INTELLIGENT SERVICES AND TOOLS FOR CONCURRENT ENGINEERING - AN APPROACH TOWARDS THE NEXT GENERATION OF COLLABORATION PLATFORMS

SUBMITTED: September 2001
REVISED: November 2001
PUBLISHED: December 2001 at http://itcon.org/2001/9/

Peter Katranuschkov, Dr.-Ing.
Technische Universität Dresden, Professur für Computeranwendung im Bauwesen
email:Peter.Katranuschkov@cib.bau.tu-dresden.de, http://cib.bau.tu-dresden.de/mitarbeiter/pik.html

Raimar J. Scherer, Prof. Dr.-Ing.
Technische Universität Dresden, Professur für Computeranwendung im Bauwesen
email:Scherer@cib.bau.tu-dresden.de, http://cib.bau.tu-dresden.de/mitarbeiter/rjs.html

Ziga Turk, Assoc. Prof., Dr.-Ing.
University of Ljubljana, Faculty of Civil and Geodetic Engineering, Slovenia.
email:ziga.turk@itc.fgg.uni-lj.si, http://itc.fgg.uni-lj.si/zturk/

***SUMMARY**: The Internet is being increasingly used as a communication backbone of the construction industry. Through Web browsers and other standard tools, design and planning communication and information exchange take place. Several dotcom companies are offering such collaboration environments for rent. However, these environments are closed, project-centred and only provide for file level information exchange in basic document management. ISTforCE (Intelligent Services and Tools for Concurrent Engineering) is a European 5th Framework Information Society project (2001-2003) aimed at developing technologies for the next generation of such collaboration platforms. The substantial novelties in ISTforCE are that (1) it provides a personalised human-centred environment, enhancing current, less flexible project-centred approaches, (2) it sets up an open collaboration platform where new services and tools may be easily integrated and where providers of engineering information, services and tools meet project managers, engineers and architects, (3) it makes flexible and customisable object-level data exchange possible, and (4) it provides an infrastructure for on-line e-business by integrating seamlessly legal and financial transactions, at all system levels. In this paper we present the actors and use cases of the ISTforCE environment, the overall multi-tier client-server architecture, the basic interoperability cases and the top-level GUI of the ISTforCE prototype.*

***KEYWORDS**: collaboration, concurrent engineering, distance working, computer integrated construction, civil engineering, distributed client-server system, ISTforCE.*

1. INTRODUCTION

Construction projects are unique not only in terms of the features of the product – a constructed facility, but the partners and the processes in which this product is built. This uniqueness is a major challenge for the application of information technology, as it typically leads to loosely structured, strongly decentralised and at the same time weakly integrated IT environments in which information requirements are not likely to be known beforehand (Hannus et al., 1995; IAI, 1999). Therefore, to achieve high efficiency and quality of the collaboration in each construction project, it is essential not only to support the communication processes within the project, but to consider the multi-project work and the individual needs of the players as well. This *user-centric approach* is the baseline of the conceptual architecture of the proposed novel IT environment presented in this paper.

1.1. Current situation

In the second part of the 1990s the Internet has been intensively explored as a platform, which could be used to exchange information between architects, engineers, construction managers, and the construction companies on the building site (cf. Ouzounis, 2001; Turk et al., 2000b; Weisberg, 2001). However, the Internet is still typically used to support mainly secondary non value-adding activities in the construction value chain. It is increasingly used as a communication platform (email) and a source of information (Web pages), but it has not yet been used as a place where the actual engineering work and primary non value-adding collaboration tasks are carried out. Indeed, several companies have started offering Internet based project support on a rental basis. On Web sites, such as Bricsnet, Citadon and several others, companies and groups of companies can rent shared project space, with functionalities for publishing and retrieving design files, establishing security and access rights, versioning and configuration management, redlining, safe communication channels, mailing lists, notifications etc. (Bricsnet, 2001; Buzzsaw, 2001; Citadon, 2001; Conject, 2001; Weisberg, 2001). However, in spite of many advanced features, this is still only infrastructure - practically no tools are available that can actually get the engineering or architectural work done - work that contributes to the evolution of the design or process plan. This is due to the fact that these sites are project-centred – they allow creating the support for one or several projects, but most engineers in construction practice work on several projects at the same time. Also, they only allow for file/document level information exchange, but can hardly manage more structured project information.

