Deutscher Luft- und Raumfahrtkongress 2008
DocumentID: 81237

AIRCRAFT MODEL BASED SIMULATION LEVEARGING MULTIDISCIPLINARY APPROACH

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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 itself.
Implementation of a Multi Disciplinary Data Model shared by all stake holders of the Aircraft program, leveraging benefits of the latter Common Data Model versus multi physics simulation, enables real world idealization and simulation of reality in an efficient manner.

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 the engineering data to manage beyond PDM scope include 3 additional domains:

- The requirements domain gathering requirements related to product capabilities, performance and behavior,
- The product domain gathering product information
- The test bed (or 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.

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 how ever 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. Such a domain should be addressed by forthcoming project Crescendo, proposed to the 7th Framework Program.
MSC.Software intends to support it with SimEnterprise based solution, combining the outcome of Vivace EDM Framework, and Multi-Disciplinary Simulation engine as well as automated process concept facilitating optimization effort.
Such a platform has already been adopted by key players the Aero Industry, with whom MSC is partnering to deploy Mechatronic models of flying Aircraft as premise of Virtual Certification.

2. 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 bewtween more partners, accorss 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.

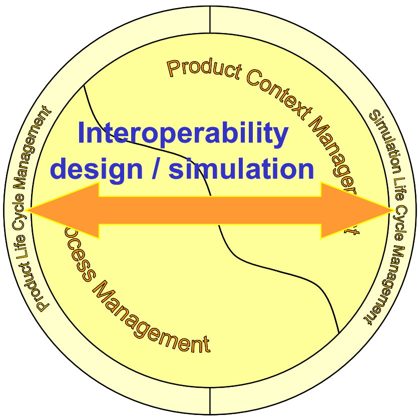

Figure 1 Interoperability at Disciplines level

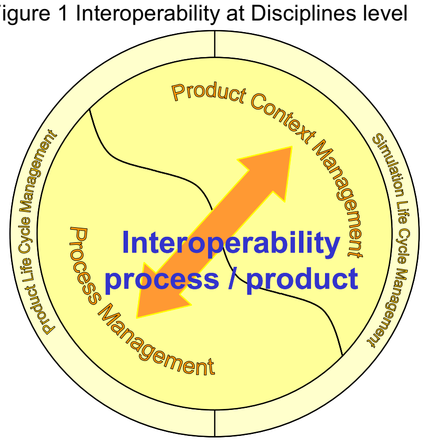

Figure 2 Interoperability at context level

2.1. 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).

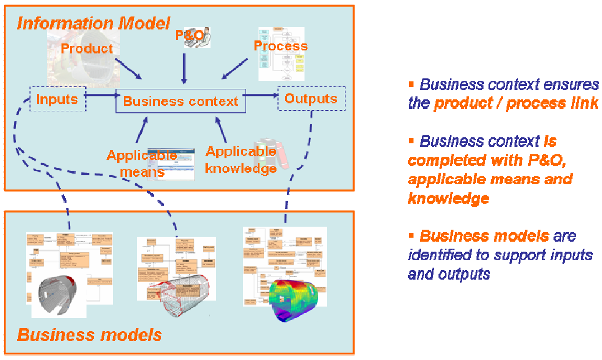

Figure 3 EDM and Context Management

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).

2.2. 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.

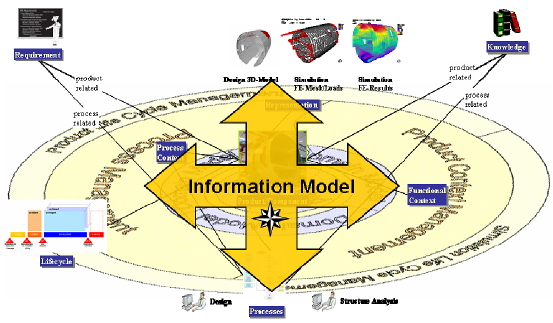

Figure 4 Role of information model in EDM Framework

2.3. 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.

