A ROUTE TOWARD VIRTUAL CERTIFICATION OF AIRCRAFT

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Abstract

ACARE (Advisory Council for Aeronautics Research in Europe) Vision 2020 clearly established business objectives proposed to European Aerospace Industry, like noise and emission reduction or enhanced safety.

Taking advantage of their 40 plus years of expertise in the arena of Virtual Product Development, MSC.Software established Strategic Partnership with Aircraft manufacturers and their supply chain, and heavily invested in solutions enabling expansion of the Simulation role in the Airplane development lifecycle. The proposed target resides in the capability to better predict physical models, and systems behavior and control, which in turn limits re work activity, and ultimately opens the door to optimal design in the time to market constraints.

Such an initiative can be summarized by the establishment of Aircraft Virtual Certification.

In that respect, it is important to deploy a solution that will idealize the Virtual world Physics with enough accuracy. Virtual Development has therefore to step out of Discipline Based simulation of components on to Model Based representation of the Aircraft.

1 Introduction

In order to face Marketplace competition, Aerospace Industry is strongly introducing Virtual Aircraft Development approach in the context of Extended Enterprise. This accelerates the need for changes in today's concurrent engineering process that is 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, or Bill of Materials (BOMs). Such data are fully supported by Product Management (PDM) Systems that Industries have already started to deploy. This implementation effort already represents a complex work, as the aim is not only to deal with the product representation using configuration management methods (including effectively management), but also to manage the related collaborative activities and modification processes (change management, impact analysis, etc.). Full Virtual Aircraft Development requires even more ambitious solution as engineering data to manage beyond PDM scope include 3 additional domains:

- Requirements domain related to product capabilities, performance & behavior,
- Product domain for product information
- Test bed (simulation) related to product environment enabling validation of product definition regarding the set of identified requirements.

Adoption of shared simulation data management capabilities by Aircraft development partners will lead to a significant enhancement of the development process.

Engineering Data Management (EDM) Work Package, within the VIVACE European Commission 6th Framework Program, got assigned the objective to manage engineering data in such a broader perspective. By developing an innovative EDM framework, the consortium has enabled to extend the today DMU-oriented data management methods to the management of a full distributed modeling and simulation environment life-cycle (Virtual Aircraft/Virtual Enterprise).

In order to capitalize on one of the 7 wonders of VIVACE, MSC.Software invested in the industrialization of the components they developed along the curse of the project.
ACARE objectives for the next decade however remain even more ambitious. As publicly stated by Philippe Homsi, the VIVACE Program Manager, the goal is to move from virtual testing of sub-assemblies to Virtual Certification of an Aircraft. The latter objective is currently maturing along with the contribution of FP7 projects MAAXIMUS and CRESENDO.
The first of these two efforts now running since April 1st 2008 is aiming to a highly optimized structure in domains of:

- Weight
- Production rate and ramp-up
- Maintenance
- Structure/System integration

With high level objectives motto on "fast development right the first time" via

- High-Confidence Virtual Testing capabilities
- Robust Simulation-Based Design process on innovative technologies
- Integrated CAD-Analysis-CAM-NDI-Test process

The second one is moving toward subsystem at Aircraft level, and concept of Behavioral Digital Aircraft in order to contribute to:

- 10% reduction of design & development lifecycle time/cost
- 50% reduction in rework
- 20% cost reduction of physical tests

MSC.Software's role along this ambitious target mainly relies on SimManager technology to sustain the simulation lifecycle components and SimXpert capability to enable process capture & automation of engineering best practices.

2 Engineering Data Management

2.1 Engineering Data Model

As underlined by VIVACE scenario, Virtual Aircraft Development requires an Engineering Data Management platform enabling **several partners** (from aircraft, to engine, or landing gear) throughout development **life cycle** (from early conceptual and pre design phases to detailed validation) to **share requirement, product and simulation data**. In that respect simulation has a broad meaning, from the functional aspects, to the behavioural aspects as well as the geometrical aspects. Such a scope of data exchange to be shared across various partners and disciplines raises complexity of collaboration across a wide variety of heterogeneous software that have been selected for their strength in the niche domain they address. The targeted collaborative platform capable of real interoperability as well as data associativity appears then obviously as a non invasive environment relying on a strong SOA (software open architecture) to permit specific solutions integration.
Unlike PDM (Product Data Management) systems where data created, exchanged and integrated must have exactly the same semantic objects, the increasing number of attributes attached to the global engineering product and motivated by interaction between more partners, across more disciplines, drives the need to provide control on data processed trough targeted data management system that will have to face two major issues:
The capability to enable the semantic parsing of data; this issue relies on the capability to define and extract the collaborative and semantic objects so as they can be exploited by 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.

