Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-TP-98220

Know-how management in distributed engineering environments

M.E.S. Vogels and W. Loeve

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-TP-98220

Know-how management in distributed engineering environments

M.E.S. Vogels and W. Loeve

This report is based on an article to be published in The globalization of Manufacturing in the Digital Communications Era of the 21st Century: Innovation, Agility, and the Virtual Enterprise, by Chapman & Hall 1998.

Division:	Informatics
Issued:	May 1998
Classification of title:	unclassified

Abstract

Enterprises need flexibility in application of engineering know-how and continuous increase of engineering know-how to lower cost of production while the speed of changes in the global market place increases. A threat for enterprises however is loss of engineering know-how through floating staff: staff is hired on temporary contracts and experts continuously are looking for new opportunities for self-development. Information and Communication Technology (ICT) offers opportunities for support of management, conservation, accumulation and flexible application of engineering know-how. ICT also can be applied to support synergy between staff know-how and accumulated enterprise know-how. In the paper opportunities created by ICT to realise continuous increase and flexible application of know-how are illustrated by creation of virtual engineering environments.

Contents

Abstract 2

1 Introduction 4

2 Requirements for the virtual MDO environment 6

3 Architecture and Construction of the virtual MDO environment 8

4 Experiences 11

5 Future work 13

References 14

Biography 15

5 figures

(15 pages in total)

Introduction

Survival of an enterprise requires satisfied customers. For customers to become satisfied, the enterprise has to ensure on time delivery of the product, competitive cost of the product and customer appreciation of the product. For customers to stay satisfied the enterprise continuously has to enhance the performance of the enterprise. This means that products are delivered in shorter time, products are becoming cheaper and customer appreciation is increased. Enterprises need flexibility in application of engineering know-how and increase of engineering know-how, to lower cost of production while the speed of changes in the global market place increases and requirements concerning ecological aspects of the product life cycle become more difficult to meet.

Engineering is an important process in the production process chain. To achieve continuous enhancement of the enterprise, the enterprise has to continuously increase the engineering know-how. Moreover the enterprise needs to take measures to enable the application of engineering know-how from all relevant disciplines in an integrated way in a variety of iterative engineering processes. The enterprise nowadays is confronted by several threats that endanger the increase of engineering know-how and the ability to apply the know-how in the required flexible way.

Enterprises on the one hand need to continuously adapt the engineering work force to the workload 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 that 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 know-how of engineers and the know-how accumulated in the enterprise. The enterprise know-how stems from the previous experiences in similar business processes. It is a threat for enterprises that enterprises can not rely any more on preservation of enterprise specific know-how in the work force. Enterprises have to take measures to preserve the know-how.

People are the origin of the know-how in enterprises. In enterprises know-how of people can be conserved in three know-how carriers: documents, data and software. Software such as for analysis by simulation in engineering contains know-how in an implicit very condensed form. Documentation such as describing the use and application boundaries of software serves to make the know-how in software explicit. The enterprise has to introduce tools and procedures supporting a way of working that enable conservation of know-how in documents, data and software.

Measures have to be taken to ensure re-use of the conserved enterprise know-how in an integrated way by successive generations of specialised engineers in a variety of engineering processes.

Information and Communication Technology (ICT) offers opportunities to create virtual engineering environments in which engineering know-how can be conserved, accumulated and re-used in complex processes. Facilitating synergy between individual know-how and the accumulated enterprise know-how in the virtual environment requires making a process model of the engineering processes and arranging the know-how carriers in the environment in such a way that the know-how structure reflects the relevant process structure. The application of ICT to create effective virtual engineering environments will be illustrated for multi-disciplinary analysis and optimisation with a variety of analysis tools from various disciplines.

The experiences and results of the MDO project[1] aiming at the integration of design and analysis tools creating a Multi-Discipline Optimisation (MDO) capability serve as background for the description in the present paper. The ICT contribution in the MDO project is given in References (Vogels, 1998a) and (Vogels, 1998b). The organisational experiences with the development of the environment for multi-discipline engineering are reviewed. Experiences with the creation of the virtual MDO environment will be compared with experiences with the creation of a virtual environment for mono-disciplinary aerodynamic analysis. The application of the concerning tools is described in Reference (Burg van der, 1997). It concerns the FASTFLO project[2].

[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).