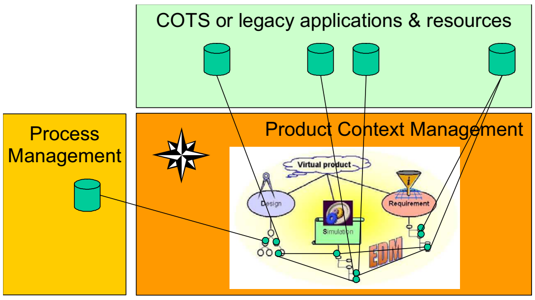

Figure 5 Positioning of workflow engine

2.4. Domain Model

As we move 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 the scope of business interpretation of the data, it empowers the user to bind the information he needs and wants to share for collaborative engineering activities with the various stakeholders of the aircraft program within the virtual and extended enterprise.

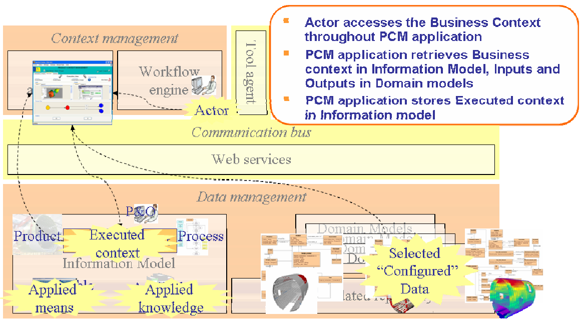

Figure 6 Perimeter of domain model in EDM architecture

2.5. 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. Use case scenario and implementation

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

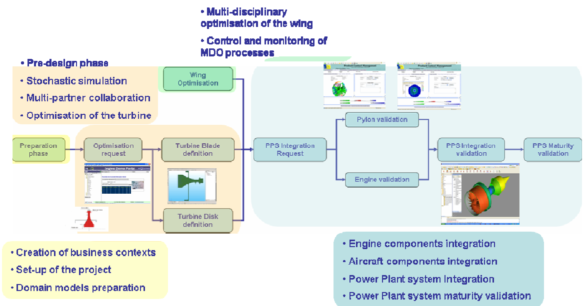

Figure 7 Overall VIVACE EDM Scenario

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 the 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.

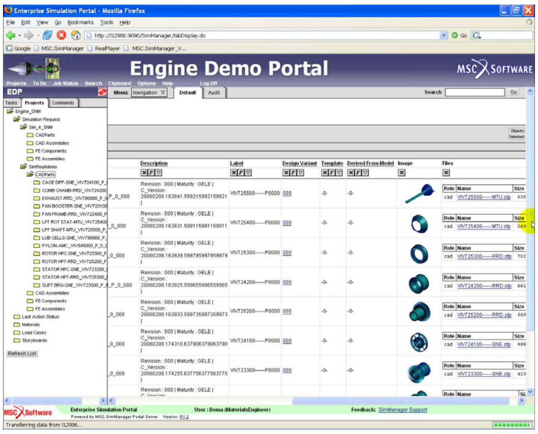

Figure 8 Simulation Life Cycle Management

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 a parallel process emphasizes on simulation knowledge application to validate consequence of bird strike and associated effects.
The demonstrated EDM framework architecture can be summarized by the following figure

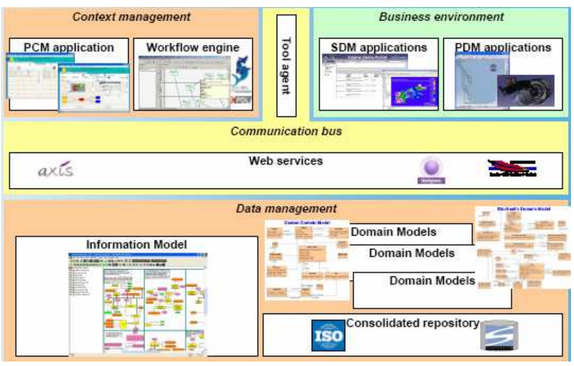

Figure 9 EDM framework deployed architecture

A componentized description of the Vivace EDM framework deliverables is also presented in the next figure that underlines the Software Open Architecture (SOA) and the services oriented approach used for the solution.

