

Collaborative Multi-Company- Multi-Disciplinary Jet Engine Design Optimization

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Abstract

Economic realities result in ever increasing demands on aeronautical engines as well as on their development programmes becoming virtual organisations. Design evolution requires close collaboration between the engineers involved, across disciplines, geographic sites and organisations. Typically each organisation will have its own proprietary tool suite. This paper presents the realisation of a virtual enterprise allowing flexible addition or modification of partners and/or accommodation of tool suites. The approach demonstrates efficient support of evolving engine design for a realistic design problem in a realistic organisational setting thereby alluding to its potential in similar high-tech design collaborations.

1 Introduction

Aircraft engines have evolved into extremely complex high-tech systems. To comply with ever increasing environmental and economical requirements, a continuous design improvement is necessary. Correspondingly, engine design is technically challenging and costly and cannot be achieved by one company alone.

The engine integrator company must collaborate tightly with its first tier suppliers, especially during the design process. Traditionally, this includes sending specifications, CAD- and simulation-models back and forth between the partner companies, using ground-mail, e-mail or other file sharing mechanisms.

The call for a decreasing time to market dictates that these time consuming manual tasks are substituted by a streamlined, automated design process and the technical information is shared, not pushed around, between the collaborating partners.

This collaborative design system needs to work in an extremely heterogeneous environment, since each of the risk sharing partners will use their own, partly proprietary, tool suite. As this design tool suite is the core asset of each partner and different engine projects comprise of different partners, the intellectual property of each partner needs protection. Consequently a partner needs access to other partners tool suites within a specific engine collaboration framework, but can not be allowed a copy of it.

During the course of the engine design, the design objectives will inevitably evolve, which the collaboration needs to accommodate in an agile manner. The result is a need for a multi-site, multi-company collaboration. The design system used in such a virtual enterprise must respond to the following challenges:

Data Sharing

It is essential to always know where to find approved data and how to notify other stakeholders of changes to that data. If the data is not managed properly, configuration management and issues arising from it will consume a lot of time and resources during the life cycle of the product. By sharing data, configuration management can be managed with less effort during the full life cycle of the product, independent of in what phase of the life cycle the product is.

Work Process Sharing

Since the development process of such complex products is highly iterative, automated, shared work flows need to be in place to optimize and verify the performance of the product. Any human interaction in these simulation driven work flows will cause unacceptable bottlenecks and slow down the time to market.

Intellectual Property Encapsulation

The nature of the virtual enterprise implies that the partners for one project might be competitors for another project. Therefore it is absolutely necessary that the intellectual property of each partner is not exposed to the virtual enterprise. This implies that e.g. no parametric CAD-geometry files are shared and that the local simulation based engineering work flows are totally opaque to the partners.

Access Rights and Security

The shared information needs to be secured against unauthorized access both from within the virtual enterprise and from the outside. The design system of the virtual enterprise must not jeopardise the security of the IT-infrastructure within each partner company.

The next section describes the concept of such a design system, that meets the challenges stated above. The section after this then illustrates a first implementation of the VEC-Hub Concept for a realistic jet engine design task. While this work gives an overview on the collaborative aspects, more technical details and descriptions of the local design systems can be found in ref. 1 - 3.

2 The VEC-Hub: A Concept for a Collaborative IT-Infrastructure for the Virtual Enterprise

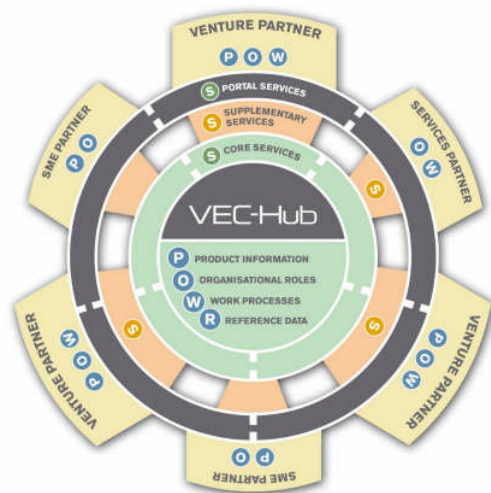


Figure 1: The VEC-Hub Concept

Within the European Union Research Project VIVACE, a concept has been developed to address the needs for such a multi-enterprise collaborative design system, the Virtual Enterprise Collaboration Hub, see reference 4. The objective of the VEC-Hub, illustrated in figure 1, is to provide a partner managed platform that is neutral with respect to technical (vendor and system), internal and external aspects.