[2] The FASTFLO project aims at a common, automated European CFD system and is a collaboration between NLR, DLR, FFA, SAAB, DASA-LM, IBK. The project is funded by the CEC under the BRITE EURAM initiative (Project Ref: BRPR-CT96-0184).

Requirements for the virtual MDO environment

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 (Allwright, 1996a). 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 the various disciplines. As a consequence in the engineering process information generation and analysis occurs in various disciplines and information exchange between disciplines on more than one level of detail is essential.

For Multi-Discipline Optimisation (MDO) both problem specification and problem solution (via process execution) is required. 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.

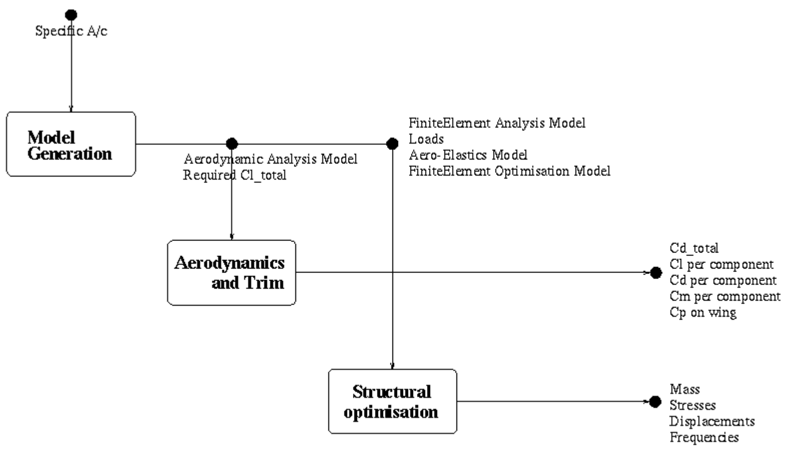

Figure 1 Example of contributing disciplines in analysis

To turn software and data into enterprise know-how, the capability to access and apply the know-how independently of the originator has to be created. The first measure for this is to document the operation, theoretical background, and practical limitations. To realise synergy between individual know-how and the know-how in the enterprise a required second measure is to make the software, data, and documents accessible and applicable. Accessibility and applicability mostly is complicated. Software, data and documents in general reside on a heterogeneous distributed network. In case of co-operating enterprises more than one network is involved.

Architecture and Construction of the virtual MDO environment

The architecture of the MDO environment, populated with software, data and documents is presented in Figure 2 (Vogels, 1998a). The users interact with the MDO environment through a common user interface. The user interface supports:

Using the MDO Process Interpreter to control the execution of Calculation Modules (including Design, Analysis, and Optimisation).

Using the Data Manager to control design data relating to the exploitation of MDO.

Using the Document Viewer to access the documentation concerning the software tools, data, and the MDO process.

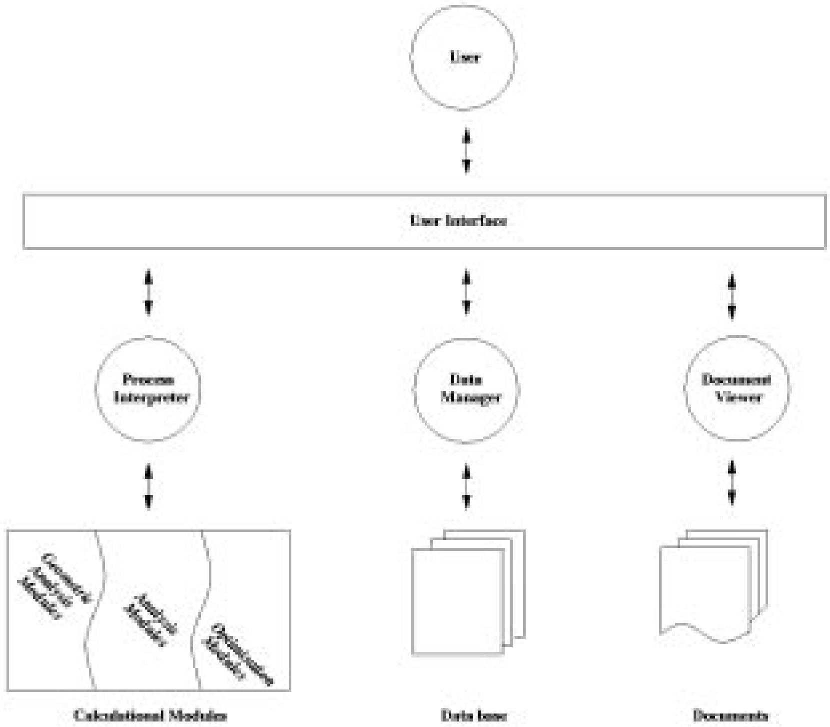

Figure 2 Generic architecture of the virtual MDO environment

The MDO prototype environment, demonstrated to the MDO Consortium in January 1998, consists of the cooperating software elements:

SPINEware for the User Interface, Process Interpreter (generic functions, and chaining of tools), and Document Viewer (Baalbergen, 1998), (Loeve, 1997)

tdmb for Data Manager (Allwright, 1996b)

TOSCA for the specific Process Interpreter function of iteration of a suite of tools (Vogels, 1998b)

The following calculation modules are part of the MDO prototype environment:
mmg for the generation of all analysis models from the aircraft specification (Vogels, 1998b)
rqpmin for optimisation algorithm

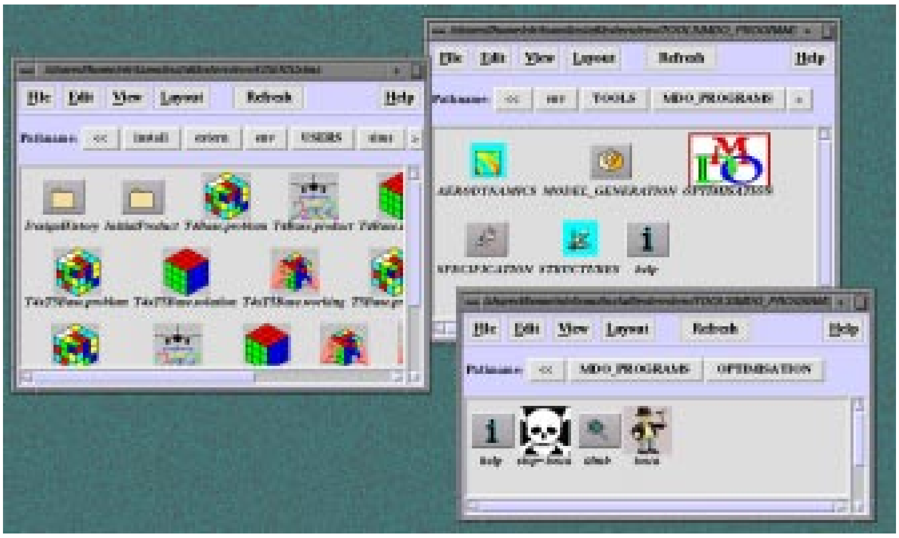

Figure 3 Snapshot of a session

Icons represent the software, data and documents in the environment. 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 3.

The "help" icon in the open Software window serves to retrieve the 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 environment 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 environment). In the near future, the wrappers for CORBA-compliant tools can be reduced.

In (Groothuizen, 1998) it is described how SPINEware is used to give engineers like in the MDO environment, access to documents, data and software in connected networks of co-operating enterprises. If security problems are solved, the approach is a proper basis for virtual engineering environments in which co-operating enterprises can act as one extended enterprise.

The interactions during iterations of Analysis suite and Optimiser under the control of TOSCA is shown in Figure 4 (Vogels, 1998a). Similar to the browsing of documents and software, data concerning previous designs can be browsed, visualised, or used for further analysis.

