Are workflow management systems useful for collaborative engineering? *

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ABSTRACT: The paper comprises a reflection on a deployment of modern workflow management systems (WMSs) in distributed engineering applications. With a global access to the Internet, engineers working in distributed teams look for tools that support their distributed collaborative work. In recent years many new WM tools were introduced, with relatively a very few being targeted at engineering applications.
WMSs that are relevant for engineering applications have been identified and initially compared in the paper. Our experiments were based on the WMS and the tool integration environment called ASTAI(R). This tool was used in a collaboration between two distributed partners of the 5FP IST project E-Colleg, namely ITE, Warsaw and Thales Optronique, Paris. The experience gained in the development of collaborative workflows has been summarised in the paper.

1 INTRODUCTION

Workflow Management is a modern information technology proving its utility in distributed environments that cross borders of organisations. Until recently, objects that were handled by WM Systems (WMSs) were documents. With Internet-based technologies penetrating more and more engineering processes, engineers often are confronted with questions concerning the applicability of WMSs to manage their distributed and collaborative design scenarios. Theoretically, WMSs can provide much advantageous functionality to engineers, especially to engineers who work in large companies with many departments located in remote places. Workflow Management Systems offer them an immediate access to company resources (data, tools, and people). They should also enable outsourcing, as they simplify integration of external IP providers into the design engineering workflows of the company.

The term collaborative engineering has been formulated already in 1996 as an "innovative method for product development which integrates widely distributed engineers for virtual collaboration" (Cutkosky 1996). It is our strong belief that WMSs can play an important integration role in distributed engineering teams. Their integration into distributed design methodologies and respectively distributed engineering environments constitute still a challenge. The paper is intended as an introductory reasoning about utility of available WMSs for distributed engineering applications.

The first part of the paper comprises a short overview of selected Workflow Management Systems, namely: Ultimus (ULT 2002), MQSeries workflow (IBM 2002) Action Request System (REM 2001), Meteor (INF 2002), BEA Process Integrator (BEA 2002), TIBCO (TIB 2001) and REUBEN (Kozminski 1995). Their utility for a group of electronic engineers that work in remote sites has been assessed. For the purpose of this evaluation, the most important from an engineering perspective attributes of WMSs from an engineering perspective have been identified.

The discussed attributes comprise:

- Flexibility and scalability (possibility for encapsulation and integration of additional tools)
- Security of stored and transmitted data
- Ability to handle large volumes of engineering data
- Workflow monitoring and reporting
- Quality of user interface
- Supported network protocols and OS platforms

The second part of the article presents results of the experiment conducted at ITE, Warsaw. A Workflow Management System was customised to support a distributed hardware IP design process realised in the pan-European collaborative project E-Colleg (IST-1999-11746) (http://www.ecolleg.org). The example shows problems related to deployment

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of WMSs to a real engineering scenario. Conclusions are drawn from the experiments realised within the E-Colleg project. Finally, some perspectives for application of WMSs in electronic systems design are envisioned.

2 WORKFLOW MANAGEMENT SYSTEMS

Workflow is commonly conceived as a concept to accelerate heterogeneous working procedures, which consists of a set of activities that support a specific process (WFMC 2002). Workflow specifications include actions to be performed, statements on control and data flow among these actions, agents allowed executing actions, and policies that describe the organisational environment. In an electronic engineering domain, a workflow allows a designer to create a virtual design environment that integrates tools and services (e.g., compilers, simulators, logic and behavioural synthesis tools, physical design tools, test equipment, product data management systems and/or databases) that are distributed over different sites, platforms, and often enterprises (DDECS 2001). Distributed tools and services require a workflow management system that supports enterprise level integration dealing with many kinds of cross-domain issues. Below, selected relevant WMSs have been discussed. The intention of this short overview of leading WMSs is to identify their basic functionality that is relevant for their deployment in engineering applications.

2.1 *Ultimus*

Ultimus (ULT 2002) defines a workflow as: "Any task performed in series or in parallel by two or more members of a workgroup to reach a common goal".

