Towards the Extended Enterprise in Project Business

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Abstract

This paper studies the evolution of engineering information systems towards full support of distributed operations in project business. The results reported are based on an industrial project called *Connecting Distributed Competencies (CoDisCo).* With multiple industrial collaborators the project brings together project management, Internet and the construction of complex products. The aim of the project is to outline the best practices, both managerial and tool-wise, on how to connect distributed partners and their competencies in such a way that the end-product is delivered in time, with right quality, reliable documentation and within the planned budget frame. From the cases ranging from complex scientific instrumentation to traditional industries such as shipbuilding it becomes evident that modern communication systems can improve efficiency and reduce mistakes, yet they do not make well-allocated face-to-face reviews with collaborating parties obsolete. It is also reported that despite the sophisticated network applications the routines performed with them are trivial and that higher-level system integration between parties requires information to be structured in a coherent way. Introduction of formal data structures is laborious, but when completed project efficiency is improved. It is concluded that in order to turn project-oriented businesses into extended enterprises the deployment of Internet and WWW play a decisive role.

Keywords: configuration management, document management, project management, Internet, World Wide Web (WWW), distributed product development, networking, one-of-a-kind manufacturing, complex products, supply chain management.

1. Motivation

No major achievement requiring multiple technological disciplines and significant design work can be materialised without geographically distributed operations. The networked operations are becoming normal routines even for industries producing conventional products. Continuous pursuit on better performance has in many cases trimmed the production processes right to the maximum and significant productivity increases cannot be achieved without major investments. Development focus has been turned on human interaction and especially on how documents and information in these networked collaborations are managed. Companies that manage best the activities related to the creation, distribution and management of knowledge in a distributed environment are likely to be the future winners. This trend has given configuration and product management a key role together with networking when companies are restructuring their operational procedures. The increasing part of product value added by suppliers instead of the principal

contractor increases the need for tight control and exchange of documents between contractors and geographically distributed suppliers. This article pursues this trend.

Distributed operations, increased outsourcing and global competition push companies and project organisations towards networking and improved communication. Spurred by the advancement of information technology, this evolution has led many companies to invest in Information Technology (IT) solutions such as Enterprise Resource Planning (ERP) and Product Data Management (PDM) to improve information management. In addition to the market boom for such systems, the common understanding that tools alone are not enough has got inductive support as implementation base has grown. Well-founded management procedures can do much more to improve the performance of a company than fancy IT applications. In the current business environment, processes and information within the company are no longer the primary focus, but rather those of the *Extended Enterprise* enclosing into well managed information network the suppliers and customers as well as the primary contractors.

The motivation for better information management is further increased by the trends in the current project business environment (Hameri, 1997):

- Products are the results of geographically distributed interaction between specialised and highly qualified teams;
- Electronic communication, document manipulation and sharing has become mandatory;
- Complexity of products, even those with simple functions, is continuously increasing;
- Continuous pressures to cut down operational expenditures and at the same time maintain the given quality and time objectives;
- Companies are forced to increase out-sourcing and service contracting in order to concentrate on their core competencies.

These requirements tend to amplify each other and demand a flexible project organisation with a capability to evolve and maintain the needed level of expertise through the conceptualisation, design, manufacturing, assembly, commissioning and maintenance, and even up to the demolition phases of the product life-cycle. Thus, efficient communication and information management across the extended enterprise of project partners is of ever-increasing importance.

These issues are addressed by the industrial research and development project CoDisCo – Connecting Distributed Competencies. The project consortium and the actual research setting include a shipyard, IT companies producing tools for ship builders and an engineering organisation specialised in complex system deliveries. The project is partially funded by the Nordic Industry fund (NI). The focus of the project is both on the management processes for distributed projects, as well as on Internet-based tools and how they can be used to support these processes. From the start in late 1998 the partners in the CoDisCo-project have created a virtual organisation between the participants using WWW-based project and document management tools for all communication and document sharing.

