Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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COMPETENCE MANAGEMENT IN ENGINEERING ENVIRONMENTS WITH HPCN

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Abstract. Currently enterprises are operating in a dynamic environment with respect to both market and work force. As part of the enterprise's quality management, management of the competence of the enterprise is essential for survival of the enterprise.
An ICT framework for multi-discipline engineering is described from the viewpoint of competence management. The approach enables that HPCN - as used in engineering - becomes a commodity. The organisational experiences with the required development process for the framework for multi-discipline engineering are reviewed.

Introduction

The purpose of introducing *quality management* is, for many enterprises, to promote survival of the enterprise in the global competition. The aim of quality management is to realise ever better satisfaction with the enterprise's customers, which means:

– delivering the product in shorter time,
– producing at lower cost,
– and achieving better customer appreciation.

This is achieved by the industrial enterprise through continuously increasing the engineering know-how, the capability to apply the know-how in a flexible way in the business process and, on the metalevel, the know-why to ensure the enterprise capability to adapt to a changing environment.

The combination of know-how, know-why and the capability to apply know-how is defined as *enterprise competence*. Only proper management of competence enables an enterprise to cope with the need to lower cost of production while, at the same time, the speed of changes in the global market place increases and additional requirements such as ecological aspects of the product life cycle, become more difficult to meet.

Enterprises have to react fast and in a flexible way to this changing environment and global competition. This means:

- attracting the right people
- educating and training the work force,
- and introducing and maintaining a competence oriented way of working and supporting tools in the enterprise.

Enterprises on the one hand need to continuously adapt the engineering work force to the work load to minimise enterprise cost. Engineers on the other hand need to be attractive for enterprises to be hired. As a consequence, enterprises are continuously searching for competent engineers whereas engineers are continuously searching for positions which increase their market value. The situation results in many cases in a *floating work force* in enterprises.

The position of an enterprise in the global competition is determined by the degree of *synergy* between the individual competence of engineers and the competence accumulated in the enterprise. The enterprise competence stems from the previous experiences in similar business processes. Where previously, the enterprise specific know-how and know-why was preserved in the work force, now, the enterprise has to take measures to preserve the know-how and know-why in other carriers, viz. software, data, and documents.

In the present paper an Information and Communication Technology (ICT) framework for multi-discipline engineering is described from the viewpoint of competence management. The approach enables that HPCN - as used in engineering - becomes a commodity. The organisational experiences with the required development process for the framework for multi-discipline engineering are reviewed. The experiences and results of the MDO project [1] aiming at the integration of design and analysis tools creating a Multi-Discipline Optimisation capability, serve as background for the description in the present paper. The ICT contribution in the MDO project is given in References [6] and [7].

Requirements for the MDO Framework

To effectively resolve cross discipline trade off's to improve both the product and reduce development time scales and costs, a stepwise approach is applied in the engineering process (Ref. [2]). In this process in general a preliminary design and a detailed design are distinguished. Each step has its own depth of analysis. As a consequence frequently different analysis methods are applied by the contributing disciplines in the different steps (see e.g. Figure 1). To speed up the engineering process design choices are made and analysed concurrently in

[1] The MDO project (Multi-Discipline Design, Analysis and Optimisation of Aerospace Vehicles) is a collaboration between British Aerospace, Aerospatiale, DASA, Dassault, SAAB, CASA, Alenia, Aermacchi, HAI, NLR, DERA, ONERA, and the Universities of Delft and Cranfield. The project is managed by the British Aerospace and is funded by the CEC under the BRITE-EURAM initiative (Project Ref: BE95-2056).

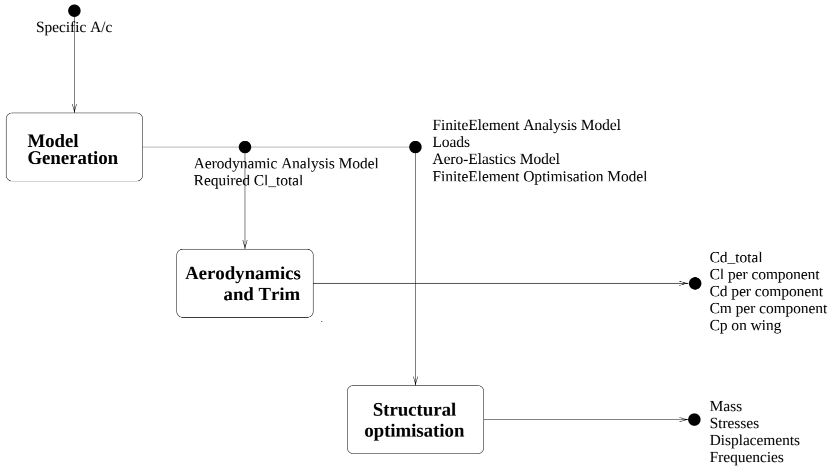

Fig. 1. Example of an MDO process model.

