

WEB SERVICES AS A VIRTUAL PRODUCT DEVELOPMENT ENVIRONMENT

Mario Štorga, Nenad Bojčetić, Dorian Marjanović

Abstract

As a result of a new product development paradigm, there is a greater need for software tools to effectively support the formal representation, collect and exchange of product information during the product development stage. This paper presents a vision of next-generation engineering working environments for virtual enterprises. The concept of “Virtual product development environment” (VPDE) that is enabled by a new generation of Internet based services is discussed. In considering the VPDE, the following issues have been identified as crucial: (i) integration of different applications within the same organization; (ii) integration of organizations, applications and content between different organizations in the same virtual enterprise; (iii) integration of partners. The Web Service, the latest evolutionary step in distributed computing, has been proposed as the platform for realizing the VPDE infrastructure. Different possible roles of the Web Services technology in the process of product development are explained: organizational model, vocabularies definition, integration of processes and actions in product development, and communication of the product development process status. A Web Service for Collaborative Product Data Management as a test study of the presented research is introduced.

Keywords: integrated and distributed product design, virtual enterprises, web-based systems

1 Introduction

In the past, product development was often carried out within a single company by co-located design teams. In more recent years, there has been a shift in product development paradigms. Development teams involved in the product development are often geographically and temporally distributed. There is a high level of outsourcing, not only in the domain of manufacturing but also in the actual product development efforts [1].

In order to achieve a market objective that otherwise could be out of reach, SMEs, which do not have the complete knowledge for developing all the components needed for their products, need to outsource the development of specific parts; in this way a cooperation with other enterprises working in the same industrial sector starts. The cooperation often implies not just a simple made-to-order development but also a real collaboration among the companies involved in the definition of a new product. It is then possible to say that enterprises give rise to a special type of “virtual enterprise”, in which each company maintains the greatest flexibility and business independence [2]. Each member contributes its specific core know-how to the virtual enterprise. This concept enables very fast and flexible reactions to changed market conditions or new opportunities.

In the virtual enterprising context, it is possible to define the term “virtual product development” as a temporary cooperative activity of independent and distributed partners concerned with the translation of customer requirements into system functionalities [3]. As such partners deal with large products, complex design processes and engineering knowledge, the management and maintenance of the relevant information is diverse. Phases in the process of product development, particularly the early ones, are characterised by dynamic, evolutionary, vague, incomplete and occasionally conflicting product specifications as well as imprecise product defining data within distributed and heterogeneous IT-system environments.

Nevertheless, the current generation of product development software tools addresses the needs of the traditional product development process, and does not adequately support the new paradigm needs of industry described above. People exchange information across distributed design teams and corporate boundaries, and reuse information to a greater extent. Since the existing software tools do not capture a broad spectrum of product development information, these exchanges occur informally (face-to-face across a table, by phone, by paper). It is a lack of formal representations of product development information that creates a significant barrier to its effective capture and exchange. Moreover, high efforts in product data search (e.g. with respect to data format, data type, and data content) as well as in data interpretation (due to the domain specific codification) hinder the product innovation and produce unnecessary development iterations. In other words, the support of existing software tools is inadequate for satisfying the needs of modern virtual enterprises.

As a result of this new product development paradigm, there is a greater need for software tools to effectively support the formal representation, collect and exchange of product information during the development stage. As the complexity of products increases and the product development becomes more distributed, new software tools will begin to cover a broader spectrum of product development activities than the traditional mechanical CAD systems. Accordingly, the ability to collect, in an effective and formal manner, additional types of information will become a critical issue. This paper presents a vision of next-generation engineering working environments and describes a core information technology which future systems can be built on. The concept of a “Virtual product development environment” (VPDE), enabled by a new generation of Internet-based services are discussed here, as a means to stay competitive and to thrive in a turbulent market. This paper is organized as follows: Section 2 gives an overview of the Web Services technology, Section 3 discusses the critical issues of the “Virtual product development environment”, Section 4 presents the roles of the Web Services in the VPDE, and Section 5 briefly illustrates the implementation of Web Service for Collaborative Product Data Management. Finally, Section 6 ends with conclusions.