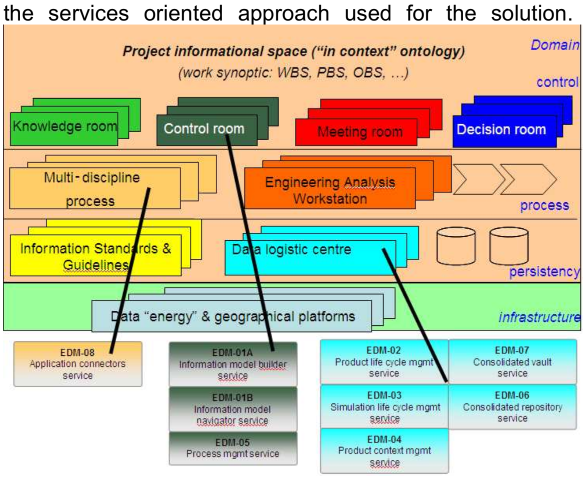

Figure 10 EDM Service contribution to VIVACE Toolbox

3. SIMULATION LIFE CYCLE MANAGEMENT

MSC.Software who contributed to the EDM framework specification effort and drove its development along the four years of the project decided to capitalize on the industry requirements knowledge they acquired thanks to a tight collaboration with all industrial partners involved. Being at a crucial milestone of the development of their game changing solution SimEnterprise, MSC took the opportunity to speed up its deployment capacity by integrating the concepts validated by EDM and required by the market. SimManager that has been widely used in earlier releases to support the SLM aspect of the EDM framework represents the backbone of SimEnterprise and leverages in today R3 version most of the outcome of Vivace EDM. The SOA architecture it relies on covers all requirements highlighted by Vivace use cases. This goes from the content management, to process management though the Enterprise collaboration relying on an open and expandable data model that is pluggable to the enterprise resources via application services capabilities. The add on of SImManager in the SimEnterprise context is the out of the box implementation with CAD and CAE domain tools like MSC.SimDesigner and MSC.SimXpert, that facilitate SImManager deployment without impacting agnostic philosophy versus any other domain tool collaboration.