The Ultimus workflow system targeted mainly for business applications is a Web-based Client/Server application that supports design, simulation, monitoring, and measuring workflows for different administrative business processes. Processes supported are Purchase Order, Expense report, Time Card, Change Order and many others. Its authors claim it is easy to integrate with other applications. Ultimus Workflow Suite (ver. 4.2) is based on the Microsoft Transaction Server (MTS) and Microsoft Internet Information Server (IIS), ActiveX with Dynamic HTML for Internet Explorer browsers and Java with Dynamic HTML for Netscape browsers. Over 150 elements for workflow automation are offered in the library. These include tools for: collaborative design of workflows, cross-platform support, automatic workflow documentation, etc. Ultimus is primarily designed to automate administrative workflows.

The starting point for creation of a new workflow is to define activities that a workgroup needs to perform and business rules governing these activities. Each activity should be broken down into steps, which represent a well-defined list of things that ought to be performed by one user. Business judgement is required to decide how to split each activity into a sequence of steps and decide which user may be called to perform each step. If some steps will be performed on a conditional basis the conditions should be defined. The Ultimus WMS has many advantages:

- Workflows are well adapted to end-users' needs
- Simulation of new workflows working in a collaborative manner on different computers can be done on one computer.
- It provides a powerful development, implementation, and maintenance tool for the Internet and Intranet
- Straightforward participation of users in administrative distributed processes using a Web access
- Monitoring and measurement of workflows in use due to a status report and processes tracking
- Automatic interaction with databases, word processors and spreadsheets to perform tasks
- Workflows can communicate with each other
- Possibility of triggering periodical processes

Graphically represented workflows may be well monitored. An important advantage of Ultimus is a possibility of creating and managing a workflow without programming, scripting or writing macros (user interface is intuitive and consistent with Microsoft Office). It is easy to do because there are limited applications on Microsoft Windows platform, which can be integrated in workflows: Microsoft Excel, Microsoft Word for Windows, WordPerfect for Windows, Lotus 1-2-3, ASCII Files, ODBC Database, Lotus Notes User.

An interface based on HTML opens it to other platforms. The ODBC allows a connection to other databases. On the other hand, use of COM/DCOM to connect workflows on different PCs seriously decreases security of workflows and transfer of documents among them.

2.2 *MQSeries Workflow*

One of the most advanced WMSs is the MQSeries Workflow (IBM 2002b). MQSeries Workflow is one of five parts of WebSphere MQ Family (MQSeries Workflow, WebSphere MQ, WebSphere Adapters, WebSphere MQ Integrator, MQSeries Everyplace) produced by IBM (IBM 2002a). A prototype of this workflow was developed in the project CROSS-FLOW (CRO 2002). The biggest advantage of MQSeries lies in its support on 35 system platforms including Microsoft Windows, Solaris, HP-UX and many others. Another advantage is that it supports almost all Internet and databases community protocols. The system supports multiprocessing and clustering on all types of processors, from x86, and RISC to mainframe.

MQSeries Workflow is a “workflow management system that allows one to completely define, manage, and execute business processes through the execution of software whose order of execution is driven by computer representation of the workflow logic" (IBM 2002b).

Creation and management of a workflow are aided by many features of the MQSeries Workflow. Buildtime and Runtime are functions defined in MQSeries (IBM 1999). The first one allows to model using graphical means: the business process, defining users and levels, data structure, registering programs and so on. The second one, manages the flow of work at run time while monitoring the whole workflow, notifying delays, assigning the individual tasks to the right people, invoking the attached applications automatically and so on.

Operations in MQSeries environment, like: creation of new workflows, description of new tools, and managing workflows, have graphical interfaces. Additionally, there is an API for several languages (e.g., C++, Java beans or COBOL) in creation of new clients. Components of MQSeries Workflow (Fig.1) have a three-tier architecture.

Client components through APIs are responsible for execution of program activities that interact with users. Communication with servers is through CORBA, IIOP or RMI.

Server components are responsible for execution of processes at runtime. The components can be distributed across several machines.

Database server holds workflow relevant data for a system group including status and set-up information.

