user environment.
By an external reference mechanism Product Context Management is able to keep a link on proprietary information managed by COTS, legacy application or process management system. The information exposed in the Product Context Management are the necessary subset of Domain Model to perform integrated activities, the user of the proposed system is responsible of the definition of the subset he wants to expose. Nevertheless, the link to the proprietary environment from which they have been extracted is maintained by the Product Context Management.

3.2 - **EDM framework architecture**

The EDM framework concept described previously is deployed in a logical architecture composed of three layers:

- A layer dedicated to **Process Management**, the operational and collaboration layer that contains the activity tools (COTS, legacy tools and portals)
- A layer implementing the **Product Context Management**.

![Figure 8 – EDM logical architecture](image)

The Process Management layer provides the dynamic aspect of the Process in term of workflow implementation, tools communication and interoperability. The operational tools are, for the Design activities, PLM systems coupled with CAD and DMU applications and for Simulation and Test activities, SLM systems coupled with CAE facilities. As EDM frameworks target integration and not substitution of these tools, the Product Context Management supplies connectors to communicate with PLM & SLM environments. The connectors are based on Web services and enable the exchange of Information that needs to be consolidated. The activities shared by different partners, different domains or different disciplines, are performed in collaboration tools. The collaboration facilities are demonstrated in EDM framework with the dedicated user interface (PCM UI) and with communication established between Product Context Management and applicable portals realized in the scope of VIVACE. The Product Context Management layer constitutes the infrastructure of EDM framework architecture, it is composed of:

- communication component offering Web services to build connectors with operational and collaborative tools,
- Information Model component (associated with the Information Navigator service) that offers the contextualization of information (Product, Process, Resource, applicable knowledge, Decision …),
• Domain Model component that provides a frame for each domain or discipline to publish and share the Information needed for collaborative tasks,
• Consolidated Repository that provides a frame for multi-domain consolidation of information in a common semantic: PLCS [12]

While looking at the industrial constraints our developments must be managed under four major rules.
• Use a standard so as to develop the interoperability between the different data
• Provide a non-invasive structure so as not to interfere with the partners’ “at home configuration”
• Develop a layer of collaborative services
• Create models for data relevant management and interoperability

Such constraints have encouraged us to turn to STEP (STandard for the Exchange of Product model data – ISO 10303) use. The use of such a standard to answer the different issues is motivated by the fact that some models have already been implemented in industry and that the application range is sufficient enough for the aeronautical industry. The use of the PLCS (Product Life Cycle Support – AP239) and application protocols such as AP 209 and related PART 42 and 104 provide enough semantic referential to develop a model between design and simulation for example. In the same objective the language of EXPRESS is consistent enough so as to provide a real architecture implementation [7, 12].

4 - EDM for mechanical simulation Use Case

Through a detailed Use Case Scenario, this part illustrates how the EDM Framework can be used to enhance the Engineering Data Management within an Extended Enterprise.
This scenario is built around the Whole Engine Model optimization loop, with a stochastic problematic add on, and with an Engine-Aircraft integration proposal. It permits to illustrate:
• Design & Simulation information consistency management for the Mechanical Domain
• Product Context Management
• Heterogeneous Workflows integration

A PCM UI (Product Context Management User Interface) is required to illustrate the concept of Product Context, Product – Process link and Information Model. The specification presented below, shows how the user of EDM framework could navigate on Information and how he could access to Product in the context of Process.

The first main operation allowed by the PCM UI is the context positioning to set-up the frame in which the user will interact with the Product Context Management system. The aim is for the user to focus on the Product (or Component) and relative activity he is interested in. The user, step by step, refines his context of work by setting a Project Context and a Process Context. Then the system, by using the Information Model, is able to retrieve pertinent and dedicated Information for the user.

The navigation is simplified for frequent users by the user workspace. The user workspace keeps a trace of previous contexts and allows the user to go directly to his current activities or to the product (or component) he is working on.

The second main operation allowed by the system is the access to the Information. From the context the Information Model retrieves the accurate Information, either by the Process (and the related Products are deduced) or by the Product (and the related activities are deduced). The layout of the user interface is organized to display:
• in the north and west of the screen the information relative to the Product and design activity,
• in the south and east of the screen the information relative to the Process and simulation activity.