This paper describes how information systems such as PDM and ERP can support the processes of the Extended Enterprise and how these issues are handled within the partners of the CoDisCo-project. In order to do this we first discuss the PDM and ERP markets and their evolution from project management point of view, then we discuss the practical results obtained from the industrial collaboration with regard to systems used for distributed project deliveries. Finally, we discuss the extended enterprise approach and the challenges it sets for the management processes and the related IT systems.

2. PDM and ERP - markets and their evolution

Electronic document archives have been around for a while, but typically with focus on administrative data or used within one department of a company. PDM systems address product configuration management and document management for engineering organisations, throughout the product lifecycle. Special focus is put on handling data generated in the design phase such as Computer Aided Design and Manufacturing (CAD/CAM) models and drawings as this is the time where changes are less costly to process. One of the most important features of the PDM systems is that they impose disciplined processing of all product configuration changes, which due to less errors results in better quality and faster delivery times.

The market for PDM systems has gone from $400 million in 1994 with an average 30% annual growth to $ 1.4 billion in 1998 (CIMdata, 1999). Multiple sources report that investments in PDM have one to three year payback times. However, this is only half-true, as successful implementation of PDM requires detailed documentation of the design process and strict rules of configuration management. It could be anticipated that these payback times are based on calculations when the system is fully exploited by the organisation. To get this far is a lengthy process and experience indicates that PDM implementation may easily take several years before returns from the investment could be expected. On the other hand the positive trend from the investment tends to continue even after three years of full use of the system.

ERP systems such as SAP and BAAN are an evolution from Material Resource Planning and Material Requirements Planning systems for handling inventories and orders for the manufacturing industry. Today's ERP systems are often marketed as the solution to all needs of information management and e-business. Compared to ERP and other manufacturing management software, the PDM sector is taking only a narrow slice of the total market. In 1998 the manufacturing industry spent almost $22 billion on software from hundreds of vendors around the world (AMR Research, 1999).

Traditional PDM systems (e.g. Metaphase, Sherpa, CADIM) and ERP systems have been designed for use within one single enterprise with a uniform computing infrastructure that allows employees from different departments like engineering, manufacturing, administration and sales to access the system. In addition to provide employees access to the system, a company also has the possibility to enforce organisational procedures and train users, which is a prerequisite for successful use of an information management system. The PDM and ERP success stories that have fuelled the sales of such systems are mostly based on isolated studies of implementations within one enterprise, typically in businesses with long traditions with configuration management processes, such as aerospace, automotive and machine-tools industry. The trends in manufacturing and the supporting management processes and systems are depicted in table 1.

	1960/70s	1980s	1990s	2000
Competition	Price	Quality Price	Variety Quality Price	GLOBAL
Manufacturing Focus	Plant efficiency	JIT and TQM	Agile Manufacturing	
Manufacturing environment	Make into Stock	Assembly to order	Engineer to order	Customized design
Manufacturing Support Systems	MRP	CAD MRP II CIM	PDM ERP CAD, DMU	EES CPC Web
Productivity bottleneck	Manufacturing Capacity	Review & validation integration of design and manufacturing	Supply Chain Management	Knowledge

Table 1: Manufacturing management trends (IBM, 1995, with added projections).

3. PDM and the extended enterprise

According to Preiss (1997), a group of enterprises is transformed into an extended enterprise as companies move from being stand alone entities passing products one to another, to become links in an interactive, adaptive, extended enterprise which deals successfully with rapid change, an unprecedented level of integration of people, business and technology required. Today's projects are often carried out by virtual enterprises spanning to different locations, organisational cultures and last but not least, IT platforms (Schönsleben & Büchel, 1998). In the *extended enterprise* between a contractor and it's suppliers different computer applications with different data formats, are used throughout the product lifecycle (Figure 1). Product data is stored in different archives, each of them providing only a partial view of the product and thus hindering information flow. Contractors and suppliers typically have different organisational procedures and cultures that prevent a uniform information management policy.