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the various disciplines. This means that the engineering process is characterised by information generation and analysis in various disciplines and information exchange between disciplines on more than one level of detail.

Multi-Discipline Optimisation is an activity which requires both problem specification and problem solution (via process execution). Because of the nature of the MDO activity, the followed process in the sequence and the depth of the analysis steps should be flexible: the MDO process is characterised by continuously improving the process structure and the tools that are applied in the process. Because the data can only be interpreted in the view of the process in which they were created, it is required that data and processes are integrated. Further, support of implementing changes in the tools requires that tools can be invoked in many different ways ranging from a single tool, via a chain of tools, to fully automated iteration with a suite of analysis tools and an optimiser tool. Similarly, the support requires that data from a single tool invocation can be accessed, that data from a chain invocation can be accessed, and that data from fully automated iterations can be accessed.

To turn the software and data into competence, the capability to access and apply them *independently of the originator* has to be created. The first measure for this is to document the operation, theoretical background, and practical limitations. The second measure is to make the software, data, and documents accessible and applyable. This is more complex because the software, data and documents reside on the enterprise's heterogeneous distributed network.

Architecture and Construction of the MDO Framework

The architecture of the MDO Framework, populated with software, data and documents is presented in Figure 2 (Ref. [6]). The Users interact with the MDO Framework through a User Interface:

- to use the MDO Process Interpreter to control the execution of Calculation Modules (including Design, Analysis, and Optimisation)
- to use the Data Manager to control design data relating to the exploitation of MDO.
- to use the Document Viewer to access the documentation concerning the software tools, data, and the MDO process.

The primary architecture components required then of any generic MDO environment are:

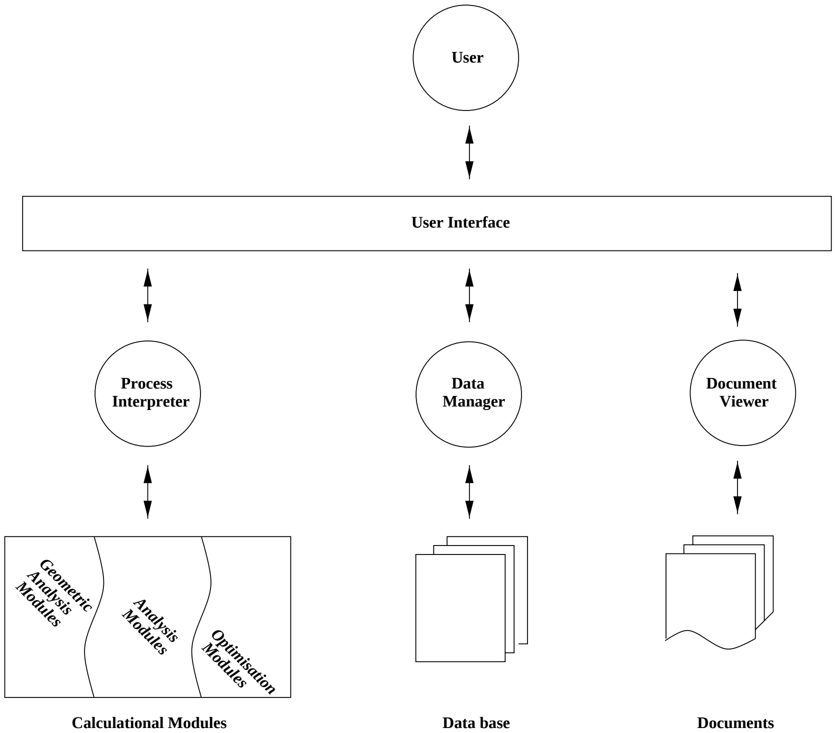

Fig. 2. Architecture of the MDO Framework

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- Process Interpreter,
- Data Manager,
- Document Viewer,
- and User Interface.