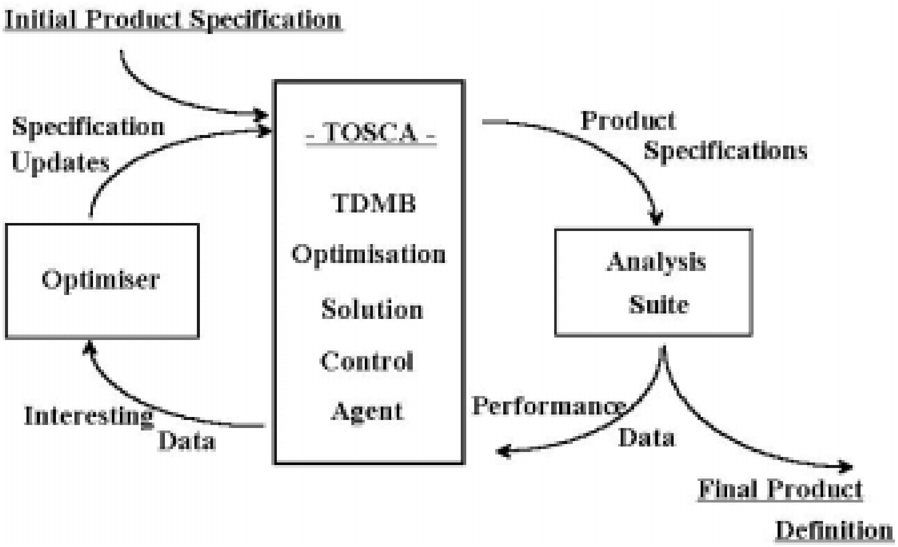

Figure 4 TOSCA's control over iterations

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.

Engineering environments as described above serve individual interests of engineers by supporting access to tools in the network, by easy re-use of specific tools like for conversion of data and by support of management of data. The environments support the interest of enterprises by presenting a framework for configuration management and control for documents, data and software and for providing users with supporting help information. In this way the engineering environments support conservation, accumulation and application of know-how generated by the people in the enterprise

Experiences

Flexibility with respect to the engineering processes and the related variation in the number of engineers on the payroll requires that enterprises pay attention to conservation, accumulation and re-use of know-how. This involves continuous education and training of engineers and management, tools for people to assist them and a way of working in the enterprise that is directed towards know-how management.

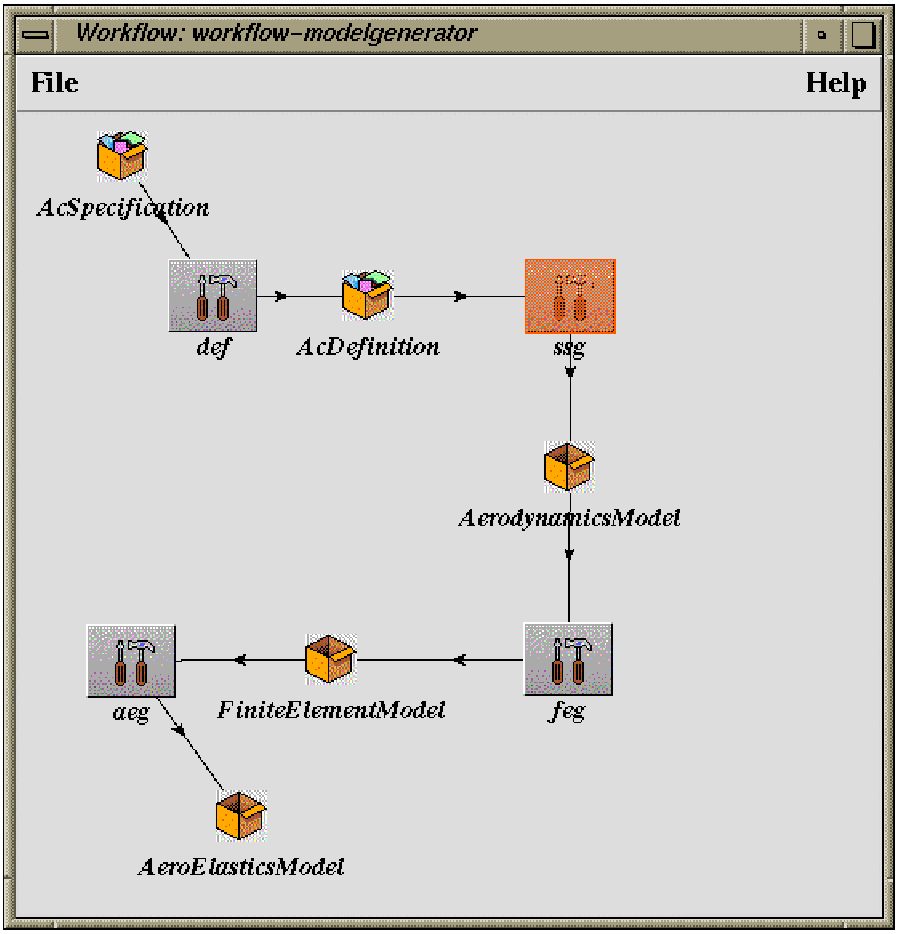

Figure 5 Workflow

The effort to realise that engineers are willing to co-operate and to share information and that engineers want to contribute to know-how management, strongly depends on the involvement of the management in application and continuous enhancement of process and product control in the enterprise.