The use of services based on platform independent application integration standards, the Web Services Description Language (WSDL), promotes, from a technical point of view, this neutrality and facilitates the usage of partner internal design processes by exposing only the interface of these processes to the VEC-Hub and keeping all implementation details internal.

The requirement on the collaboration project is to have a common agile set-up of partner roles, product information, work processes and reference data. This information, categorized into Organizational Data (O), Product Data (P), Work Processes (W) and Reference Data (R), determines who will do what, when and how. It is stored and managed centrally on the VEC-Hub, in the light gray circle in the center of figure 1.

The partners of the virtual enterprise can access the services providing them with the relevant information through the VEC-Hub-Portal-Services, either using commodity tools like web browsers or application programming interfaces (APIs), if they wish to include them into their own automated local design processes.

At the outer circumference of the wheel picture 1 the partners of the virtual enterprise are located. They can have different roles: collaborating companies that only consume services are labeled SME, small to medium enterprises. A venture partner is an entity that

provides both product data and design services to the virtual enterprise and makes use of the VEC-Hub services in it's internal processes.

Each of the organizations joining a Virtual Enterprise Collaboration has its own internal infrastructure, e.g. applications, operating systems, firewalls, security solutions. They also have means for managing their organization, their products and their processes describing how to develop those products. The Virtual Enterprise does not require the partners to align their infrastructure.

Instead the shared information is made usable for each partner independent of their preferred infrastructure by using a neutral and, preferably, standardised data structures. Neutral formats supports interoperability but also persistence, i.e. long- term archiving, which is important in most businesses of today and tomorrow.