2 A new age of the Internet: the Web Services

The Internet is a world-wide conglomerate (“meta network”) of different networks that communicate among each other via a common protocol, independently of the hardware type used. Various network services can be used by everyone, either supplying or demanding them. A large range of distribution, the platform independence, an enormous number of user-friendly services that are easily accessible through the World Wide Web as well as the open standards used and free or budget-priced products (such as browsers, html editors, software updates) have lead to a high and continuously growing proliferation of the Internet. The advantages offered by the Internet for covering the information needs are held to be the following:

- Reduction of (transaction) costs by way of automation of information processing on the supply and/or the demand side;
- Reduction of local barriers by means of world-wide information offers;
- Reduction of time barriers by means of permanently available information;
- Improved coordination and cooperation with external partners using an integrated information and communication platform (e.g. platform independence, information exchange without media ruptures).

However, the application-to-application communication problem still exists. Businesses have needed a standardized way for applications to communicate with one another over networks, no matter how those applications were originally implemented. Web Services, the latest evolutionary step in distributed computing, represent exactly this solution by providing a standardized method of communication by means of which different applications can be integrated together in ways not possible before. Different applications can be made to call on each other's resources easily and reliably, and the different resources that applications already provide can be linked together to provide new sorts of resources and functionality [4]. Moreover, the application integration becomes much more flexible because Web Services provide a form of communication that is not tied to any particular platform or programming language.

At the core, the Web Services represent a unit of business, application, or system functionality that can be accessed over the Web. Web Services are applicable to any type of Web environment, Internet, Intranet, or Extranet, and be focused on business-to consumer, business-to-business, department-to-department, or peer-to-peer communication. A Web Service consumer could be a human user accessing the service through a desktop or a wireless browser; it could also be an application program or even another Web Service [4].

One of the key features of Web Services is that they are self-describing - you can use someone else's Web Service without knowing how it has been built. The foundation of the Web Services is XML messaging over standard web protocols which are independent of the hardware platform. These industry standards enjoy widespread industry acceptance, making them very low-risk technologies for corporations to adopt. The Web Services exhibit the following basic characteristic [5], [6]:

- Web Services communicate over standard Web protocols using XML message. **SOAP** (Simple Object Access Protocol) provides an extensible XML messaging protocol and also supports an RPC (Remote Procedure Call) programming model.
- Web Services expose an XML interface description. **WSDL** (Web Service Description Language) is a common XML framework for describing a particular Web Service. The WSDL specification is an XML document, which describes the interface, semantic, and administrative rules of a call to the Web Service.
- Web Services could be registered and can be located through a Web Service Registry. The **UDDI** (Universal Description, Discovery, and Integration) initiative is an industry consortium developing specifications for a universal, web-based business directory called UDDI Business Registry (UBR). Users can query the UBR to discover Web Services and to locate the information needed to interoperate with the service.

There are three major challenges in building Web Services that participate in a business web:

- **Build client tier-connectivity** to allow consumers of Web Services to connect and make use of a Web Service. The major types of clients that can connect to a Web

Service are: web browsers, PDA-s, wireless devices, applets, standalone applications, and existing systems.

- **Implement the web service** including workflow logic, data transformation logic, business logic and data access logic. There is functionality behind the Web Service that performs work on behalf of the clients.
- **Connect to back-end systems** that may include one or more databases, existing enterprise information systems, information repositories, business partners that publish their own Web Services and a shared context repository for user information shared across many systems.

The figure below provides a conceptual model of the Web Services and explains how the standards described above are related to each other.