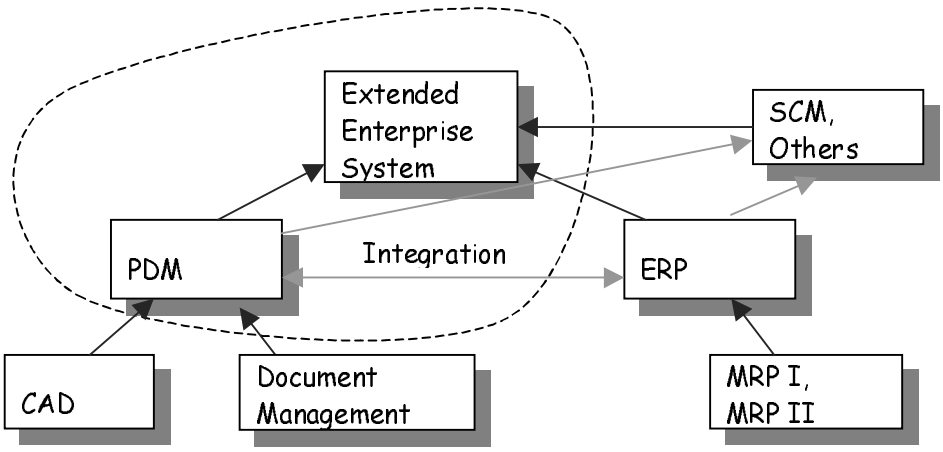

Figure 1. Design and manufacturing systems for the extended enterprise.

There is a stronger and stronger need to link different corporate IT systems across departments and with partners (Miller et al., 1998). These market forces drives PDM

vendors towards integration solutions, where different proprietary IT system have to communicate with each other. PDM originates from CAD/CAM and engineering activities and usually have interfaces to CAD-packages and Office automation tools. Increasingly PDM systems are linked to ERP that is used in the financial, administrative and manufacturing departments. Currently there seems to be a clear connection between the number of systems to which a PDMs can integrate, and the growth of revenues of the software vendor. The PDM market is still segmented among many players, but there are some prevailing trends:

- All PDM vendors have realised the need for a WWW-interface, but in many cases they are limited to passive consultation of data in the system. Also vendors tend to replicate native interfaces in Java for use on the WWW, thus loosing the simplicity offered by WWW and HTML.
- ERP systems such as SAP have started to offer PDM functionality, thus entering into engineering departments and posing a threat to "traditional" PDM vendors.
- *Supply Chain Management* (SCM) using the WWW is starting to take off in some industries. SCM is either done with dedicated WWW technology or via a PDM system. In automotive industry there are several examples of productive Internet-based SCM systems (see e.g. *http://supplier.bmw.de/en/index.html).*
- E-business is becoming a hot topic as companies put product catalogues on Internet and allow customers to browse and order goods via the WWW. Ideally the product data should come from PDM, but features such as encryption and electronic signature that are key to e-business are not yet widely supported by PDM systems.
- Share valuation of PDM and ERP vendors have been hit by reports telling that implementation projects get wrecked through complexity resulting in budget overruns. Some vendors try to re-profile themselves as e-business providers, but the underlying technology remains proprietary.

In an Extended Enterprise System (EES) product data, once generated and approved, should be available to all partners at every stage of the product lifecycle. The data should be independent of the software and hardware used to create it, or the location of information sources and destinations within single or multiple enterprises (see also Upton & McAfee, 1996). To be able to serve these needs an EES needs four key characteristics: easy to integrate to the other systems, easy to configure to the different user needs, simple to use and secure – these factors all point towards WWW-based information management systems. The future winners among management information systems are those that manage to combine open WWW technology with strong know-how of configuration management and understanding of business processes.