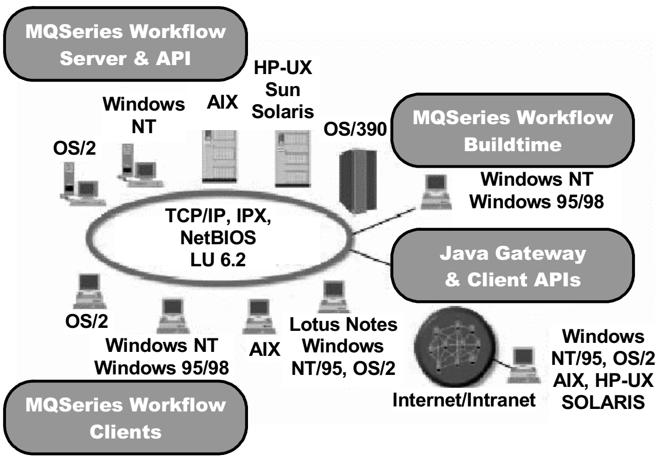

Figure1. MQSeries Workflow functions (IBM 1999)

2.3 *Action Request System*

Action Request System (REM 2001) is a workflow system produced by Remedy Corporation. The system is targeted towards document, mail and databases management, and is widely used in business (a coverage of 60% percent of Fortune 100 companies is claimed).

ARS has the capability of supporting Web browsers on a client site. The system can work with many types of databases and system management platforms. However, there is no public information about network protocols or even detailed description on how to create, manage and use workflows in this system.

2.4 *Meteor*

Infocosm developed the METEOR (Managing End-To-End Applications) tools (INF 2002). EappS - the METEOR Enterprise Application Suite of tools and services exploits CORBA, Java, and Internet-based component middleware to help enterprises meet their application integration requirements, especially in the context of managing mission-critical processes.

The workflow is defined in Meteor as “human activities and automated task implemented as heterogeneous application and transactions”.

The METEOR EAppS (Fig. 2) consists of a suite of four services and tools: EAppBuilder, EAppRepository, EappEnactment (ORBWork, WebWork) and EAppManager.

EAppBuilder is a toolkit to graphically specify and build a workflow related to an enterprise application, including tasks, data objects, and the task invocation details. Human or automated tasks can be run on any networked computer. The task design tool provides interfaces to various external task development tools (e.g., Microsoft’s FrontPage to design the interface of a human-oriented task, or a rapid application development tool). EAppBuilder has the capability to model complex and varied tasks in a conceptual and easy-to-use manner that shields the designer of the enterprise application from the underlying details of the infrastructure or the runtime environment. It communicates with repository services.

EAppRepository maintains information about workflow and associated business processes. It is available to the builder services and also to the enactment services to provide necessary information about the workflow application to be enacted.

There are two available EAppEnactment services - ORBWork and WebWork. Both ORBWork and WebWork use a fully distributed open architecture, but WebWork is a comparatively lightweight implementation that is well suited for traditional workflow, help-desk, and data exchange applications. ORBWork is better suited for more demanding, mission-critical enterprise applications requiring high scalability, robustness and dynamic modifications. Both have code generators that interpret the standard process definitions generated by EAppBuilder (these definitions can be optionally stored in a repository). In the case of ORBWork, the code generator outputs specifications for task schedulers (including their routing information), task invocation details, data object access information, user interface templates, and other necessary data. The code generator also outputs native code (in Java) necessary to maintain and manipulate business domain objects created by EAppBuilder.