3 Using the VEC-Hub for Multi Company, Multi Disciplinary Optimization

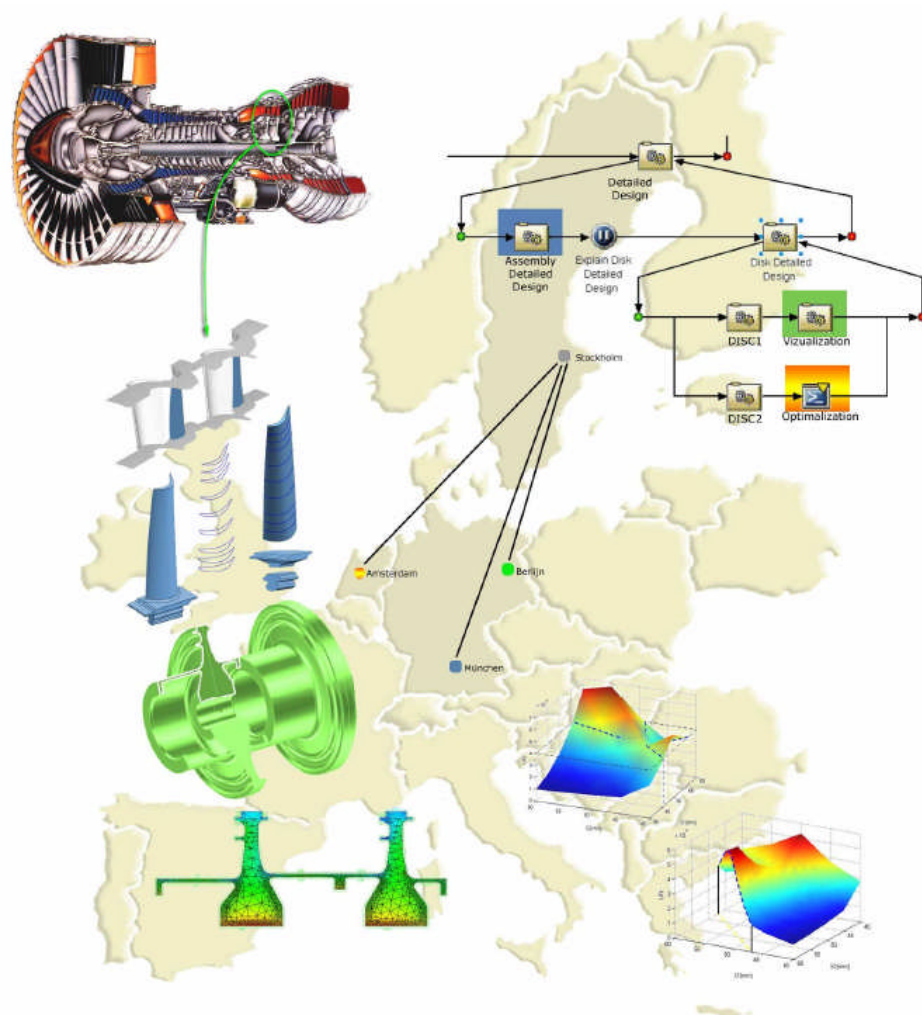


Figure 2: Multi-partner multi-site virtual enterprise collaboration for an engine multidisciplinary design analysis process.

Within the VIVACE project, a two stage high pressure turbine of a jet engine is selected as the test bed to illustrate the benefits of applying the VEC-Hub concept. Located immediately after the combustion chamber, this assembly has to withstand extremely high gas temperatures and is a critical part for the overall life time of the engine.

Aerodynamic and mechanical design of 2-stage turbine

Design contents

- Aerodynamic detail design optimisation
- Optimisation of rotor design as an assembly of rotor 1 and rotor 2 including life cycle analysis

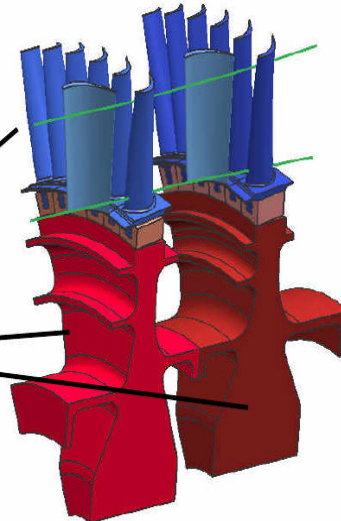


Figure 3: Design Tasks for the High Pressure Turbine

This work focus on the detailed design phase of that assembly, where four venture partners work together, the integrator, the blade designer and the disk designers for each of the two rotating blade rows. Figure 2 sketches the involved partners and their physical locations and figure 3 gives an overview of the design tasks.

During the preliminary design phase, which is implemented with a slightly different set of risk sharing companies, but also using the VEC-Hub, the requirements for the detailed design phase are derived.