The MDO Prototype Framework, demonstrated to the MDO Consortium in January 1998, consists of the cooperating software elements (see Figure 3):

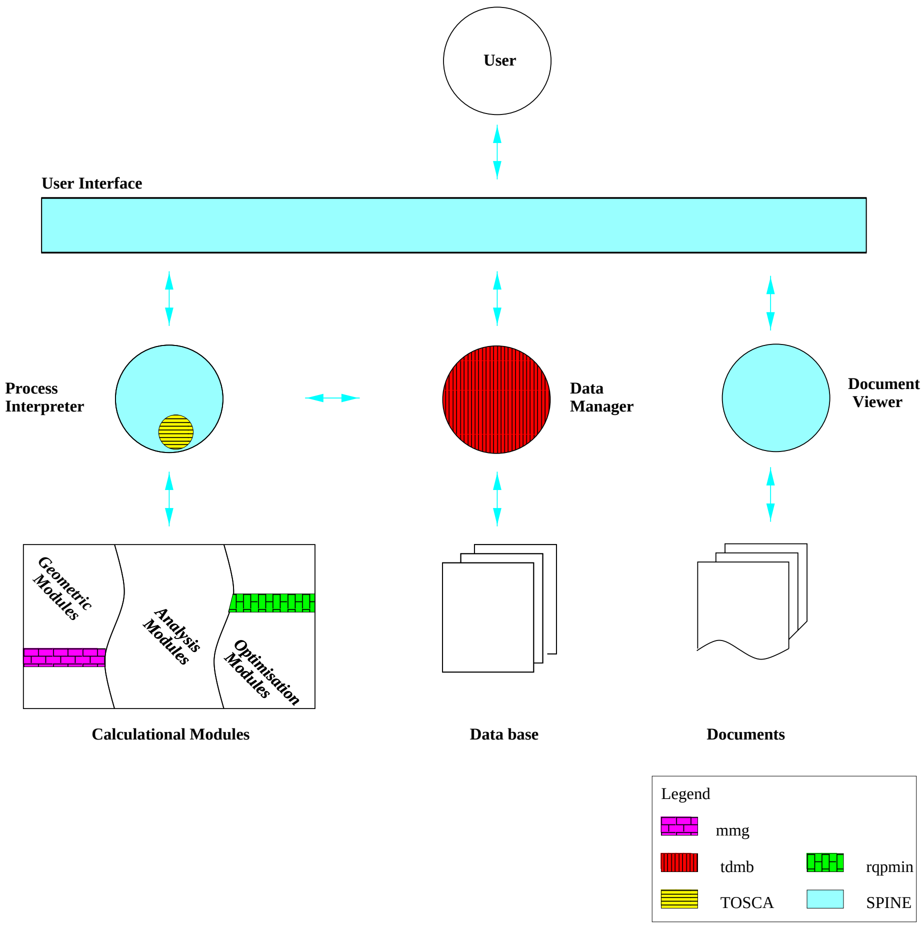

Fig. 3. Implementation of the MDO Prototype Framework

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- SPINEware for the User Interface, Process Interpreter (generic functions, and chaining of tools), and Document Viewer (Refs. [3] and [4])
- tdmb for Data Manager (Ref. [1])
- TOSCA for the specific Process Interpreter function of iteration of a suite of tools (Ref. [6])

with the Calculational Modules:

- mmg for the generation of all analysis models from the aircraft specification (Ref. [6])
- rqpmin for optimisation algorithm

In the environment, the software, data and documents are represented by icons. The Users browse through the environment in a window-like manner, with complete flexibility with respect to displaying the interesting bits. A snapshot of a session showing several windows with relevant Data and Software is given in Figure 4. The "help" icon in the open Software window serves to retrieve the