1.2. Goals of the ISTforCE project

ISTforCE (EP IST-11508) is a 27-month EU 5th framework IST project, running from February 2000 through to April 2002 with an overall budget of about 4 million Euro. The acronym stands for "Intelligent Services and Tools for Concurrent Engineering". The ten partners that carry out the project come from Germany, France, Italy, Spain, UK, The Czech Republic and Slovenia.

Taking the existing Internet infrastructures for granted, ISTforCE is developing ideas that would raise on-line collaboration in construction to a new level (Scherer, 2000). The main project objective is to establish an open concurrent engineering platform with access to intelligent services and tools that will support two main needs of engineers:

1) *Individuality*. Due to their different roles, expertise and personal experience engineers have different individual preferences and capabilities. They need services that can support their individual creative work in flexible and adaptable fashion.
2) *Multi-project work*. In construction, engineers typically participate in several virtual enterprises in parallel, working concurrently on several projects at the same time. This aspect of construction IT is in strong contrast to other industries and requires appropriate non standard solutions.

In accordance with that, ISTforCE addresses a number of novel issues in Internet-based collaborative work:

1) *Human-centred instead of project-centred collaboration*. Today's existing Web-based collaboration environments handle a project as the main unit or aggregation of information – one project, several participants. However, in construction it is typical that engineers work on several projects at once - one person, several projects. The environment should therefore be adapted to such work. Typically, the engineer needs to take into account the overlaps among his/her current projects, as well as the historic information from previous projects.
2) *Open services platform*. A different approach to Web sites, which are open but limited in functionality, is currently observed in the development of proprietary frameworks built around a set of comprehensive design tools, such as AutoCAD 2000i (cf. Goldberg, 2001). However, no single company, not even Microsoft, AutoDesk or Primavera, is in a position to provide all the services and tools required to support all working tasks in a construction project. They provide collaboration infrastructure, but not integrated with the variety of heterogeneous tools engineers, architects and managers would need. In contrast, on the ISTforCE platform, the providers of software, services and tools *meet* with the end-users. The platform is open and allows for integration of design software, dimensioning tools, analysis tools, CAD systems etc. but, as a platform on the Internet, it can only support companies that *can* provide services, tools and software on the Internet. In construction, where 97% of the companies employ less than 20 persons, a typical company is an SME. It cannot be expected that these companies have an Internet strategy or a person with the required knowledge to allow for this company to participate in the new economy. ISTforCE is providing such a service to them.
3) *Product data based integration*. When different software becomes available through a single platform, it is very useful to enable information exchange among this software. ISTforCE builds

on the development of product modelling in the last two decades to support the exchange and sharing of project data conforming to the industry standard IFC schemas (Wix & Liebich, 2001).

In short, ISTforCE caters for both the end users and the service providers and brings them together onto one open platform.

2. PERSONALIZED CONCURRENT ENGINEERING SERVICES PLATFORM

2.1. End-user view

Central to the ISTforCE approach is the concept of an open, personalised Concurrent Engineering Services Platform (CESP). The platform (Fig. 1) provides the end user with access to various services and tools available on the Internet, that he may need to solve his engineering tasks. He does not have to care as to where these tools are actually located. Tools can be plugged into the platform and are registered by an information service. They are flexibly exchangeable. They can either be downloaded and hosted at the user's desktop or they can be accessed remotely. An e-Commerce service (EOS) with a billing component takes care about the financial aspects, and a training and on-line human support service (TOS) provides continuously accessible help about any IT aspects of the platform.

Furthermore, the platform can provide the end user with easy access to information and data from different project servers. The interoperability service (IOS) manages data and information operability, and a model access service (MAS) provides an engineering like communication interface (Scherer & Katranuschkov, 1999) based on a new engineering ontology developed in the scope of the project (Gehre & Katranuschkov, 2000). Thus, the platform acts as a bridge between information and tools, located anywhere throughout the Internet.