4. Results from the industrial collaboration

Against the background of changing working methods, virtual project organisations and increasing need for systems integration the CoDisCo project seeks for methods and tools to better integrate and exploit available resources by *collecting distributed competencies into one logical networked entity*. Focus is put on the management approach needed to support distributed processes rather than tools alone. The partners are all focusing on project and design driven businesses in different disciplines ranging from electrical and civil engineering, shipbuilding to logistics and software. The European Organisation for Nuclear Research (CERN), with its large scientific and industrial facilities is participating as a case- and technology partner. Each of the companies has to master geographically distributed design and manufacturing processes. Products are complex and errors are

costly to correct, and more so the later in the product life cycle they occur. It is the aim of the project to find best practices, both managerial and tool-wise, on how to connect distributed competencies in such a way that the end-product is delivered in time, with right quality, reliable documentation and within the planned budget frame.

The task is apparently immense as one American study reported after studying 8.000 project deliveries that only 16% met the cost, quality and schedule objectives (Frame, 1997). Best practices are identified through benchmarking of distributed design process and project management, including configuration, time, budget, risk and quality management. Benchmarks are done among partner companies in the CoDisCo consortium as well as other industrial companies. Altogether 6 companies were interviewed following the established benchmarking methodology (Andersen & Pettersen, 1995). Based on the information gathered in the benchmarks and case studies at the partner companies, managerial guidelines are compiled. The guidelines document configuration management processes needed to manage distributed projects, with special emphasis on the specification of the user requirements for distributed product data management.

Industrial companies are increasingly focusing on their quality and product configuration related processes. Engineering changes are being processed in disciplined way, and coherence of product data is seen as one of the key elements to improve quality and operational efficiency. According to the survey carried out by the CoDisCo-consortium the distributed engineering processes are being increasingly integrated with the means of the Internet. Electronic mail is used extensively to mediate design changes across geographical distances, yet more complex configuration management like product structure management is still in its infancy. Up to now the following preliminary findings on practices displaying good performance can be outlined:

- Clearly define the scope of the total project and the contributions from each participant before defining and allocating detailed activities.
- When sequencing and scheduling the resulting activities, special attention must be paid to geographic constraints. Despite the improved telecommunication means the distance plays a role in delays and misunderstandings.
- Those participants that will actually perform each task are best equipped to estimate its duration. Establish first schedule through democratic approach, not by dictating the time-windows for each deliverable.
- WWW-based tools are ideal for distributing project plans and especially for mediating changes to these. Yet, the case study indicates that this is one of the main benefits for the networked collaboration. Only in a few cases more advanced processes, like engineering changes or detailed designs were handled remotely. The potential of the WWW is far from being exploited.
- Even if being time and resource intensive, progress control must often be handled through on-site visits. Remote messaging proves to be efficient when accompanied with face-to-face visits.
- Risk identification must be handled jointly by the project consortium. Responsibility for single risk elements must be allocated to the partner suited to absorb and mitigate them.

It became apparent that moving towards an extended enterprise which encloses third parties requires that certain basic rules on how to manage operations has to be made clear to all parties. Especially when IT is concerned, guidelines concerning information management and how the information is structured plays a crucial role before any of the advanced functions concerning product and project management can be exploited. We display here

three cases that have been further studied within the CoDisCo project: One from the well-established shipbuilding environment, one from a scientific collaboration, namely the large engineering project to construct scientific instrumentation, and the communications and information sharing in the CoDisCo-project itself. From the extended enterprise point of view these cases highlight the very first steps towards real networked engineering and project collaboration with the help of WWW-technology. In each of these projects the WWW and Internet has been used to integrate existing data repositories to achieve the sharing of information that is needed to move towards an extended enterprise comprising supplier and end-customers. By means of systems integration and giving access to relevant information, real networking is enabled across company boundaries. These cases established the practical essence of CoDisCo-project as they have confronted the real obstacles that are faced when trying to implement WWW-integrated information processes in project environments.