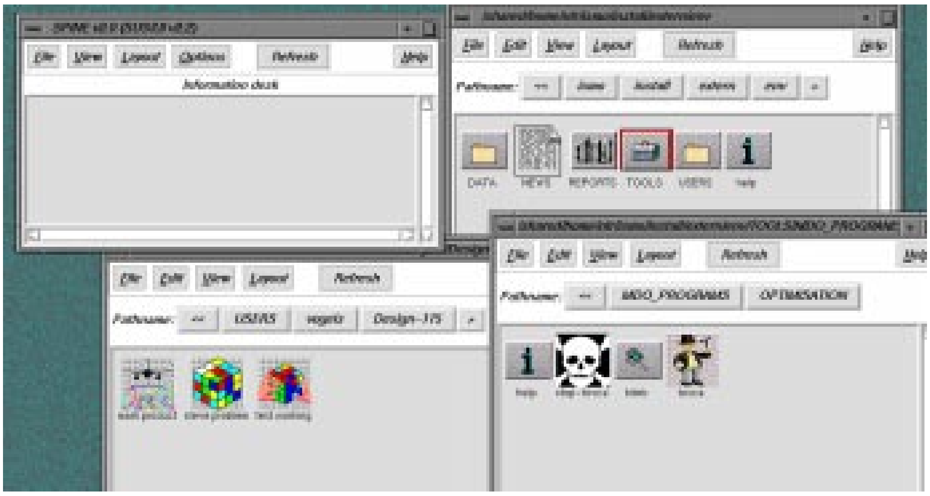

Fig. 4. Snapshot of a session in the MDO Framework

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documentation of the operation of the software. The documentation is shown when the Users drop an icon representing the software on the "help" icon. The help information is linked through to the other relevant documentation such as theoretical background and practical limitations. This latter documentation is also available by browsing through the documentation. Both ways to access the documentation are enabled by SPINEware; the integration of the documentation into the Framework is extremely easy.

Tools are invoked by dragging and dropping the icons representing the selected input-data on the icon representing the tool. If the tools or the data reside on a remote node in the enterprise's network, the data are automatically transferred to the processing node, the tool is invoked, and results are transferred back to the resident node. These actions are defined in the wrappers around the original tool (which usually is developed independent of the MDO Framework). In the near future, the wrappers for CORBA-compliant tools can be reduced.

Users can build chains of tools via mouse-operations by (1) selecting tools and dragging and dropping tools on a canvas and (2) creating data-containers for input-data, intermediate data, and output-data. In Figure 5 an example is given of a chain of tools generated with `SPINEware`. The data-containers are all filled.

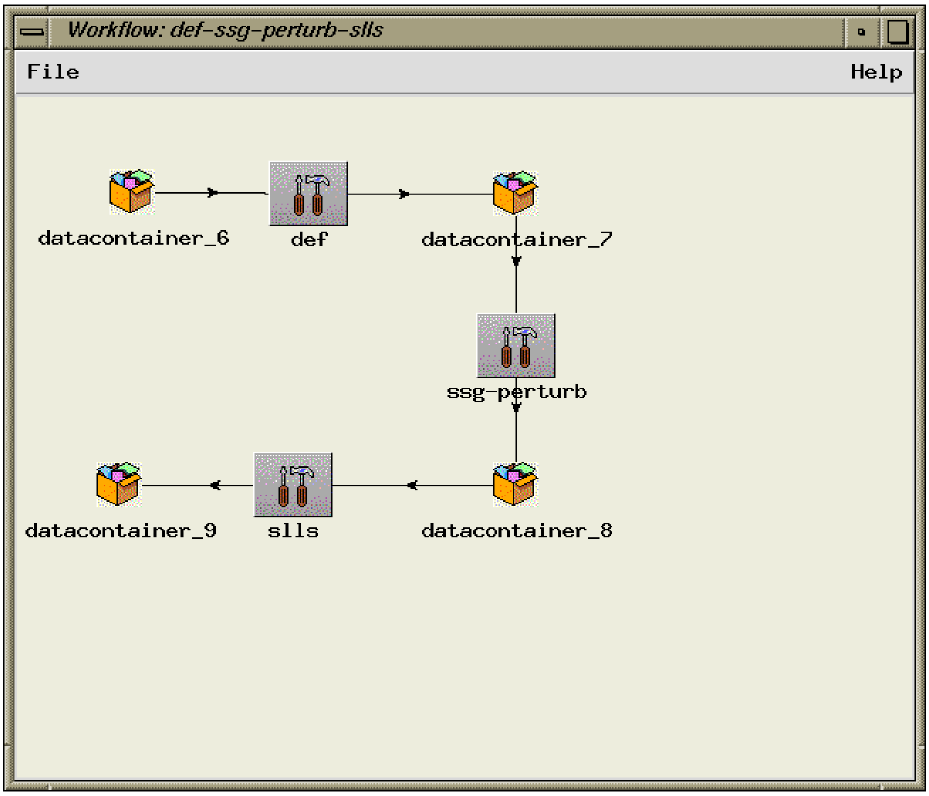

Fig. 5. Chaining in `SPINEware`

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The interactions during iterations of Analysis suite and Optimiser under the control of `TOSCA` is shown in Figure 6 (Ref. [6]).