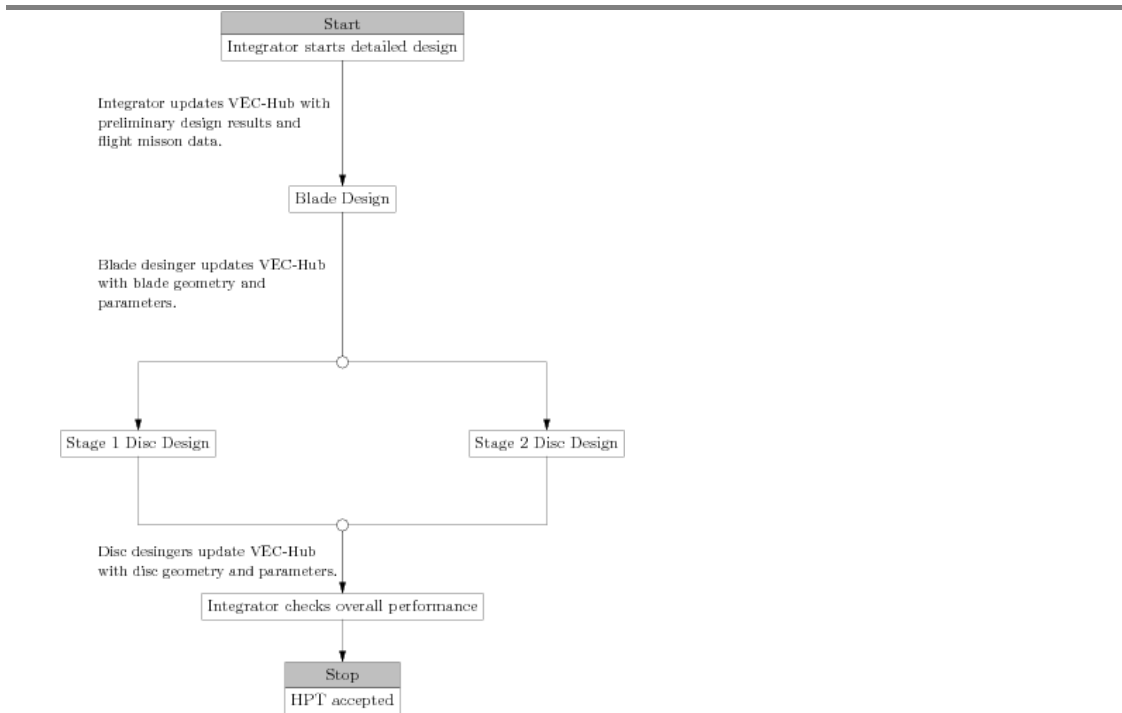


Figure 4: Flowchart for the Detailed Design Process

As stated in the flowchart of the detailed design process in figure 4, the integrator starts the automated work flow by updating the shared product and flight mission data at the VEC-Hub. He accesses the VEC-Hub through the API provided by the portal services, as depicted in figure 1.

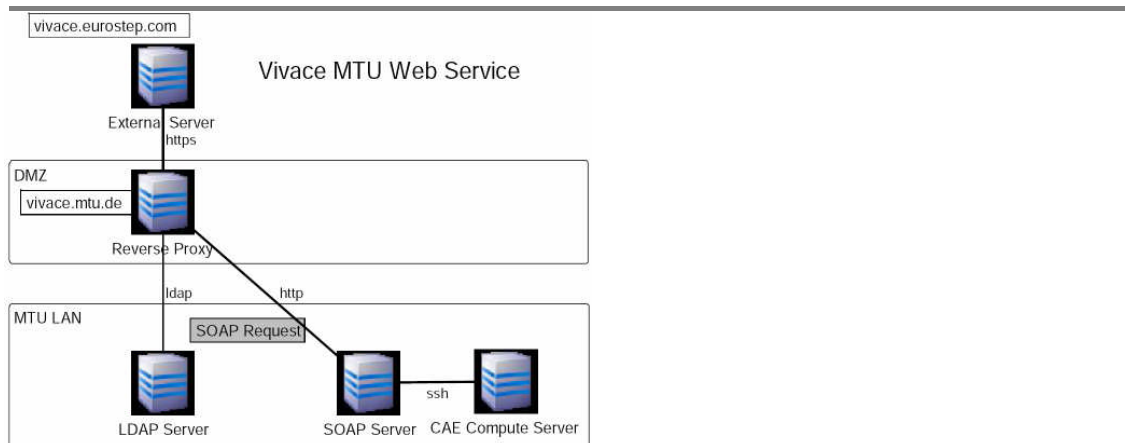


Figure 5: Airfoil Design Service Connection

The partner responsible for the blade uses his own in-house optimization system and exposes only the necessary interface parameters to the VEC-Hub as a Web-Service, as shown in figure 5.