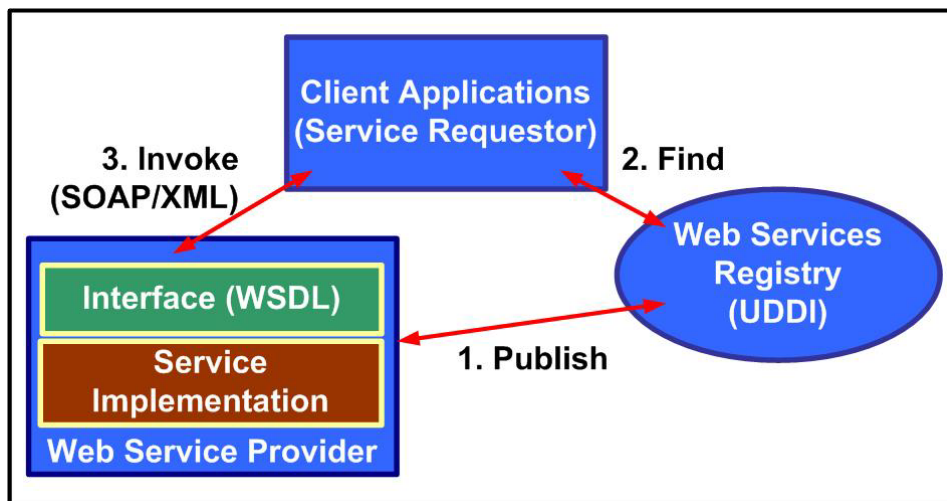


Figure 1: Web Services conceptual model

3 Virtual product development environment (VPDE)

Considering today's product development process requirements, VPDE should enable SMEs, its customers, suppliers and partners to share and exchange information about the product development process, engineering knowledge, customer requirements, manufacturing resource and entire supply chain [7]. When communicating with each other, enterprises may not speak the same “language” or understand particular design solutions adopted by others. To create and provide the right set of information and knowledge and to convey it into the right format in a controlled and secure manner to all participants in the product development cycle is one of the most critical aspects of a successful VPDE. The crucial issues that must be addressed in VPDE for supporting the product development process can be summarized as follows (adapted according to [8] and [9]):

Integration of different applications within the same organization: This is primarily the domain of VPDE, which provides solutions for connecting and interoperating disparate applications. These applications are typically applications for the creation of information (CAE systems) and management tools for controlling the flow of information (ERP/PDM systems, knowledge management systems, human resource). In this scope, the emphasis is on interoperability and integration between these functionally differently applications. It is possible that very large organizations will have different packaged applications in the same category - for instance two different CAD systems.

Integration of organizations, applications, and content between different organizations in the same virtual enterprise: Mergers and acquisitions have been quite common and frequent especially in the past 10 years. In most cases the acquired or merged organizations have different CAE systems, engineering databases, processes, and applications. The integration will involve consolidating the various applications and content from different organizations. The main difference with respect to the previous issue is that there is typically more heterogeneity in different systems that are integrated "top-down."

Integration of partners: This involves many different companies and collaboration agreements, security, and reliability requirements are often much more stringent. This category of integration will involve processes between many collaborative partners over extended enterprise networks.

In addition, collaborative product development process enabled by VPDE should realize the following:

- environment and integrated tools should enable teams to work together using consistent information;
- project teams should work in real-time across multiple sites separated by time and distance;
- collaborative visualization should help reduce ambiguity and data misinterpretation;
- collaboration characterized by input and feedback should help to improve design quality, reduce development times and costs;
- by supporting the decision making process during the product development, VPDE could also provide some forms of knowledge management in product design and manufacturing, including the standard component repository or online training for the design process and manufacturing procedures;
- online help documents on product development, forums, message and discussion boards, should enable interactive communication of the parties involved in the process of the product development process according to the concept of the online community.

The focus of the presented research is to investigate the possibilities of using the Web Service technology in order to add the previously described issues to the VPDE users.

4 Roles of Web Services in VPDE

Based on the experience of different research projects (iViP, GEN, ANICA, ROCHADE) as well as on the developed concepts/methods (such as PDM/EDM, EIS/MIS, AECMA, NPDM, ISO 10303 and Middleware Web services) [3], the benefits of using Web Service technology as a core IT platform for VPDE, have been identified. They comprise minimized processing times and costs and the improvement of the following features:

- functionality – system supporting and/or fully automating product development process;
- integration – system to (internal or external) system communication;
- usability – effortless communication between the human user and the system;
- security – protection of the enterprise knowledge;
- flexibility – easily adjustable to a fast-changing business environment.

There are some inherent advantages that make Web Services the ideal platform for realizing VPDE infrastructure. They include the ease of integration, the ubiquity of XML and HTTP, and the ease with which collaboration partners may be discovered. Web Services can be used in product development process for:

1. *Organizational model*

The UDDI registries in the Web Services architectures already support comprehensive information about organizations to enable the creation of partners or participants in virtual organizations and the product development process. The UDDI model or other Web Services could be offered to support rich organizational information for dynamic integration of participants in the development process.

2. *Vocabularies definition*

As mentioned before the XML message or document payload represents the input and output data of a particular exchange or activity. Different types of applications (ERP, CAD, KM, HR) have their own data types and operations. XML transformations can also be implemented as Web Services, which then provide transformational functionality between vocabularies or data types.

3. *Integration of processes in product development*

Integration of processes in product development is an ideal way to compose Web Services. Thus, different Web Services can be brought together through the process integration and can be offered as new Web Service. An important advantage of such functional model is that it supports the parallel and distributed computation of services. That is precisely what is needed with Web Services that get executed by different applications, possibly within different organizations.