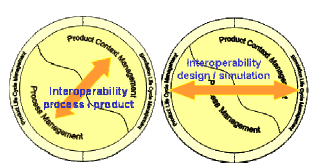

Figure 1: Interoperability at Disciplines & context level

2.2 Product Context Management

Master Key of the services developed by the EDM framework is the capability to manage information in context. The aircraft program lifecycle encompasses incredible number of data exchange between domains and disciplines, relying on very large series of tools, often fully deployed as in-house solutions. Information interpretation and or importance might vary from one specialty to the other, and adequate format has to be maintained as well as the pedigree associated to the data itself, in order to make it meaningful for the user. For instance how do I idealize loads on a structure for sizing purpose, global model validation, and detailed analysis and how do this relates to the initial requirements and potentially test data? This could cover several departments in my extended enterprise across which I have to maintain consistency even though they use several pre and post platforms, independent and specific solvers, domain approaches (virtual versus physical tests).

Ultimately the PCM (Product Context Management) will represent the management service taking care of the business context activity and the specific concerns of business users (application, with knowledge as a co-driver).

2.3 Information Model

In order to properly behave and distribute or track the flow of information, PCM requires somehow a global positioning system and its map. Such a navigation service is defined in EDM framework as Information model that is manipulating the multi-disciplinary engineering data domain in order to link product, processes, resources and applicable knowledge in order to convert it in a business activity input.

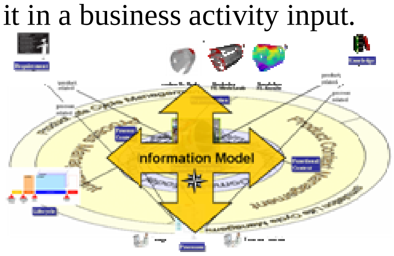

Figure 2: Role of information model in EDM

2.4 Workflow Engine

Now we hit the point of traceability associated to the engineering process. In other words, consistency and coherency in the sequences of actions the framework is controlling relies on a workflow engine.

2.5 Domain Model

Moving down to the domain application, we understand here, design, testing and simulation were we can define finer granularity, like thermal, structural, aerodynamics, multi-body analysis, with potentially deep coupling, we need to extract and manipulate information for the relevant subset of the domain ontology. Beyond scope of business interpretation of data, it empowers the user to bind information he needs to share in collaborative engineering with various stakeholders of the aircraft program through virtual &extended enterprise.

2.6 Interoperability

Interoperability in the aircraft development life cycle appears at several levels as underlined by the VIVACE EDM requirements and use case scenario. First of all bridging Design discipline with Virtual and physical testing highlights the need for collaboration between heterogeneous environments. EDM addresses such a request by the deployment of services supporting the business processes. The achievement is to link Product Life Cycle Management (PDM) with Simulation Life Cycle Management (SLM).

The second level of interaction resides in the duality between product and process. We already described how context of information and associated resources were taken care of by the Information Model.

The third aspect of interoperability has been identified by VIVACE as the multi-domain link. In the case of simulation it represents the possibility to exchange and share information across various analysis spectrums, like mechanical, aerodynamic, and thermal or system for instance. We also depicted the role of domain model validated by EDM framework, and we will see later in the presentation how such a concept has been industrialized in commercial solutions.

Finally the fourth level presented as multi partners links in the context of Extended Enterprise along VIVACE results is the commonly one understood as collaborative activity. VIVACE EDM framework provided solution to take care scalability of deployment, confidentiality and share ability of information, privilege access, and multi view filtering of the data.

2.6 Consolidated Repository

As we manage data (store, merge, exchange…) from different models and though various media and tools, the concept that has been leverage here, is to capitalize on standards format and protocols. The underlying idea is to consolidate the non invasive solution approach. We mean that none of the Customers of the Shelf (COTS), in-house development of specific module is impacted by the adoption of the EDM Framework, unlike some alternative options that promote and enforce usage of unique data architecture.
The choice adopter by VIVACE EDM Partners is to rely on STEP application protocol 239 (PLCS) knowing that Product Life Cycle Support is an ISO STEP standard (ISO 10303-239) enabling creation and management though time of an Assured set of Product and Support Information (APSI) that complies with complex product's life requirements.