This layout intends to support Product oriented and Process oriented use cases. It enables the illustration of collaborative activities between Design and Simulation disciplines.
4.1 - Use case analysis

The Mechanical scenario is a sequential high level process steering several operational sub-processes:
- PCM1, PCM2 & PCM3: Analysis and management tasks that realize the transitions between the operational sub-processes.
- SDM1: Simulation sub-process, that Perform a collaborative blade & disk analysis
- PDM: Design sub-process, that Perform a design modification
- SDM2: Simulation sub-process, that Perform a mechanical Analysis on collaborative data

Six different Design & Simulation collaborative activities are illustrated in the scenario:
- Collaborative Analysis on blade & disk
- Design change request
- Design Modification
- Simulation Request
- Check integration on Aircraft (Pylon + Whole Engine)
- Results Analysis

**Simulation Data Management 1:** Perform Collaborative blade & disk analysis
- Demonstration of Simulation Data Management Capabilities
  - Capabilities to use in-house solvers
  - Control simulation process from request to result
  - Control analysis run
- Perform collaborative activities
  - Information Exchange
  - Web services customization

**Product Context Management 1:** Analysis of previous simulation – launch of design change request
- Contextualization tool
  - Define global context of process
  - Control of interoperability and associativity of data
- Interoperability with COTS and Legacy
  - Web services call
  - Integration with tools (Enovia, SimManager…)

- Access User workspace
  - Select an activity
  - Visualize design and simulation report together
  - Close analysis task
  - Prepare the change request
  - Send change request
- Integrated environment is complete in terms of PDM and SDM
- Scenario optimization loop à (last step) End of first analysis loop
**Product Data Management**: Perform design modification

- Perform design and changes in context
  - Use of consolidated data for the collaboration
  - Manage access authorization
- Use in-house tools and configuration
  - Control of in house system preservation through the use of Web services
  - Standardized and directly operable data

- Consult workflow
- Perform change
- Close activity
- ENOVIA to program Enovia Workflow
- Realize modification in encapsulated interface of CATIA
- Close activity on Enovia workflow
- Web service to store updated file in EDM Called by Enovia workflow

**Product Context Management 2**: Design analysis & validation – Launch of simulation request

- Load pertinent data
  - Use of Domain model enables to get the relevant information
  - Access to last updated data
- Navigation facilitated
  - Capability to enter context with product structure or process definition
  - Web services queries

- Validate new design
- Design correct
- Interfaces respected
- Close change request
- Launch the simulation request
**Simulation Data Management 2 :** Perform Analysis on collaborative data

- Perform analysis with collaborative objects
- Interoperability design & simulation worlds

- Consult workflow/notification
- Run simulation workflow
- Close workflow (publish report)

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**Product Context Management 3 :** Analysis of the current loop

- Perform results analysis
  - Access to the different product reviews analysis...
  - Management of the links between Design & Simulation information

- Log on PCM UI
- Access User workspace
- Select an activity
- Visualize design and simulation report together
- Close analysis task
5 - Conclusion

Currently, major components such as data models, information models and the consolidated repository of the EDM architecture have been developed in order to provide the first approach on interoperable objects required for the framework to become reality.

EDM is then a set of new concepts that enable:

- Real and efficient Collaborative activities between:
  - Partners
  - Domains (Aerodynamic, Systems, Mechanical, etc.)

- Real management links between:
  - Design & Simulation worlds
  - Product & Process in order to work in context

- Persistence of all accurate related information for Collaborative Engineering activities

The demonstrator based on COTS integration shows that:

- Legacy can be integrated
- Skills can keep their autonomy (process & tools & data structure)

Furthermore, as EDM is based on STEP Standards for data sharing, the developed framework is open and permits any new integration.

With all other VIVACE project Work Packages, EDM will contribute to a significant reduction of the time to market and of the number of design loop iterations within the Extended and/or the Virtual Enterprise.

Acknowledgment
As this study is realized within a European project, we would like to thanks all the participants (and specially those from Airbus, EPM Technology, MSC Software and SNECMA) who helped us to develop this framework.

6 - References