Case1: Shipbuilding industry

A shipbuilding project can typically be divided into three phases:

- Design phase: the project breakdown is based on system level (e.g. decks, main engine, hot water system and tanks), which enables better cost estimation and launching of the main bidding process.
- Detailed engineering: The ship is broken into blocks or zones, which corresponds to the physical and location related structure of the ship. Typically the structure is based on a steel structure, which is a hierarchical bill-of-material view of the ship. It is also used to block associate parts of this structure to the location in the finished ship.
- Construction and assembly: detailed structure is based on blocks or smaller units, called e.g. single design units, these include the detailed work/activities and the related descriptions/instructions.

On aggregate level there are three structures: systems level, bill-of-material of the steel-structure, and assembly-structure based on the physical location with work instruction to assemble modules together. The problem is in managing information between structures which originates from different collaborating parties, for example finding overall costs by summing working hours in the assembly-structure and purchasing costs from the system's structure, or how to manage changes in the steel-structure, which affect assembly work. No system can yet automate this in a way so that the changes are adopted automatically and users asked for to-be-up-dated or otherwise missing information. Experienced engineers manage these tasks "by rule of thumb" based on many years of practical experience. Typically several IT systems have to be consulted before finding the information needed to support decisions about changes.

A pilot project was set up in the shipyard to study how a simple WWW application integrated with the ship design software can be used to disseminate information between the parties involved. The starting point was to exchange drawings and to gradually add more advanced functions on top of the document based information exchange. By mediating the document status and approval comments from a single drawings data source, the collaborators were able to track on-line changes and design progress. Secured access to the WWW data management system enabled selective communication even on more sensitive documents. As the documents were structured according to the bill-of-material that resided in the design database, the pilot turned out to sell itself for remote users without special push. Without this rudimentary integration and the general knowledge on the product structure among the collaborators the exercise would most probably have been useless.

It was learned that the steps towards extended enterprise, or more realistically towards integrating external partners contributing the project require the IT applications to be integrated on a level where the true exchange of information takes place. This means that benefits can only be reached from solutions that make collaborators to communicate directly with the original data sources, all other solutions duplicate and complicate the existing situation. Even though the pilot project was performed at a small scale, it involved external collaborators, as well as the design team at the shipyard. This set-up resulted in improved communication both internally and externally thanks to the simplified access to the in-house design database. Without lightweight WWW-technology this could not have taken place.

Case 2: The LHC accelerator project at CERN

As the birthplace of the World Wide Web and host laboratory for a global engineering project, CERN provides a unique environment for using Internet facilities for distributed project and product data management. CERN and its accelerator project was used as a fore-front benchmark on how to use Internet in global design and manufacturing project to mange and maintain documents, project information and individual communication. The Large Hadron Collider (LHC) project at CERN and the challenges involved for the management of the engineering data throughout the project lifecycle of 20 years puts strong requirements on the configuration management processes in the project. The basis for configuration management in the LHC project is a set of reference breakdown structures that describe the accelerator during the project lifecycle (Hameri & Nitter, 2000). The structures and attached documents are available through the WWW for all project participants and partners. Based on the information in the documents and structures, formal change management procedures have been established.

In order to support the distributed project management, CERN has implemented a WWW-based interface to engineering, manufacturing and maintenance data. The interface supports the globally distributed design work by making documents and information resident in corporate databases available to remote collaborators across the Internet. The system is also used to interface other databases from administrative contract follow-up procedures to the management of market survey documents (Figure 2).