2.7 User Case Scenario and Implementation

The Scenario elected for the EDM framework demonstrator can be summarized as follows:

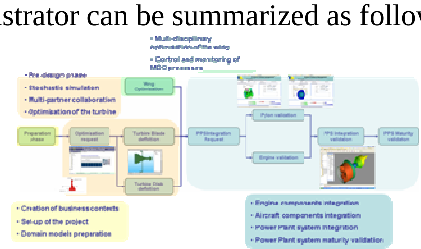

Figure 3: Overall VIVACE EDM Scenario

Instantiation of a program ignite the validation of a new engine, for which pre design phase followed by multi partner collaboration aiming to a turbine optimization will be ran:
Pre design starts before any Product structure is fully defined (before PDM action scope) and is driven by analytical methods (no Finite Element involved)
Optimization of the turbine consists in a stochastic thermo-mechanical simulation of a disc fully detailed at one partner and getting input from a masked process around the blade provided by a second partner.
A design phase of a full engine is then performed by an integrator based upon the engine product data structure populated by initial step partners. This part of the scenario emphasizes on concurrent engineering between multiple partners using various engineering and design environments, and addresses the complementary requirements between PDM and SLM:
Along the simulation assembly of the engine differentiation between Bill of Material (BoM) and its simulation counterpart Analysis Bill of Material (ABoM)
The idealized simulation request highlighting key milestones of real simulation process including the simulation process itself and workflow management as well as simulation knowledge management, the audit ability and traceability of the simulation workflow down to the report generation.

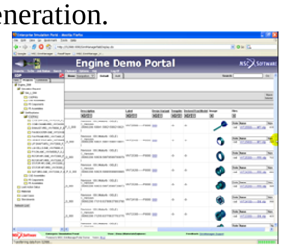

Figure 4: Simulation Life Cycle Management

Results of the latter step is finally extended to the concurrent engineering aspect with a design scenario consisting in the validation of design along clash analysis of the engine/pylon interaction done in the aircraft manufacturer environment, while parallel process emphasizes on simulation knowledge application to validate consequence of bird strike.
The demonstrated EDM framework architecture can be summarized by the following figure

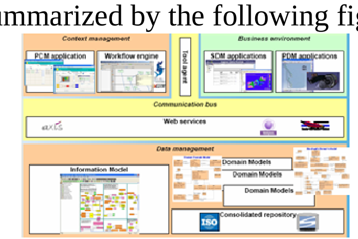

Figure 5: EDM framework architecture

3 Simulation Data & Process Management Application (SDPM)

MAAXIMUS project structure can be summarized by a matrix: 6 subprojects covering the fuselage lifecycle:

- SP1: Aircraft Requirements
- SP2: Design
- SP3: Analysis
- SP4: Manufacturing & Assembly
- SP5: NDT on line Process Monitoring
- SP6: Test Correlation & Monitoring

On the top of which 5 transverse hubs define:

- HUB A: Virtual Aircraft Structure Engineering and Manufacturing
- HUB B: Numerical Technologies for Optimization and Analysis
- HUB C: Multi-skill Integration Framework
- HUB D: Advanced Composite Technology
- HUB E: Full scale Composite Fuselage Barrel Validation

Hub D and E represent the Physical Validation of Virtual Solution proposed by Hub A to C.
MSC SDPM deployment is falls in Hub C framework umbrella while it is directly addresses SP3 capability.

3.1 MAAXIMUS Technical Context

Full scale applicability of previously detailed engineering data management has been tested in MAAXIMUS along automated process required in order to capture meshing rules associated to a parametric approach that will aim to the delivery of a fully loaded GFEM representation of an Aircraft barrel. This GFEM barrel will sustain composite structure representation from CAD to CAE idealization for simulation. Analysis is set under various loading conditions spreading from Internal Loads evaluation to Rapid Sizing Process. Aim of automating these various steps is a systematic optimization loops.
Role of MSC is the overall MAAXIMUS environment is bounded to implementation of such a parameterized GFEM model generation that will feed other partners domain application like Hub C "to be" Sizing process with Design Data" as sketched in Figure 6: Hub C to "be sizing process".

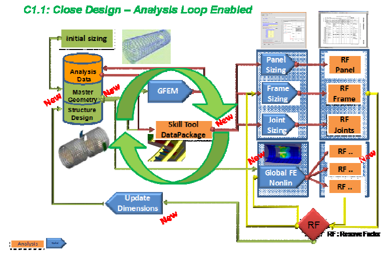

Figure 6: Hub C to "be sizing process"

However, such Hub A to Hub C collaborative activity relies on efficient validation of each sub process prior they can be reliably interconnected. In that respect MSC and their SP3 partners have undertaken demonstration of SDPM platform in order to execute solid testing of the automated GFEM building step.

3.2 Summary of Work Performed

Parameterized geometric models are used in collaborative mode from CAD to CAE domains. Multi Runs and DOE mandatory in context of optimization & rapid sizing require that GFEM model updates can impact FE parameters like properties as well as structural elements changes (frame numbers of positions)
Meshing procedures control definition of FE generation on parameterized PGS for analysis in codes like Nastran or Abaqus.
Loads distribution strategy has been built in the system to Simulation revision controlled objects stored and collaboratively distributed to aircraft Global FEM stake holders.