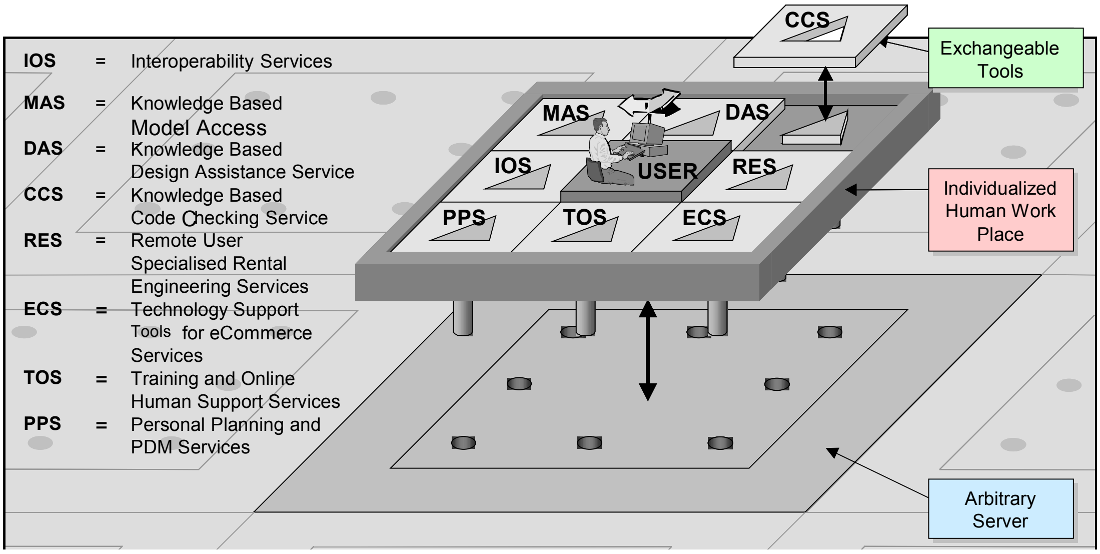

Fig. 1: Illustration of the ISTforCE platform and its components – the user is in the centre.

2.2. Requirements and scope

The requirements of the platform are as follows:

- It should be open*, so that any service or tool, Web or workstation based, could be integrated into it. Current collaboration portals offer only a small, fixed set of such functionality.*
- It should be customisable to individuals, so that many AEC professionals with different personal and professional requirements would be able to use it. Levels of customisation of current solutions are "screen deep".
- It should be customisable to products. Each construction product may require a different IT infrastructure because construction products are unique.

- It should be customisable to projects. Each construction project may require a different IT infrastructure because projects are unique as well.
- It should be scalable. Companies with different IT infrastructures may take part in an AEC project. The platform should be usable both on modest as well as advanced state-of-the-art equipment and networking speeds.
- It should be available. Setting up IT is not the core business of design companies. They should be able to rent the required infrastructure and be allowed to tailor it to their own specific needs.
- It should be attractive to information providers, so that they would be motivated to plug in their services into the platform and thus make it available to a broad range of projects.

In accordance with these requirements, a broader scope of components in comparison to typical Web sites needs to be established, including a set of advanced features as listed below.

1) Combining engineering work and electronic commerce through:
    - Intelligent clients for accessing engineering services that can be rented on the Web, and enabling various distant working and outsourcing paradigms (RES);
      In the context of the ISTforCE prototype environment this encompasses the following three selected services: (1) an automated engineering service provider (AESP) enabling on-line consulting for seismic risk assessment and special foundation design tasks, (2) a software rental service (SRS) for a set of geotechnical tasks, and (3) a virtual test laboratory service (VTLS) providing both Internet-based access to comprehensive simulation tools for the analysis of structural behaviour, as well as effective on-line user support (cf. Mangini & Protopsaltis, 2000; Cervenka & Pukl, 2000);
    - Intelligent access to knowledge libraries, such as knowledge-based code checking services on a rental basis (CCS);
      The ISTforCE prototype environment provides a representative example of such a service through the developed, freely available to owners, architects and regulation authorities, knowledge-based code compliance service for disabled persons accessibility in buildings;
    - Intelligent negotiation and payment e-Commerce services (ECS), enabling appropriate user authentication, secure transactions, billing and auditing.
2) Combining engineering design and business processes through:
    - Personal workflow planning for multi-project participation (PPS);
    - Services for accessing and managing distributed multi-project data (MAS), enabling remote (third-party) IFC-based product data servers to be plugged into the platform with the help of a set of interoperability adapters supporting RMI/IIOP and HTTP communication for both XML and SPF-based data exchange.
3) Improving human capabilities by enabling easy access to knowledge through:
    - Knowledge-based design assistance services, represented in ISTforCE by two sample design assistance tools for preliminary structural and geotechnical design (DAS);
    - Knowledge-based model access by using a user-friendly engineering ontology (MAS/EO);
    - Providing individual knowledge through training and on-line support services, including a comprehensive helpdesk system and a videoconference facility (TOS).