4. *Actions in the product development process*

The composition of Web Services specifications through product development processes allows the specification of the different process templates. As indicated before, the product development process management spans and includes the workflow, enterprise application integration, and business-to-business integration [Figure 2.]. Each of these categories or processes that primarily include participants in one of these categories (either mostly human participants, or mostly applications) will have different requirements for the process actions mentioned here. In the definition of the product development process template there are definitions of choreographies involving many participants, ports, decision logic, and message exchanges. Once these processes are deployed, there are many Web Services that could be used for the run time execution of the processes.

5. *Communication of the product development process status*

The dynamic communication of the status of the processes integrated during the product development phase has been addressed. This is especially important for longer-duration processes. For instance, if an organization activates a large and complex development process that consists of Web Services from different partner organizations, decision makers might be interested in finding out how far the process has progressed in its choreography of Web Services activities. If human participants are involved, processes tend to be longer. Short duration processes could also benefit from Web Services that provide the execution state and history of the development process execution for particular process templates.

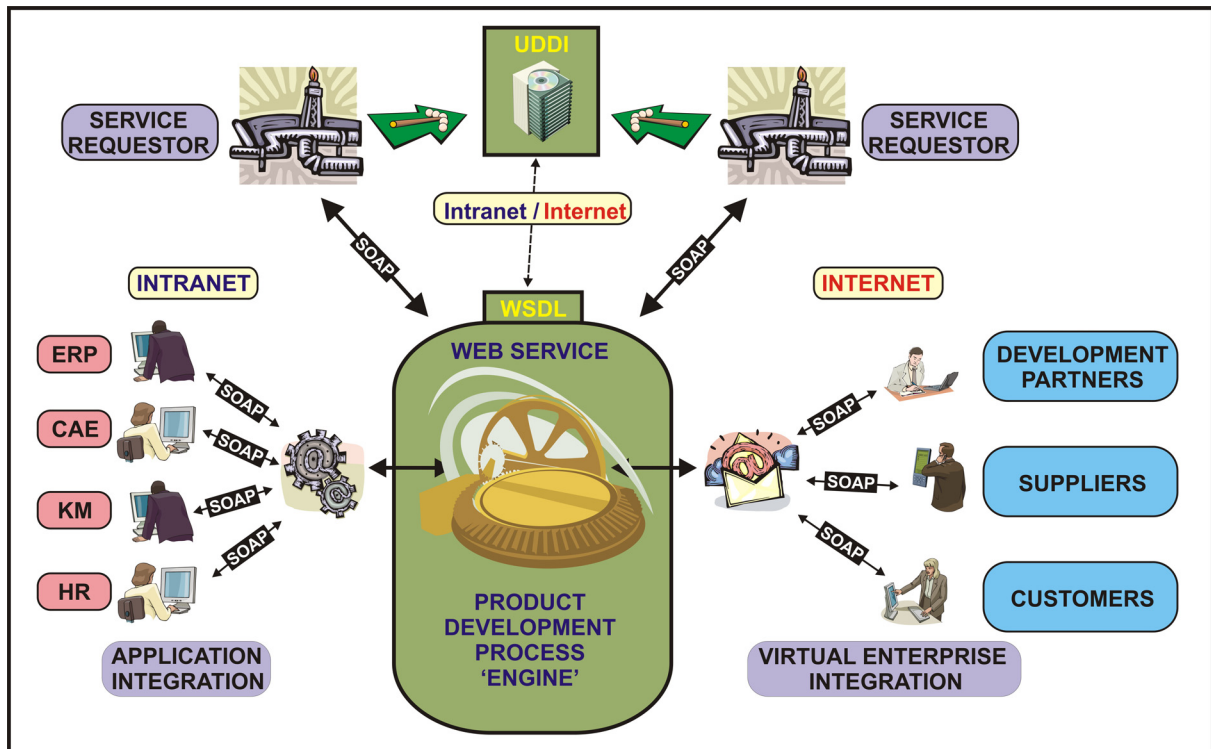


Figure 2. Overall architecture of Web Services in the management of the product development process

5 Case study: The Web Service for CPDM

A Web Service for Collaborative Product Data Management (CPDM) has been developed by the implementation of the selected ISO 10303 STEP PDM Schema entities [6], and using the benefits of Web Services technology. The aim of the whole system has been primarily to support non-geometrical data management in the product design phase, including the data management of product physical components, design process and workflow management, as well as to provide support to management of structured and configurable documents as the main parts of product physical structure. The presented solution is based on Java²™ platform that defines a standard for developing multi-tier, portable and platform neutral enterprise applications based on the technology of Web Services [10].