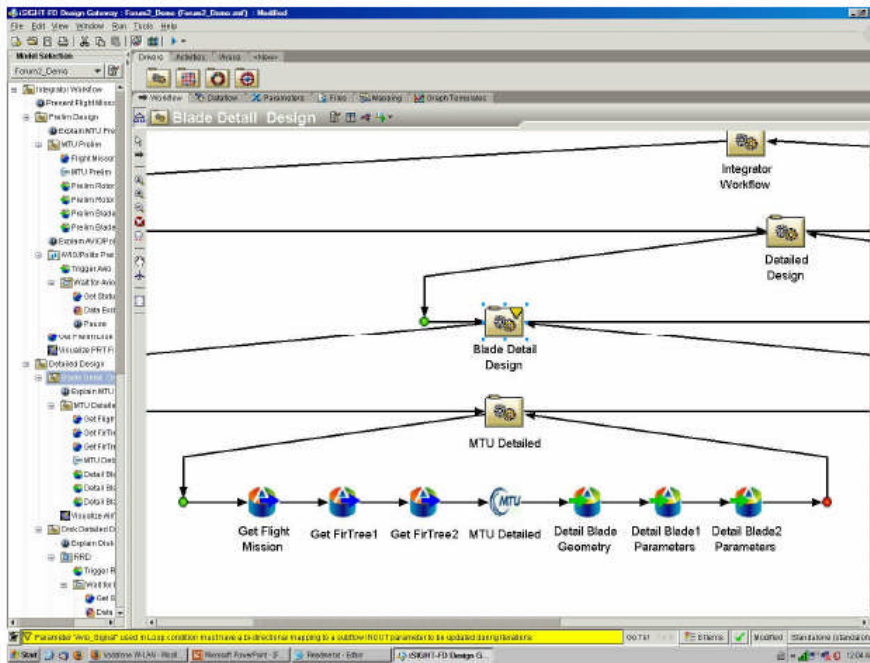


Figure 6: Detailed airfoil design. The necessary information is retrieved by the integrator in the components GetFlightMission, GetFirtree1 and GetFirtree2. After the execution of the blade optimization process in MTUDetailed, the results are shared at the VEC-Hub using the components Detail Blade Geometry, Detail Blade1 Parameters and Detail Blade2 Parameters.

Within the local optimization system, no functionality to connect to the VEC-Hub is provided and the partner doesn't wish to implement that. Therefore in the work flow at the integrator's side, this information is retrieved from the VEC-Hub, and transmitted to the partner as parameters in the call to the exposed web service, see figure 6.

After the geometry and the important parameters of the blades, number of blades, weight and center of gravity, have been determined, the design of the discs for each of the two stages can be started. This work is done in parallel by different partners, cf. figure 4.

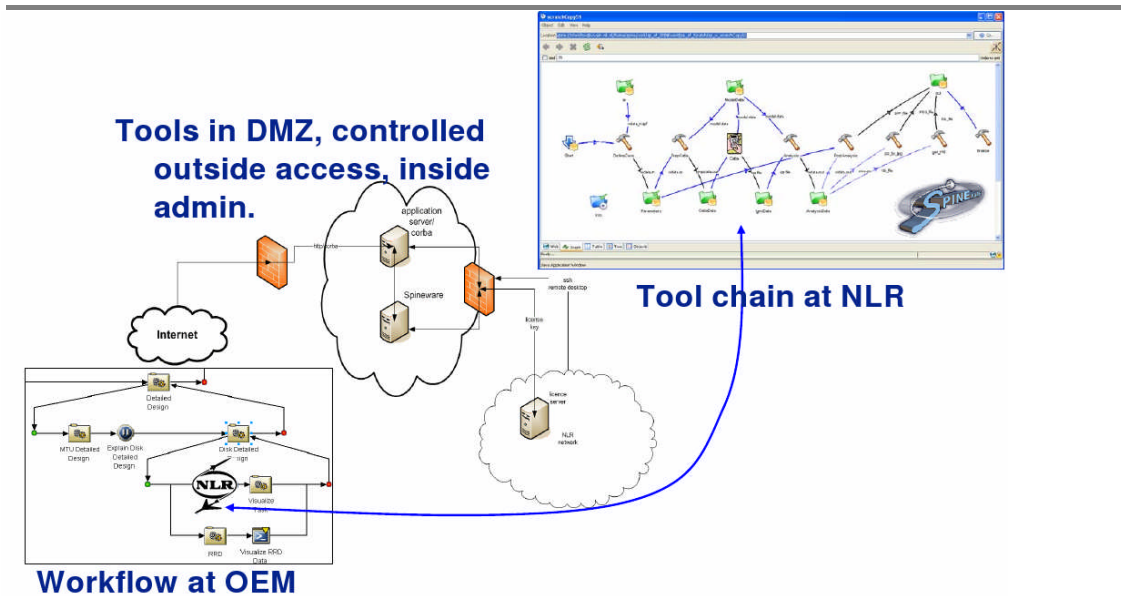
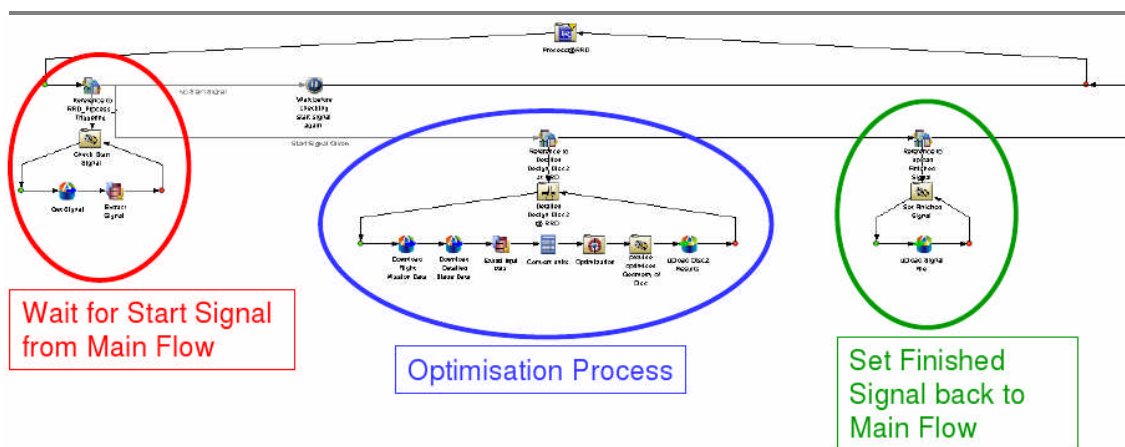