To solve conflict of interest of individual and common goals in the realisation and application of the virtual MDO environment and the virtual FASTFLO environment it appeared to be essential to serve the interests of individuals from the beginning. This was a successful guideline in the MDO project and not applying it in the FASTFLO project right from the beginning caused delays.

From analysis of the MDO and FASTFLO virtual environments it appeared that engineers especially appreciate the following features:

the possibility to execute chains of tools as one tool,

the possibility to start-up chains from other tools,

the possibility to create specific protected virtual environments for specific tasks,

the reduction of complexity of software systems via a uniform graphical user interface and structuring of software, data and documents in accordance with the structure of the engineering process.

The cost for the definition and realisation of the populated MDO environments to support the MDO work in the MDO project, amounted to about 10% of the total project cost. The cost to adapt the MDO environment to changes in the network is 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 environment. As a result of proper structuring of the know-how in the virtual environment, synergy between the accumulated know-how and the individual know-how appeared to be easy. This makes enterprises attractive for the right people and increases efficiency of engineering processes.

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 Extended 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.

References

Allwright, S. (1996a); Technical Data Management for Collaborative Multidiscipline Optimisation; published in *Proceedings of the AIAA Conference on Multidiscipline Optimisation*, Seattle, 1996.

Allwright, S. (1996b); Multidiscipline Optimisation in Preliminary Design of Commercial Transport Aircraft; published in *Proceedings of the ECCOMAS'96 Conference*, Paris, 1996.

Baalbergen, E.H. (1998); SPINEware: a practical and holistic approach to metacomputing; published in the poster section of *the Proceedings of the HPCN98 Conference*. Springer 1998.

Burg, van der J.W., Oskam, B. (1997); FASTFLO-automatic system for three-dimensional flow simulations; Conference on Industrial Technologies and 3rd Aero Days Toulouse, France, 1997, NLR TP 97556.

Groothuizen, R. Ven van der H. (1998), A NICE HPCN centre for flow simulation; published in *the Proceedings of the HPCN98 Conference*. Springer 1998.

Loeve, W., Vogels, M.E.S., Ven van der H., Baalbergen, E.H., (1997); Network middleware for enterprise enhanced operation; published in *Proceedings of the 4th International Conference on Computer Integrated Manufacturing ICCIM'97 Singapore*; Springer 1997 ISBN 981-3083-68-9.

Saini, S., Baily, D.H. (1996); NAS Parallel Benchmark (Version 1.0) Results 11-96; NASA Ames Research Center, e-mail: saini@nas.nasa.gov.

Vogels M.E.S., Allwright S.E., Stettner M., Sims Ph., Bartholomew P. (1998a); The Information and Communication Technology's Contribution to MDO; Royal Aeronautical Society MDO Conference, 1998.

Vogels M.E.S., Arendsen P., Krol R.J., Laban M., Pruis G.W. (1998b); From a monodisciplinary to a multidisciplinary approach in aerospace: as seen from an Information and Communication Technology Perspective; 21st ICAS Congress - Melbourne Australia, 1998.

Biography

Dr M.E.S. (Marli) Vogels graduated in Mathematics and Informatics at the University of Technology at Eindhoven. She obtained her PhD degree at the University of Twente. The title of her thesis is: Architecture and construction principles for computational fluid dynamics software for engineering in industry. Marli Vogels is deputy head of the mathematical models and methods department of the Informatics Division of the National Aerospace Laboratory NLR in the Netherlands. She was site manager of the MDO project and task leader of the Information and Communication Technology (ICT) task in this project. She is ICT consultant for technical automation in engineering.

W. (Wout) Loeve graduated in aeronautical engineering at Delft Technical University. He is head of the Informatics Division at NLR. He is responsible for development of aerospace information systems by NLR for customers such as aerospace industries, civil aviation authorities and armed forces. Wout Loeve introduced quality management at NLR for development of information systems including mathematical models and methods, for which the Informatics Division holds an ISO 9001 and AQAP-110 certificate.