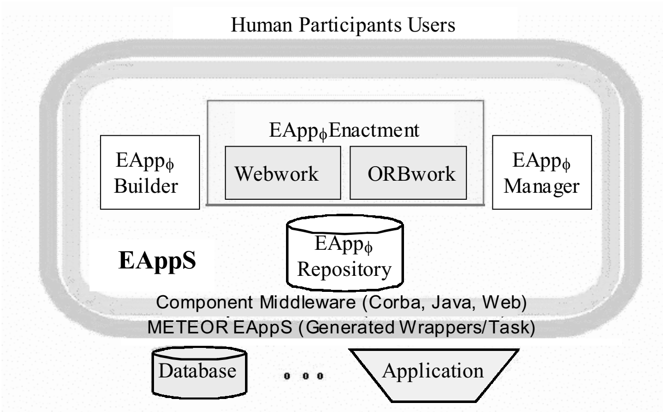

Figure 2 METEOR EappS (INF 2002)

Meteor applies the most popular communication standards: CORBA/IIOP, Java, JDBC, and HTTP. These technologies in relation with mindfulness about security aspects allow Infocosm to recommend Meteor to work not only in business, but also in healthcare or defence domain. Meteor supports two platforms only: Solaris and Windows NT, but JDBC and HTTP interfaces give possibility to connect to the EAppS workflow as a client from another machine (HTTP) and to use almost all databases (JDBC). There is a graphical interface to manage all aspects of workflow, but not all things can be done graphically (only about 60% of advanced code generation). Infocosm however, in opposition to other companies creating workflow-connected tools, makes admission of its limitations.

2.5 *BEA WebLogic Process Integration*

BEA WebLogic Process Integration (BEA 2002) is a part of a larger environment produced by BEA, which can be considered to hold a market leading position in integration middleware. It has the limitation that a user cannot separately use its components (e.g., there are no means to invoke applications without the BEA application server).

Creation of a workflow is intuitive and enables business analysts designing and managing process for which the IT staff provides the technical expertise needed. There is the possibility to implement multiple versions of a process template. These can have different process elements, e.g. controlled by date. WebLogic Process Integrator gives the possibility of monitoring and reporting the process flow. Tracking process efficiency with real-time data and statistical metrics is performed without interrupting on-going processes. The tool can be deployed with confidence using the high availability, security, scalability, and management features of the BEA WebLogic Process Integrator (Fig. 3).

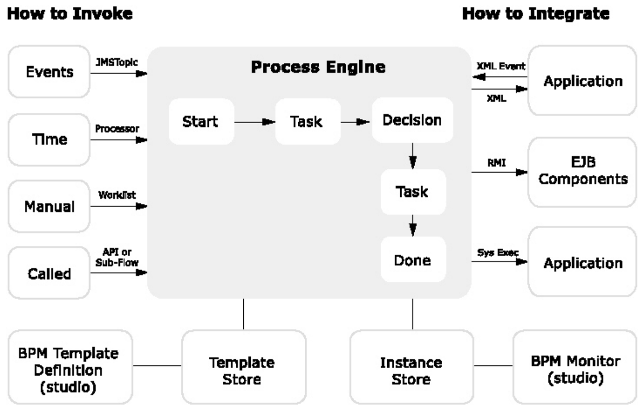

Figure 3 BEA WebLogic Process Integrator (BEA 2001)

2.6 *TIBCO*

The TIBCO ActiveEnterprise line of e-business infrastructure products (TIB 2000) supports business automation by creating an integrated network of applications, databases and information. ActiveEnterprise is aimed at bringing together disparate applications in an enterprise for real-time cross system information flow. TIBCO ActiveEnterprise integrates applications such as SAP, Peoplesoft, Siebel, Clarify, Vantive, Oracle, Informix, Microsoft, IBM, Netscape, and others. From an architectural point of view ActiveEnterprise can be considered to constitute a rather advanced product. The communication backbone supports CORBA and COM (TIB/Objectbus).

The system is based on a Publish-Subscribe mechanism: resources (applications, user) must register to receive messages, which may be safely transmitted (TIB/ETX). Thus the software realises a Message-Broker (TIB/MessageBroker). For most-needed applications adapters are available. TIBCO co-operates with Yahoo and Netscape in the portal area and with Cisco in the network area.

2.7 *ASTAI(R)*

ASTAI(R) is based on standards for communication and integration (Fig. 4). Its CORBA-based broadcasting bus realises an open messaging system compliant to TES standard from CFI (CLAB 2001). ASTAI(R) is available for several operation systems: Solaris, Windows NT 4.0 and Windows 2000 platforms. The multi-site capabilities of the WMS provide the possibility of invocation of tools and referring to services located on different locations, thus allow the management of decentralised and distributed teamwork. ASTAI® GUI represents a process as a number of related operations called workflow activities, which dependencies are controlled by the WMS.