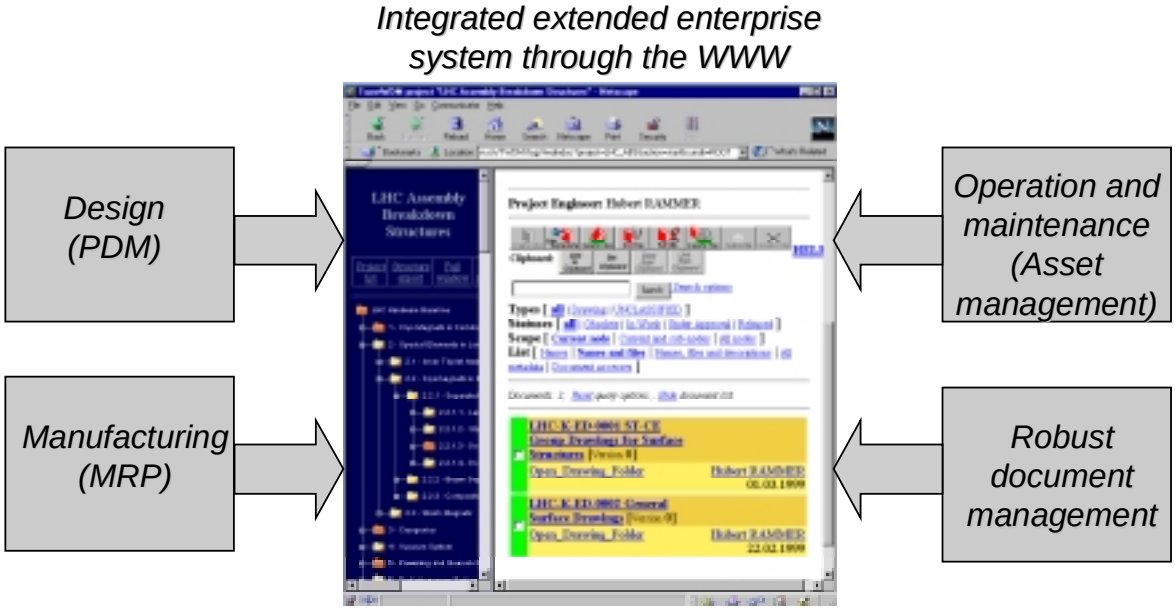

Figure 2. Using the WWW as an interface to all sources of enterprise information.

Like in the shipbuilding case, this case shows more profoundly that WWW can be used as the glue to unite different data sources, and in doing this the management of various structures (BoM, assembly structure, layout) needed for the project delivery plays a crucial role. The system is being used by more than 10.000 users in more than 30 countries. Through the unified interface the proprietary systems with their cumbersome native interfaces become easily accessible and therefore information exchange improves, as the threshold to start using the systems becomes lower. Easily editable interface templates make it easy to customise the look and feel, which is especially important when combining information from various data sources into one view. This development also imposes discipline in the development process, which surely improves the quality of the work.

Case 3: Information sharing within the CoDisCo-project

In order to support the activities of the project itself, the CoDisCo project partners from five different nations share all information via a WWW project *workspace*. The project has produced numerous reports and theses, which all are available from the project's WWW-workspace. Interaction between project partners has been active and information exchange vivid, as indicated by the statistics from the workspace (Figure 3). All information has been structured according to the original project plan, i.e. each work package and task has their own slot and users have respective roles according to their contribution in the project. The workspace is used for all information dissemination, including project reports, schedules and minutes, the only ones moving across the Europe in paper format are the invoices.