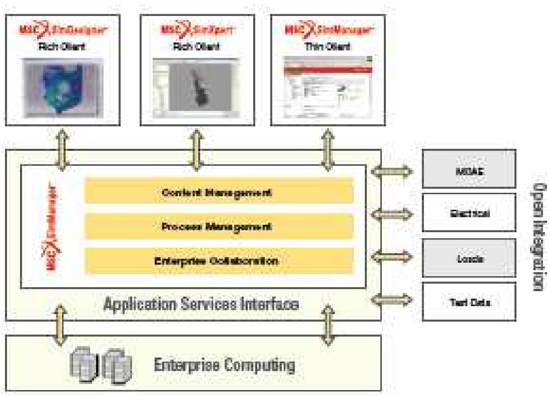

Figure 11 SimManager Backbone SimEnterprise SLM

3.1. Data Management

In order to face explosion of data characterizing evolution of simulation toward virtual product development, SimManager was originally tailored to handle wide content of information coming from heterogeneous applications and tools and delivered in various formats. As we highlighted in paragraph 2.7, the perimeter of application is complementary to widely known PDM tools. In the domain of assemblies BoM are taking into account CAD parts and the way they are related to each other in a product data structure that might also take into account links to catalogs for fasters and the revision management of latter product. The SLM ABoM can reflect the PDM assembly structure, how ever some of the simulation components in the assembled model can be defined independently of any CAD reference. This is often the case when simulation models are delivered by suppliers. Alike, fasters in simulation are more likely to be represented by equations rather than by parts to mesh or standard catalogue inputs. Finally constitutive models and material laws for simulation have a much broader scope and variety that materials definition for product design.
Second differentiator reside in the simulation work in progress and variants analysis (sensitivity analysis, optimization loops, stochastic design improvement, and more generally "what if" evaluations) that represent some simulation knowledge and has to be captured in the SLM world, even though it might have no meaning in its full for the PDM world. (Not all variant analysis leads to a design change)
Nevertheless, PDM and SLM have to be tightly coupled. Since early releases SimManager demonstrated its capability to pull or push information from or to a PDM system. Conclusion of Vivace helped MSC to make the decision for a standard way of collaborating with PDM world, enabling mapping via STEP standard based solution with Product Data Structure. This has been a key driver in MSC common data model plug in to Enterprise connect technology powered by PROSTEP OpenPDM that will offer truly robust and open integration to PLM from PDM domain to Test Data Management and Requirement Management systems.

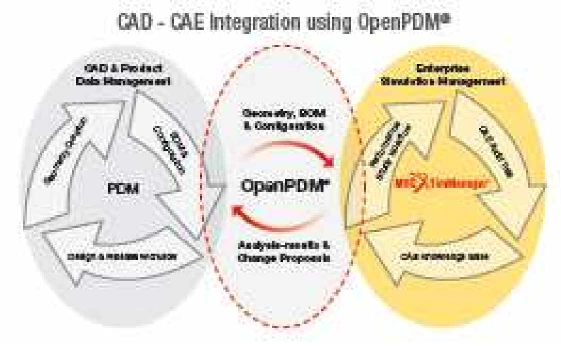

Figure 12 PLM Connector open source

3.2. Process Management

Beyond commonly proposed scope of Simulation Data Management, MSC.SimManager covers broader scope of simulation content management. The collaborative platform truly empowers all aircraft program stakeholders with searching mechanisms, in order for reduce time spent looking for the information required to perform simulation. SimManager at the same time grant them with real time update as idealized model evolves. Initial multi-domains and multi-steps of the Vivace use case scenario, we reviewed in paragraph 2.7, demonstrated how such real time update is important.
Finally process management enables meaningful usage of simulation data. Point here is that simulation processes are defined in the system as simulation objects, that also have a life cycle, and SimManager maintains relation they have with over simulation objects they generate. At the end of the day, complete pedigree of simulation workflow is traceable and auditable.

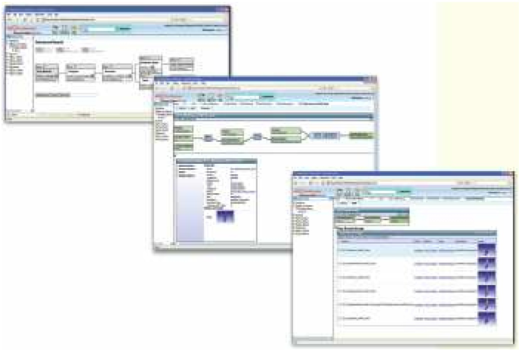

Figure 13 Data Searching, Pedigree and Audit Trail

SimManager implementation presented by Sogeti at the 2007 MSC VPD Conference, validates in an industrial environment how such a process management support in conjunction with workflow, knowledge management and more conventionally recognized data management enables true simulation life cycle management as it was defined by Vivace EDM framework