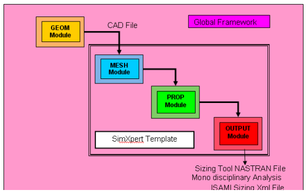

Figure 7 Global FEM simulation process

Platform addresses PLM interoperability with Aircraft Global FEM Lifecycle

3.3.1 Geometry Module

Input of Geometry Module is CAD DMU, and output is a set of CAD model associated to knowledge spreadsheets, named design tales (DT) tailored for CAE purpose.

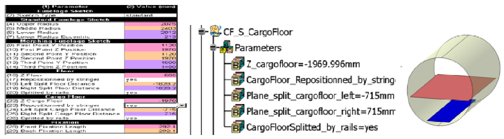

Figure 8 Parameterized CAD Part & DT

Link to Mesh Module is ensured by MSC.SimXpert capability to natively open and manage (read and update) the CATIA model structure as well as its ability to connect to DT, which will be detailed in following paragraph. As anticipated in VIVACE EDM Framework geometry used here is not Design (CAD/PDM oriented) and contains CAE specifics metadata like the DT.

As a consequence the SDPM architecture is going to be tailored to sustain objects addressing this CAD "simulation" entity as well as knowledge design tables and rules definition enabling proper understanding and usage of the design tables. In the same time the SDPM architecture will host connectors and mapping functions enabling "Simulation-Geometry" to remain in sync with DMU.

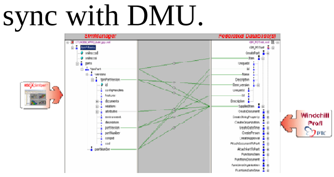

Figure 9: CAX data models connection

In the context of MAAXIMUS GFEM being supported by SimXpert & PDM by Windchill, the previous figure shows connector acting between the Simulation domain & federated database subset of information model.

3.3.2 Mesh Module

Overall goal is to encapsulate GFEM generation into an automated process including geometrical optimization. Such at target implies that undertaken loops can go through topological changes. In that context two main branches have been identified followed by refinement one. These two phases can be summarized as follows: Phase 1 will be defined as a preparation of the mesh module out of the geometry module. It will automatically extract all necessary information and store it in external files. This phase can potentially be run at each step, but its outcome remains unchanged as long as topology is not altered

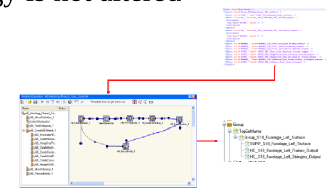

Figure 10: Mesh Phase 1 flow

Second phase,automates preparation of mesh per se, iso-topology stored data capture, panel & specific mesh areas generation are performed. Finally refinement of mesh provide detailed feature representation – (Windows, Doors and Floors)

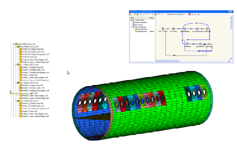

Figure 11: Mesh Pattern

3.3.2 Properties and Materials Module

Equivalent template methods were applied to synchronize Design Information (Composite & Physics of model) & its idealized FEview e. g.Composite Layup in Catia CPD format is linked to SimXpert FE automatically.

3.3.3 Optimization Loop Arena

SimManager sustains simulation Lifecycle Management Framework to validate process automation to store objects (models, results, processes), to trace audit and process trail) & to drive automated GFEM generation and simulation execution, until results capture.

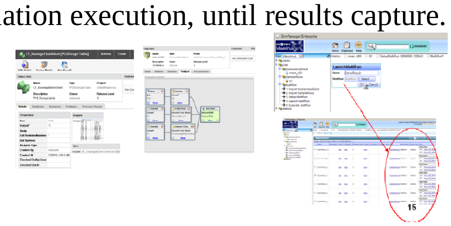

Figure 12: SDPM Framework validation

5 CRESENDO Way Forward: Conclusion

Ambition of CRESCENDO consortium is to make step change in modeling and simulation activities, carried out, by multi-disciplinary teams in collaborative enterprise, to develop new aeronautical products in a more cost and time efficient manner. MSC is engaging with leading European aerospace organizations to develop Collaboration Platform for Aerospace Engineering and Simulation."

From VIVACE **State of the Art,** where Simulation Object Management & Simulation Process capture were demonstrated, **CRESCENDO Innovation,** focuses on Generic Model management, with a Model Network for Simulation objects enabling collaborative work preserving stakeholder IP, associated to Generic Simulation workflow interpreted in context (capability templates). This effort will drive the Behavioural Digital Aircraft Architecture (BDA) implementation

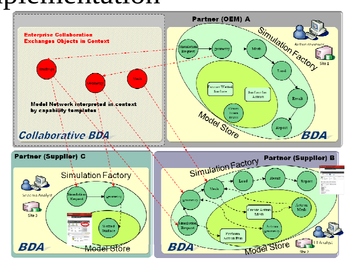

Figure 13: Model Network within BDA

Way forward resides in scaling validation of latter concept in context of Extended Enterprise.

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