2.3. Business goals

An open Internet-based infrastructure would not only improve the construction design and planning processes but would also enable different information, software and knowledge providers to market their products over the Internet because it provides the entire necessary environment that allows for an old economy company to start taking part in the new economy.

Design, consulting and software companies already were in the information business – they have been selling information. The ISTforCE infrastructure allows them to sell it on the Internet by providing e-Commerce solutions, helpdesks etc. Advanced construction software sells in rather low number of copies. It is highly specialised and relatively rarely used. Only a few companies can afford to buy an expensive program, just in case they might need it in the future. Therefore, by setting up an infrastructure for renting software, thin clients as well will have access to advanced software and the software vendors would broaden their user base.

Basically, the ISTforCE platform is a place where four main groups of people meet (see Fig. 2):

1) Engineers and architects who design and plan,
2) Managers who manage the design and planning process,
3) Chief information/internet officers (CIO) who provide information technology support for the construction projects, and
4) The providers of knowledge, information and software.

The goals and needs differ from actor to actor.

- Engineers and architects need the platform for (1) collaboration tasks such as to communicate to each other, exchange information, co-ordinate work, and (2) for their actual design and planning work. They design and plan using different CAD tools and accessing different data and knowledge bases.
- Project information managers need to manage projects, monitor the work of architects and engineers, assign and supervise tasks, allow, recommend, suggest or even inhibit the use of certain tools and services.
- CIO (Chief Information Officers) want an easy way to set up IT support for a project.
- Service and tool providers need channels through which they can sell their products. They know their trade, but may not be experienced with Internet tools. They expect an infrastructure they can rent so that they can concentrate on their core business.

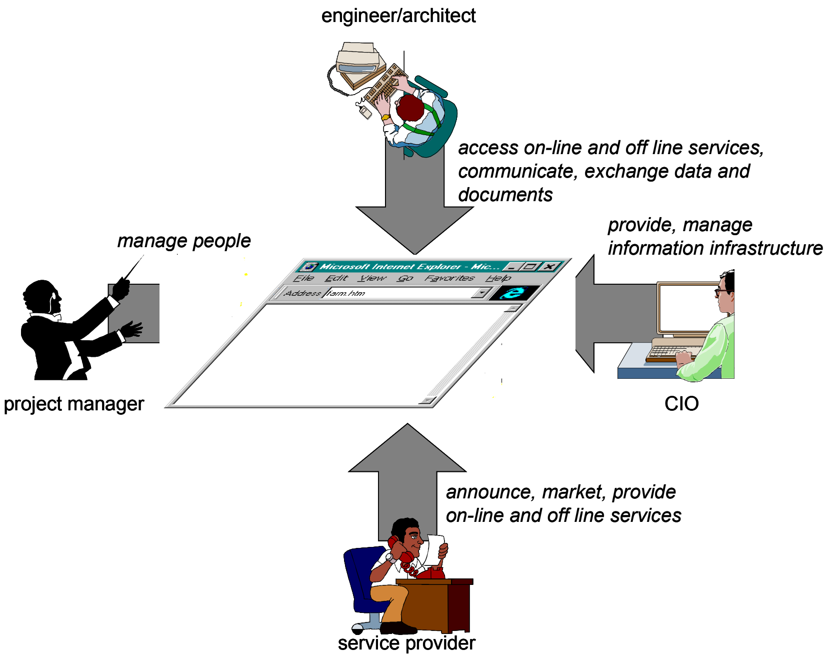

Fig. 2: Users of the platform.