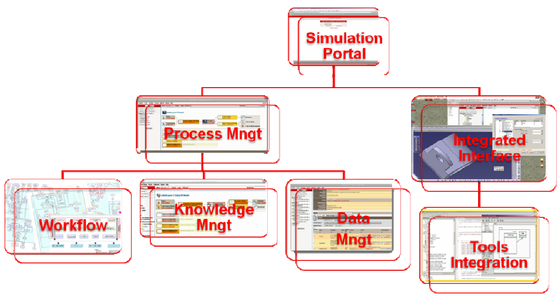

Figure 14 Sogeti Simulation Portal deployment

3.3. Context Management

We highlighted on paragraph 2.2 and 2.3 how the engineering model was taken care of by Information model and domain model in order to introduce contextual management of the information. This paradigm applied to Virtual Product Development was also anticipated by MSC.Software when they started to MD.Nastran (Multi Disciplinary) architecture that we will detail in paragraph 4. How ever it is important to mention here that it facilitates, context management of the life cycle as the Alenia implementation of SimManager emphasizes.
It can be summarize by the capability to filter information based upon tool and domain application needs.

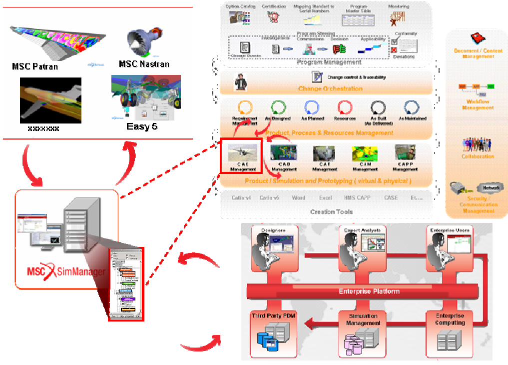

Figure 15 Alenia Simulation LifeCycle

3.4. Simulation Knowledge Capture and Reuse

Initially deployed in their Multi Disciplinary front end platform MSC.SimXpert, MSC proposed a graphical way to capture simulation process know how and convert it into reusable procedures. Airbus announced adoption of such technology end of last year. In the mean time MSC decided to apply this SimTemplate concept to broader scope, and expended the MSC.Process Builder capability to more generic usage to include virtual testing knowledge as a component of SLM. This was highlighted along Vivace forum 3 as a bridge between partners' general knowledge management activity and EDM framework effort. The topic that was covered then was the automation of a bird strike impact simulation in a turbine engine.

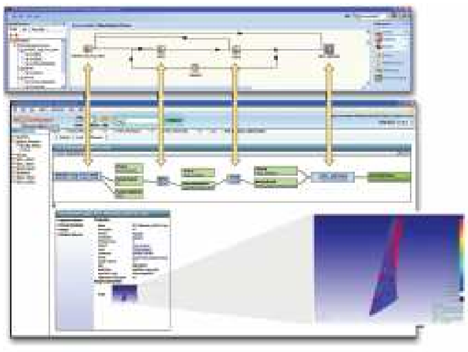

Figure 16 Process Builder and simulation methods

As a benefit for process reuse, we can mention simulation automation that is a key aspect of multi disciplinary optimization, stochastic design improvement and more broadly speaking Design for Six-Sigma (DFSS).
As a follow up of such an effort supported by Airbus, MSC is currently working in the scope of European FP7 MAAXIMUS toward the optimization of a composite barrel. Touching with next subject, we will introduce how this activity currently at a discipline and/or components level can open doors to virtual certification, provided it is deployed at full aircraft model.

4. MULTIDISCIPLYNARY SIMULATION

MSC for the last 40+ years developed leading technology addressing various domains of simulation, like structural, thermal or multi body analysis for instance and not to be exhaustive. Market trends and needs go to complex subsystems and not parts validation. Full vehicle validation then implies that one has to take care of many more environment conditions, knowing that such a complex evaluation has to be performed in compressed time as exposed in introduction.
Basic concept of MD.Nastran is to leverage specific solvers technology in a way they can be automatically chained and coupled along the analysis.
MSC developed an open Common Data Model (CDM) that supports niche simulation data models (this can be seen as a correlation to Information Model and Domain model applied to virtual testing). Such a CDM remain on purpose non-invasive thank to its SOA. For instance MSC decided not to include specific CFD solvers into MD.Nastran but to open it via OpenCFD (Pioneer Solution) to end user preferred choice (should it be COTS of in-house based). Workflow and interoperability connector (Simulation strong coupling or sequence chaining) is guaranteed by communication services.