Similar to the browsing of documents and software, data concerning previous designs can be browsed, visualised, or used for further analysis.

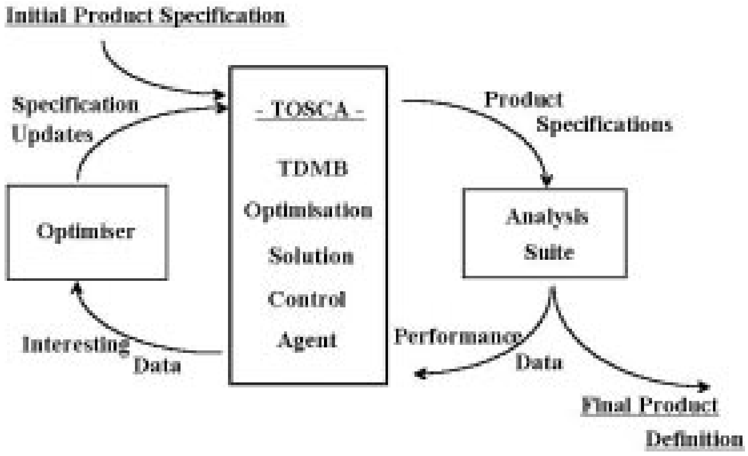

Fig. 6. Interaction (courtesy British Aerospace)

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HPCN as a commodity

For practical aircraft design the computation of design characteristics requires high performance computing on the most powerful super computers. Even then, current computation times for advanced analysis methods are in the order of 1 CPU hour per discipline, design variable, and optimisation cycle [6]. Desktop computers such as work stations and PC's are required for pre- and postprocessing (Ref. [4]). This results in a distributed HPCN environment in which the engineers have to find their way. HPCN becomes part of the enterprise competence if it is offered to the engineers as integrated part of their desktop computer without the performance limitations of desktop computers. HPCN becomes a commodity if desktop computers, high performance computers and supporting servers such as file servers, Internet and intranet servers, are integrated into one virtual computer with desktop characteristics. This can be realised with `SPINEware` as described in the preceding section.

The MDO partners make use of a variety of high performance computers and work stations. Parallel vector computers with a limited number of very powerful processors operating on a shared memory are simpler to use in software development than massively parallel processor (MPP) computers for computational fluid and solid mechanics software. It is a myth that massively parallel processor computers are cheaper than vector computers [5] and as a consequence additional efforts to develop software on these platforms are not justified. Once the software is implemented, for the MDO Framework, the use of vector computers and MPP computers is equally easy.

Experiences

To solve conflict of interest of individual and common goals in the realisation and application of the MDO Framework it appeared to be essential to serve the interests of individuals from the beginning. This was a successful guideline in the MDO project.
The effort to realise that

- engineers are willing to cooperate
- engineers are willing to share information
- engineers contribute to the competence management,

strongly depends on the degree of application of process and product control in the enterprise. The training of the enterprise work force - including the management - requires continuous attention.
The cost for the definition and realisation of the populated MDO Frameworks to support the MDO work in the MDO project, amounted to about 10 % of the total project cost. The cost for maintenance of the MDO Framework for changes in the network are estimated to be in the order of 1 man week per year.
In enterprises, security measures are implemented in the computing infrastructure. Authorisations of engineers have to match the tasks of the engineers in the MDO process.
Engineers who are new in the enterprise, appreciate the applicability of the know-how accumulated in the MDO Framework. This makes enterprises attractive for the right people.

Future work

The tendency is that enterprises cooperate in MDO processes. Equal partner consortia as well as enterprises with subcontractors need to act in an integrated way, while maintaining the protection of the competence of each enterprise. In the resulting so-called Extented Enterprise then software, data and documents shall be shared when needed. An ICT framework that integrates software, data and documents at different geographical locations, should be segmented to protect interests of partners in the Extended Enterprise.

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