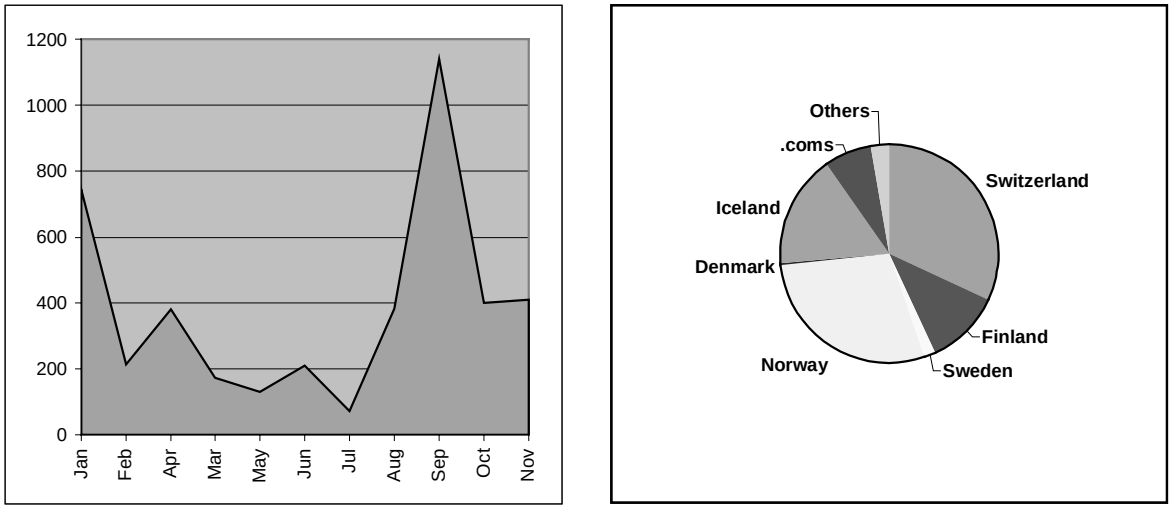

Figure 3. Overall hits in the CoDisCo WWW workspace (on left) and division of the communication by source country (on right).

The overall transactions in the workspace show highly increased activity before and after project meetings and deadlines. During the working periods between the meetings, information is exchanged among smaller, task-dedicated groups. Also the slump in activity during summer is clearly the result of the beautiful summer in 1999. One project partner uses the system to collect information from engineering and environmental studies for a planned large-scale industrial refinery. The system is also used to distribute the results to all concerned people be they in government, industry or academia.

5. Conclusions

The paper has deliberately discussed the road towards an extended enterprise in project business as an effort to integrate existing data repositories residing in various organisations

contributing to the distributed project. From the benchmarking results in the CoDisCo project, we know that the IT tools come after the partnering between collaborators has taken place and when the processes and rules have been agreed. We also learned that modern IT can not replace face-to-face communication among partners and that design review meeting should take place as planned. But it was also shown that modern IT with lightweight WWW interfaces connecting distributed databases to provide collaborators with vital and up-to-date information could speed the collaboration and prevent making errors based on ignorance. Distance between collaborating parties remains to be a hindrance, yet the response times are getting significantly shorter, which provides the distributed projects with an opportunity to improve their delivery times and overall efficiency.

Current PDM and ERP systems only partially offer the functionality needed by a true extended enterprise. The experience obtained from the industrial pilots provides inductive support that the missing link needed to knit the distributed project partners in to one logical whole is provided by the WWW-technology. It has become clear that moving towards an extended enterprise solution the WWW plays crucial role as the mean to integrate various data sources. As a by product to this it was also realised that for distributed project business environments the management of various project structures remains as the challenge to be tackled when moving towards higher integration of business processes. This will require both project management skills to streamline operational processes and engineering know-how for making the present isolated systems to communicate and unite information through the WWW.

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	Nils Høimyr got his MSc on CAD/CAM and rapid prototyping from the Norwegian Institute of Technology in 1991. Since then he has been working at CERN with Computer Aided Engineering applications, simulation and virtual prototyping. He was among the pioneers to put the WWW to use to handle engineering data in 1993 and has many years of practical experience with product data management and systems implementation.
	Marjo Viitala finished her master thesis on product data management in Spring 2000. Special focus was one-of-a-kind project deliveries and in the use of PDM to improve their productivity. Currently she acts as a project manager for Nokia Mobile Phones in order to create and deploy documentation management concept and implement a documentation management system NMP Europe and Africa region.