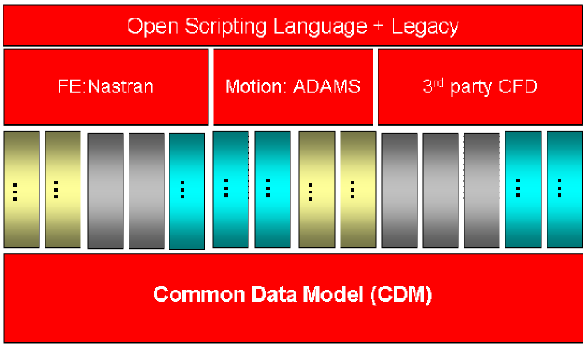

Figure 17 MD Nastran Architecture

Following Figure also shows how Bird/Strike followed by Fan Blade off (two explicit solutions representing on duty event) can be chained with implicit pre stress run and implicit unbalanced rotor dynamic that will represent engine behavior after the event.

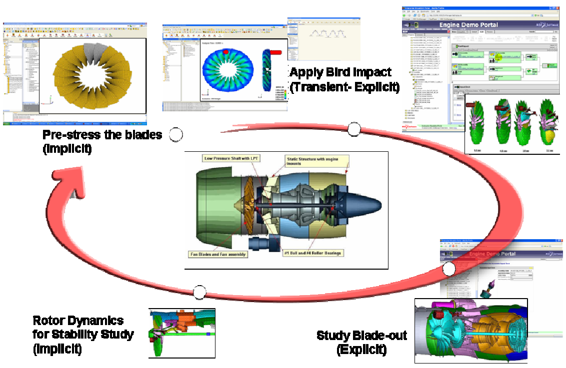

Figure 18 Egine BS/FBO simulation

Novelty in MD.Nastran versus other approaches is that no model conversion (hence no error prone) is necessary while the same simulation model is maintained from A to Z enabling real coupling and automatic chaining of the solution.

5. CONCLUSIONS PERPECTIVES

Virtual Product Development is rapidly heading toward Virtual Certification. Research projects as well as industrial applications demonstrate the validity of such a statement. MSC stepping beyond the scope of multi physics directly into multi discipline simulation that they combine with Simulation Life Cycle platform are a leading contributor to such an effort.

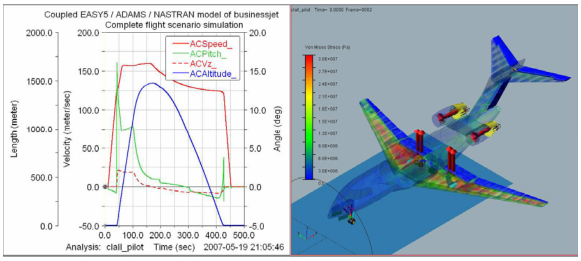

Figure 19 MD Flight Simulator

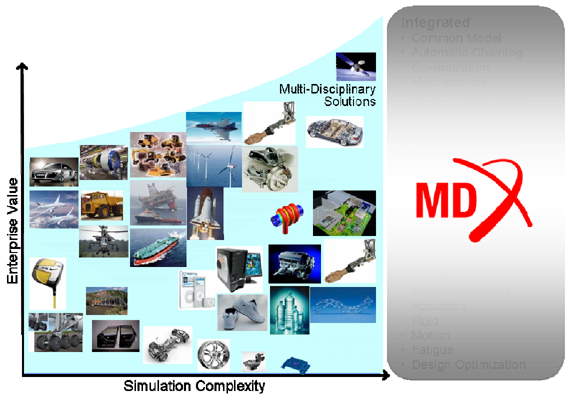

Figure 20 MD positioning

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7. TABLE OF CONTENT

8. TABLE OF FIGURES