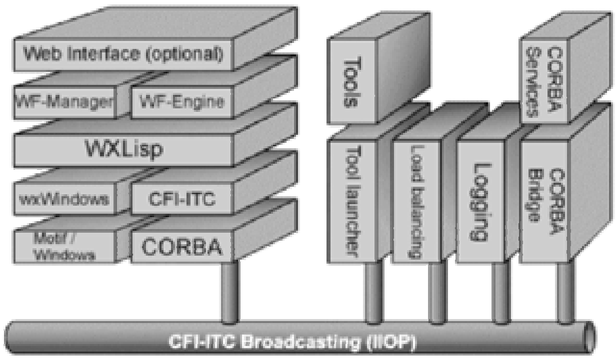

Figure 4 ASTAI® architecture (CLAB 2001)

The system provides the basic functionality for gathering additional services into its environment. Using ASTAI®, the user can incorporate standard software tools and services like MS Office, mail services, as well as more specialised applications like CAD tools.

2.8 *REUBEN*

REUBEN stands for REconfigurable and reUsable Benchmarking ENvironment. This constitutes an academic project that has been conducted at the *Collaborative Benchmarking Laboratory* (CBL 2000) at the North Carolina State University (Raleigh, USA). REUBEN environment has been coded in the script language *Tcl/Tk*, as well as, *Expect* and *rcs*. The project has developed a new X Windows manager that enables work with distributed applications.

REUBEN comprises a few modules, namely: ReubenDesktop (desktop manager and event viewer), OmniBrowser (browser of available workflows), Workflow Manager, Object Definition Templates, Workflow Libraries.

Work in the REUBEN environment constitutes mainly workflow definition and modification. A typical workflow for a distributed application comprises: : distributed machines (*host nodes*), applications and programs (*program nodes*), data (*data nodes*), as well as, decision points (*decision nodes*).

Workflow Manager is responsible for adding, deleting, editing and linking of various types on nodes. Links between nodes represent their relationships. Each node must be precisely defined using dedicated editors. *Program Definition* Manager is used for example for definition of a path of an executable program with all required parameters.

REUBEN is one of a very few tools that have been targeted at engineering applications.

Originally, REUBEN was based predominantly on UNIX tools. Application in its newer version of the script languages *Tcl/Tk* and *Expect* allowed for development of distributed workflows, while addition of the X server has enabled interaction of users with graphical tools. Use of Safe-Tcl, and later WebWiseTclTk has assured basic security mechanisms and enabled a remote access through an Internet browser.

REUBEN has been extended recently to asynchronous and synchronous collaborative *OmniFlow/OmniDesk* environment, where OmniFlow is a universal client, which creates GUI based on cdtML (extended XML) description of a task flow. This description comprises all necessary information on data, programs and their relationships. OmniDesk architecture comprises two servers, namely *Asynchronous Group Server* and *Synchronizing Group Server*. These servers maintain *Pro*ject *Data Archives, Workflow Libraries, Object Ownership Table* and *Inter-client Synchronization Table* for project participants working in both asynchronous and collaborative modes (Fig. 5). Communication among remote tools is transparent to a user and it is based on the TCP protocol with the use of clients, like: telnet, ssh, http. Also more universal socket-based solution (e.g., JavaRMI) is supported. Management of distributed data uses CVS (Concurrent Versioning System). A new version of OmniFlow has been recently released for UNIX, Linux, MacOS and Windows NT.