All these actors have different work and social habits, therefore the platform should be adaptable to their needs and *not* vice versa. On Fig. 2 the most important use cases of the actors with the platform are shown.

3. SOFTWARE ARCHITECTURE

3.1. Layer view

A typical architecture of current collaboration platforms for engineers is presented on high conceptual level on Fig. 3. Through a Web Browser on a user's desktop there is an interface to the rented project space. This project space typically includes four-layered information exchange, messaging and scheduling. A fixed set of services is available by the provider of the platform. TCP/IP is used to move data around.

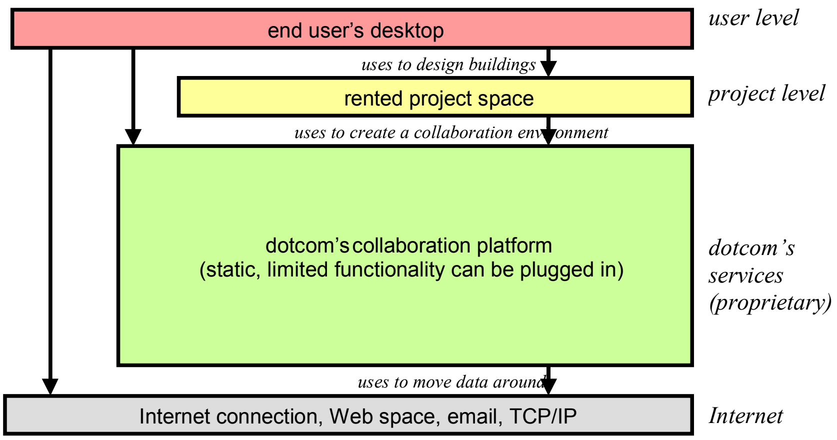

Fig. 3: Typical current architecture of services for engineers on the Web.

ISTforCE extends this architecture in two ways. First, it provides a well-defined, clearly structured, customisable architecture for the user desktop, suitable for the needs of the actors in the construction industry. The components of this "personal CESP" are flexibly selectable by the end-user; they will be discussed in more detail further below. Second, it enhances the *dotcom* collaboration platform by expanding it into three distinct, clearly defined layers as shown on Fig. 4, which are open and accessible by the actors.

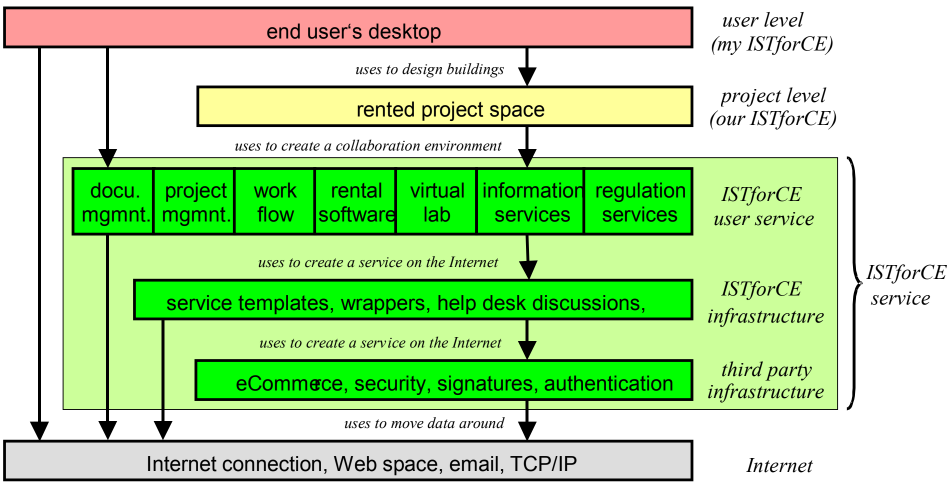

Fig. 4: ISTforCE architecture. Three kinds of services are made available.