Striving to discover the main problems of collaborative product data management, the theoretical backgrounds in the particular research area were analysed, and interviews with the members of the design departments of SMS companies were carried out [11]. On the basis of the collected findings, the main elements of the product informational metamodel, that present a foundation for building a Web Service for CPDM, were determined [6] [Figure 3.]:

- Information binding product data carriers (physical components of the product and structured documents defined by hierarchy, revisions, variants and status),
- Information binding subjects that create, own and manipulate product data (users, projects, organization, design tasks),
- Information binding activities that use the product data and that are coordinated by subjects (hierarchical structure management of products and documents, engineering change management, approval and authorisation procedures, design process documentation and history, product configuration processes).

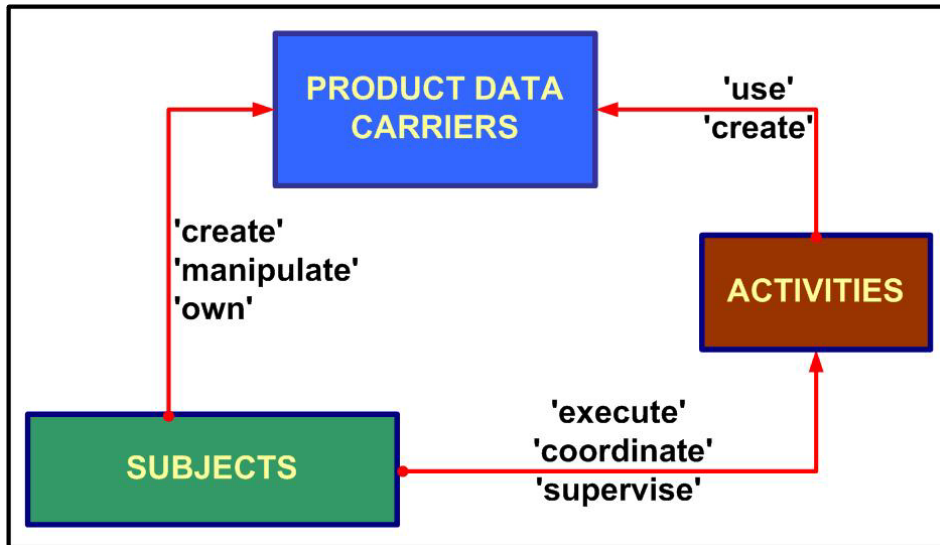


Figure 3. The main elements of the product data informational metamodel [6]

To fulfil the aim, the system, developed on the basis of such informational metamodel and the previously described technology, is made up of the following components that build the core of the proposed Web Service for CPDM [Figure 4.]:

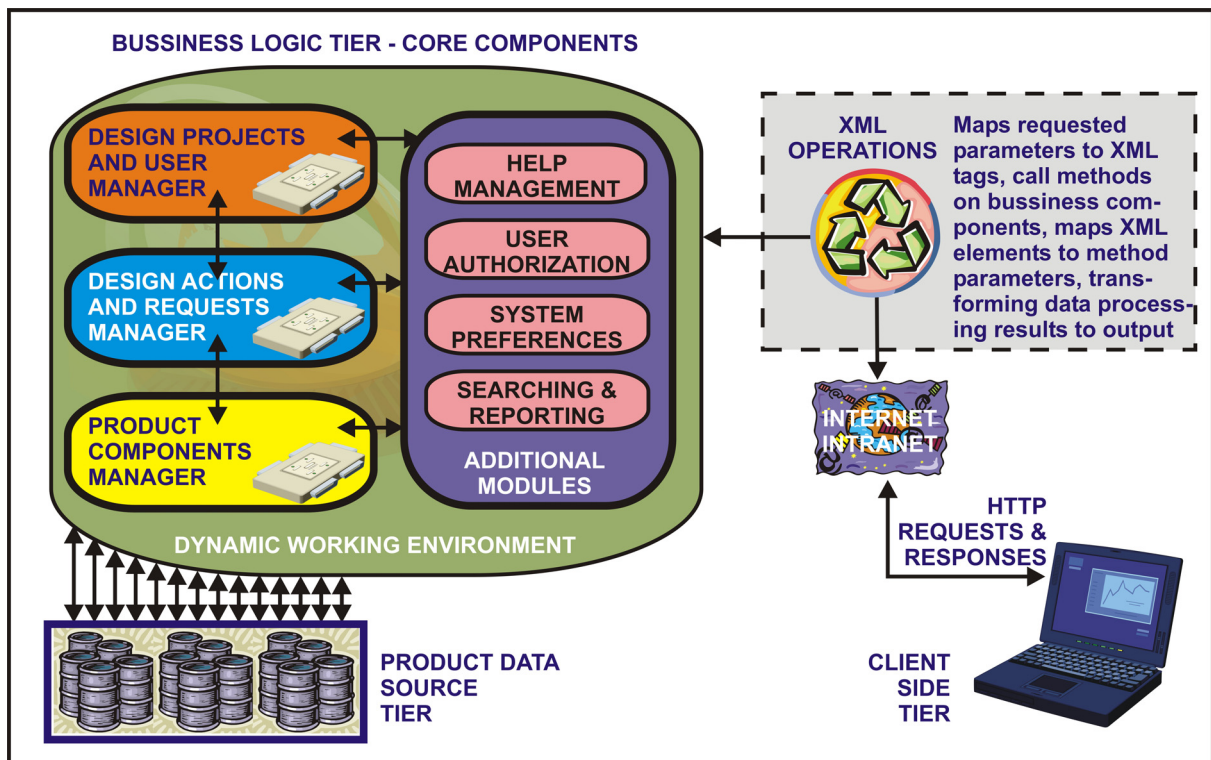


Figure 4: Web Service for CPDM – core components

- Design Projects and Users Manager:** it allows the description of time schedules and constraints for every single project, the planning and distribution of design tasks, the determination of the participant design teams and their synchronization, the description of information on every single member of the design teams, and the user status and user rights assignment and their tracking.

- **Design Actions and Requests Manager:** it allows the description of needed activities for the product design, the determination of the dependences between them, and the rules for following and tracking the status of particular design activities.
- **Product Components Manager:** it is in charge of the definition, classification and description of physical properties of the product components and related documents, as well as of the determination of relationships between them. It deals with the product structure, product data versions and status.
- **Additional modules:** include a group of tools for handling the user authorization, help management, system preferences adjustment, and different types of searching and reporting.

Besides the main components integrated as the main “engine” of the presented solution, there are components for the communication between the main modules as well as for handling external data requests. The XML Operations developed as run-time components for the communication between clients and the business layer, are of a special importance. Besides the logic for processing of the input requests, the XML Operations contain the data presentation logic for the transformation of requested product data into the form specified for a particular client type (B2B clients, different applications, web browsers, PDA & cell phones). Specific interfaces have been designed for different types of users and other applications to activate functions that are provided for them by the integrated platform, i.e. engineering change management or search for needed information.

The developed service and methodology have been tested in pilot projects carried out in the design process of power transformers. A fundamental topic of the testing has been the validation of the concept of the product data management among co-design partners using the technology of the Web Services. The results of the testing process showed that the traditional approach to the integration of engineering data between different systems can be improved by using the new technology. In addition, the full integration of structured product documentation and product data, the product data exchange in neutral XML format, and a better control of the design activities and resources become easier to manage interactively for different client types. The underlying flexible data model and methods are still under research but more advanced implementations can be expected in future.

6 Conclusion

It has been recognised that the development of Web technology provides an efficient and revolutionary tool to help different companies change their way of managing and integrating information flows in a virtual enterprise. The existing functionality and services of IT systems in the process of the product development could be integrated, enhanced and made available to participants in the product development process in the form of “Virtual product development environment” (VPDE). The concept of VPDE as an application platform for SMEs to provide the collaborative product development, product data management, engineering knowledge management and e-business services has been presented here. Web Services through their remarkable ease of integration, flexibility, and support of XML vocabularies provide the best platform to realize VPDE as almost every application or computer-human interaction can be modelled as a Web Service. The flexible integration of the product and process models with different architectures and frameworks could improve the efficiency of the product development process and prepare virtual enterprises for rapid a change in internal processes, customer interactions and supply chain arrangements.

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Corresponding author:

Mario Štorga, M.Sc. Mech.Eng.

University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture

Department of Engineering Design

Ivana Lučića 5, 10000 Zagreb

CROATIA

Tel: +385 1 6168 119

Fax: + 385 1 6156 940

E-mail: mario.storga@fsb.hr

URL: <http://www.cadlab.fsb.hr>