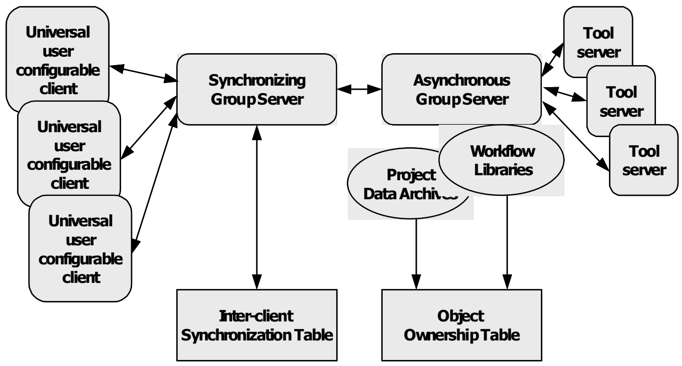

Figure 5. REUBEN architecture (CBL 1999b)

One of the advantages of REUBEN is reconfigurability of its workflows. Demos of REUBEN workflows are available at the North Carolina State University (CBL 1999a). Deployment of REUBEN to a large scale collaborative distributed design has been reported in (CBL 1999b).

2.9 *Summary on WMSs*

We commence with an executive summary of the previously introduced tools given in a perspective of WMSs deployment in engineering environments.

One can basically distinguish two types of applications. The first category uses a limited number of integrated tools on one or more compatible system platforms (e.g. Ultimus). These workflows are usually used to manage internal document flow.

Table 1. Summary of selected workflow management systems

	Ultimus	MQSeries	Action Request System	Meteor	BEA Process Integrator	TIBCO	ASTAI®	REUBEN
Server/Client Platforms	NT	Over 30 platforms	NT Solaris HP-UX AIX	NT Solaris	NT Solaris AIX HP-UX	NT Solaris HP-UX	Solaris NT	Unix Linux MacOS NT
Standards Supported	HTTP ODBC COM/DCOM	CORBA HTTP RMI DCOM		CORBA HTTP Java JDBC	DBC, J2EE EJB JMS XML	CORBA EJB TAE	CORBA TES	HTTP, SSH, SSL, Java, XML, Tcl/Tk
Tools Integration	limited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited
Security	-	+		++	+	+	+	+
Monitoring & reporting	+	++			+	+	+	+
Graphic Interface	+	+	+	+	+	+	+	+
Scalability		+	+	+	+		+	+

The documents can contain data from specified databases, which simplify and speed up their creation and distribution.

Others allow the user to specify and adapt any application (almost all of them allow adapt application graphically), needed in business process. Besides document and data managing, these workflows can perform any activity in business process that can be realised by an application (e.g. market status prognoses).

An important general advantage of a workflow is that it typically supports many system platforms. This widens its utility providing more applications and better accessibility.

For workflow management systems the supported communication standards are very important. Upper specified workflow management systems apply two or more of these standards. The best communication standard from the viewpoint of a workflow user is HTTP.

The most important features of selected workflow management systems are summarised in Table 1.

Only the CORBA standard assures secure data transfer. The possibility of a workflow controlling independent of date is very useful in business processes. In one case a template of a workflow is changed in time (BEA) in the second one a selected workflow or activity is triggered by date (Ultimus).

Many of the discussed WMSs applications and corresponding features described in this section are applicable to Collaborative Engineering and greatly ease work of distributed engineers collaborating in common projects. Nevertheless, there are some special requirements, which may demand additional functionality. Patrikalis et al. (Patrikalis 1999) describe a scenario for collaborative engineering in the area of automotive manufacturing which gives important insights. The authors state that those insights should lead to the development of interactive, easy-to-use tools which are well integrated in the overall work flow. The development of such tools for a given domain requires:

- The extensive understanding of domain practices and needs
- The comprehension of the principles of remote collaboration and visual communication
- The application of advances in computing technologies in a variety of computer science areas, including data compression, visualisation, human-computer interaction, remote collaboration, digital libraries, and design automation, and data exchange standards and efficient compression and memory utilisation techniques to facilitate the detailed representation of complex objects for manufacturing processes.