Figure 7: Connection of the Design System for Disk1

The system for designing the first disk consists of yet another set of tools, integrated within a proprietary integration framework. As with the blade optimization, it is exposed to the VEC-Hub as a web service and all necessary information is retrieved by the integrator from the VEC-Hub communicated to the local work flow as parameters in the call to the web service. At this stage no local optimization system is implemented at the partner designing disc1, instead the design search is driven at the integrator level.



Design framework for multi disciplinary optimisation and robust design of
Figure 8: Disc 2. Trigger-components are used for starting and finishing the local design
process

The IT-infrastructure at the partner developing disc 2 doesn't allow for a direct exposure of the local design system to the VEC-Hub as a web service. But here the local design system can make a connection to the services at the VEC-Hub and a trigger mechanism is implemented to start the local optimization task. A local loop requests from the VEC-Hub a specific file and only starts the design task, if the integrator work flow has updated this file with a specific value of one parameter. This is illustrated in figure 8.

After the disc design is completed, the integrator can retrieve the geometric and parametric information accessible to him using a web browser from the VEC-Hub and review the compliance, consistence and performance of the design. If this review is satisfactory, he can approve the status of the high pressure turbine on the VEC-Hub and continue with different design tasks, that might now request information about that assembly.

4 Conclusions

Based on the organisational requirements common in aircraft engine programmes a solution has been implemented which allows many distributed partners, without one dominant partner who can prescribe the tool suite to be used, to collaborate in the design of a critical engine component. The resulting integrated design capability supports the flow of technical design information without infringing the intellectual property of the collaborating partners. The chosen realisation of the tool chain allows flexible addition or modification partners and/or proprietary tool suites. The fully automated design capability efficiently supports the numerous design changes of the evolving engine design, obviating the need for time and effort consuming paper-based engineering change processes.

5 Acknowledgement

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5 References

1. E. Kessler et al.: "Empowering Engine Engineers-Advancing the State of the Art in Collaborative Multi-National Multidisciplinary Engine Design", In *Council of*

the European Aerospace Societies (CEAS-2007), Berlin, Germany, September 2007

2. E. Kessler, M. Guenov, M. Laban (eds.): “Advances in collaborative civil aeronautical multidisciplinary design optimization”, AIAA, to appear
3. Parchem R. et al.: “Demonstration of Collaborative Engineering Distributed Whole Engine Design Process”. In VIVACE Forum 2 CD-ROM, Den Haag, the Netherlands, 24-26 October 2006. Also published as NLR-TP-2007-525.,
4. Fredrik Almyren et al.: “VEC-Hub Concept Specification”, VIVACE Deliverable D3.6.1-3, available at 137.205.176.10/vivace/content/advanced/vechubcs_full.pdf, accessed March, 7th, 2008