The topmost of these layers includes most services available to the end user, such as scheduling, document management, file and object based data exchange. This layer is used by the manager and the engineers/architects.

The middle layer includes services that assist either in the creation or help during the operation of the top-layer services. They are used both by the end users as well as by the providers of the services. Examples of such services are the help desk system, templates for document management, FAQ and conferencing applications. They can augment any other service. Services on this layer can be used by the end users only if they are integrated into other services. The main users are the service providers and the CIO who may use the available templates to create a service in the context of one project.

The bottom layer provides generic services to information providers only, for example server space and email addresses, but also advanced services such as e-Commerce, electronic payment etc. They are used by the services on the layers above in a tightly integrated way. The main users of these services are other service providers, although in an embedded way, other types of users can use them as well.

3.2. Domain view

By taking a different, more technical view on the platform, the distributed information space and the different needs supported by each component can be structured in five unique domains as shown on Fig. 5. These domains are: (1) the basic CESP, (2) an information server, providing sharable core services, (3) local engineering applications, (4) extended, remote engineering services and (5) project data management services. One of their characteristics is that they have either always strictly one user (1,3) or are simultaneously available to many users and organisations (2,4,5).

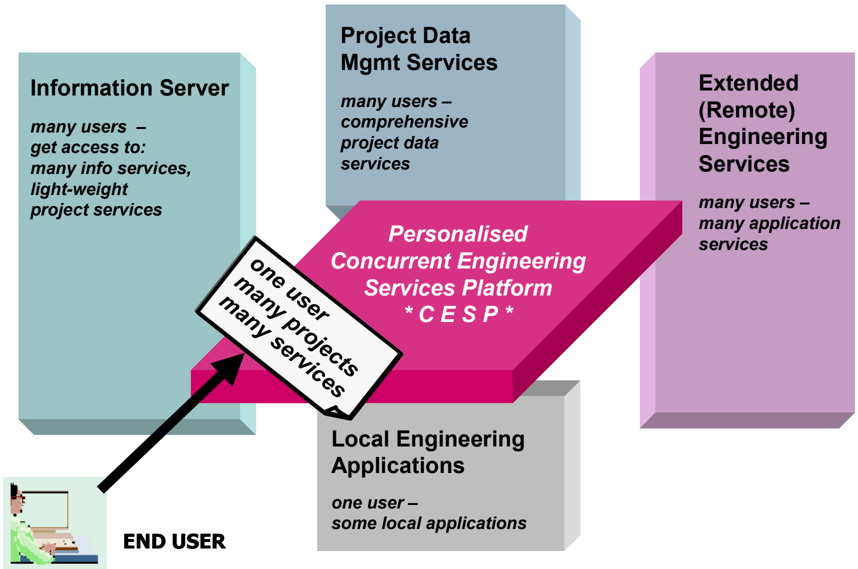

Fig. 5: The five domains of the ISTforCE architecture.

By using this view, the defined necessary components of the platform, as introduced in Section 3.1, can unambiguously be allocated, as shown on the next Fig. 6.

The Web-based Information Server contains the mentioned core information services, as well as the extended infrastructure services for process planning and workflow management (PPS/S), for knowledge-based access to project model data (MAS/S), and for negotiation and e-payment (ECS). These, eventually third-party services need not necessarily be hosted by the base Web site. It is only necessary to have well-defined server interoperability mechanisms so that the core services and data (registered users, registered projects, registered services) can be queried by each third-party service to ensure consistency and security of all transactions.

The project data management services, basically provided by a Project Data Server (PDS), would normally reside in a different information space, within the project-centred supporting environment for one or more projects (virtual enterprise server). Again, in order to incorporate such services into the platform, it is only necessary to register and define them as appropriate at the Information Server and to agree on a well-defined server interoperability protocol.

The extended (remote) engineering services (RES) will typically be dispersed over the Internet, hosted by the respective service providers. In the ISTforCE prototype environment three such services are being implemented, but in principle, for a real-world "upscaled" environment, there is no limitation as to their number. On Fig. 6 they are respectively numbered and shown in one "box" only to emphasise the common approach. By registering them at the Information Server and implementing the defined interfaces on the basis of a common high-level ontology specification, backed by more detailed data exchange specifications (Katranuschkov et al., 2001), they can all be made readily visible, selectable and accessible to the individual users of the platform - both directly, i.e. through a Web Browser, as well as indirectly, through other local or remote applications the user applies.