3 COLLABORATIVE IP DESIGN

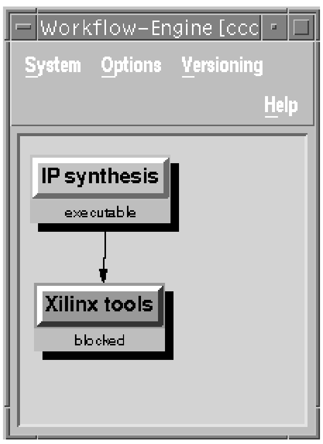

Figure 6. Hardware component design workflow

IP design methodology has been implemented into ASTAI® workflow. All applied EDA tools were integrated to allow automatic creation of a final product in a bit-stream form from an IP model, which was fully verified during workflow implementation.

A hardware component workflow was created based on the standardised IP design flow. The tools applied in a design process ran on Solaris and Windows 2000 platforms.

The workflow was divided into two successively performed sub-workflows (Fig. 6) running on these platforms. Sub-workflow 1, containing modelling of an IP component in VHDL, its simulation and synthesis activities ran on Solaris platform. Its output in a netlist form is an input for Sub-workflow 2 (Fig. 7), which is partly performed on Windows 2000 and partly on Solaris. The main activity *Xilinx tools* (Windows 2000) consists of placement & routing, bit-stream generation and back-annotation. Its outputs in VHDL and SDF formats are used in the next activity *Simulation after Implementation* (Solaris) to validate the results of the implementation. The other activities can be performed on both platforms.

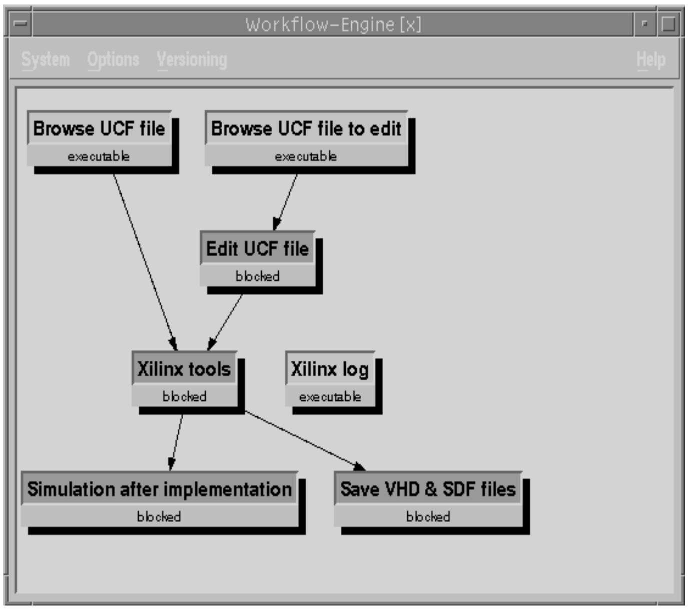

Figure 7. Xilinx tools sub-workflow

The developed IP design workflow was successively verified in a collaborative design of a servo-mechanism driver for the helmet engine used for optical camera protection.

Inter-domain connections, which have to cross firewalls, are a key problem in ASTAI® collaborative infrastructure. The collaborative workflow can be established when there are no firewalls or those firewalls are not very restrictive. In this case, the ITCGate with HTTP tunnelling software was used to connect collaborative domains. Also, it was necessary to use a machine with Solaris or Linux operation system for HTTP tunnelling, which does not support Win2000.

4 CONCLUSIONS

Majority of today's workflow management systems either is dedicated to document or to enterprise resources management. Except for some academic prototypes like REUBEN, WELD WMS (WELD, 1998), or ASTAI(R), there are no commercially available WMSs that are suited for distributed engineering design flow support combined with design tool integration and management.

Workflow management systems can be useful for collaborative engineering. Our experiments with collaborative services using ASTAI(R) management system indicated, however, that one of the most important factors that limit the deployment of those systems in engineering environment is the security problem. The collaboration and the security aspects seem to be always in a trade-off relation. EDA companies, especially those big ones, are very sensitive about the aspect of security. Simulation and synthesis tools are most frequently put behind firewalls that constitutes a real challenge for the integration of those design tools from different sites and locations.

Our recent work within the framework of the E-Colleg project is aimed at the development of collaborative services enabling wide area engineering collaboration, while effectively dealing with the security and many other kinds of cross-domain issues.

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