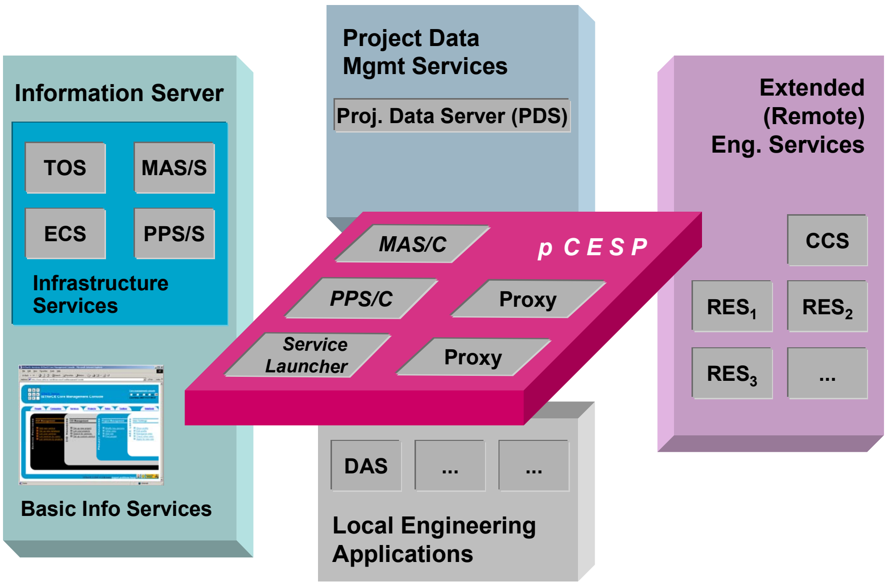

Fig. 6: Allocation of the components on the five domains of the full ISTforCE architecture.

A further important component, left without sufficient consideration in all mainstream collaboration approaches, is the personalised platform (pCESP) at the users' desktops. Typically, in dotcom environments, this component is represented only by a standard Web Browser, enhanced with relatively simple functional features provided by applets, scripting languages etc. In proprietary frameworks, it is represented by the set of locally installed design tools provided by the same vendor. In contrast, in ISTforCE the pCESP consists of a set of well-defined and structured tools, specifically designed to support collaborative work requirements, as described in Section 2. This includes: (1) a generic, configurable Service Launcher, enabling all direct connections to the Information Server, as well as to remote rental services, (2) a personal activity planning service client (PPS/C), (3) a model access service client (MAS/C), and (4) a set of specific proxy clients, supporting the transparent access to the remote engineering services.

At last, although not generally necessary, the platform can also support local user applications in the same fashion as all its other components mentioned above.

3.3. Business level view

With the structuring of information and functional components in the above five domains, three principal use levels (business cases) can be identified, emphasising the flexibility and the scalability of the ISTforCE approach. These are:

- Business level 0: Integration of services
- Business level 1: Integration of services and project data
- Business level 2: Virtual enterprise.

Level 0 enables the use of local engineering applications and remote engineering services via common GUI and APIs. Project data support as well as workflow support are not provided and have to be organised by the user on his own responsibility. However, all third-party services can be appropriately billed as needed. The involved components of the ISTforCE infrastructure and their principal interoperability are illustrated on Fig. 7. All active components are shown by white boxes, and the numbered arrows indicate the basic operation sequence. Unidirectional communication is denoted by single-arrow lines, and bi-directional communication by double-arrow lines. The information exchange is consistently based on XML, even where file exchange, such as STEP physical files, is involved.

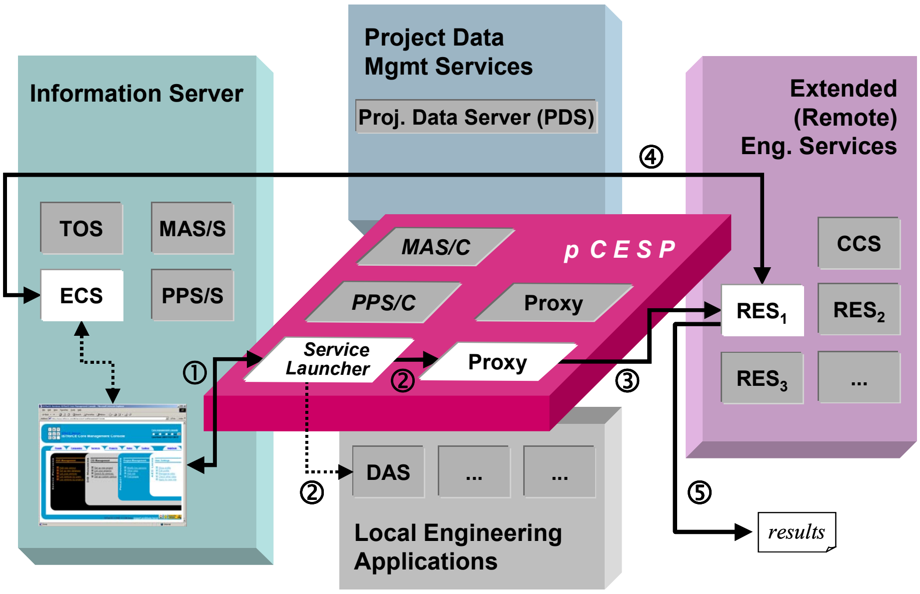

Fig. 7: Principal interoperability at business level 0 "Integration of services".

Business level 1 extends the features of business level 0 by enabling model access and project data management services. The latter can be accomplished in two ways: (1) directly, by using the specialised model access services client (MAS/C), which provides ontology-based browsing and explanation capabilities, and (2) through a local or remote application, provided that it supports the appropriate features. The involved components and interoperability are different for the two cases as shown below on Fig. 8 and Fig. 9.

In the first case, the most probable users are project managers who need fast and condensed project information. The second case is more typical for designers who have to work with detailed data. However, common to both cases is that the user has to be authenticated and that he/she does have a *project role*. Correspondingly, the user access rights can be properly determined to suit user needs and responsibilities.

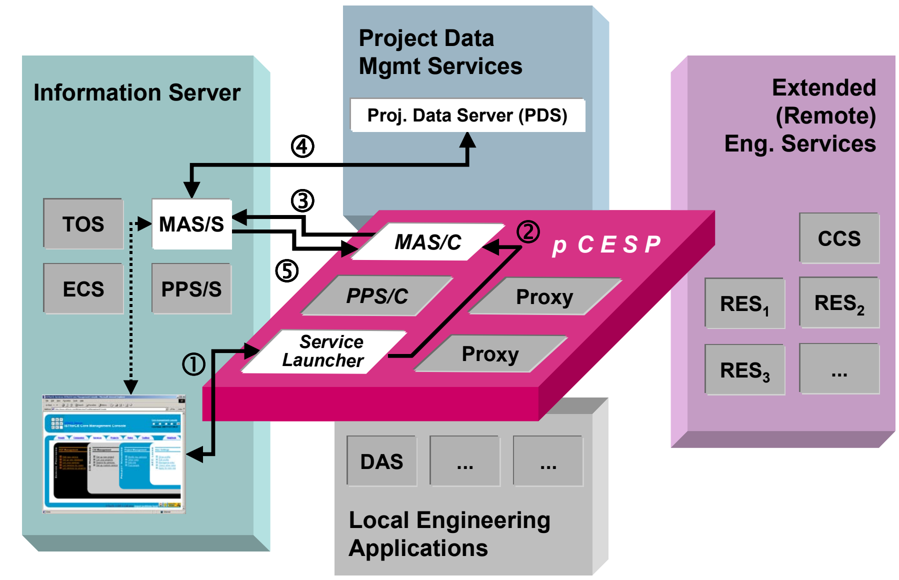

Fig. 8: Principal interoperability at business level 1 "Integration of services and project data" for the case of directly accessing the project data repositories with the help of MAS/C.

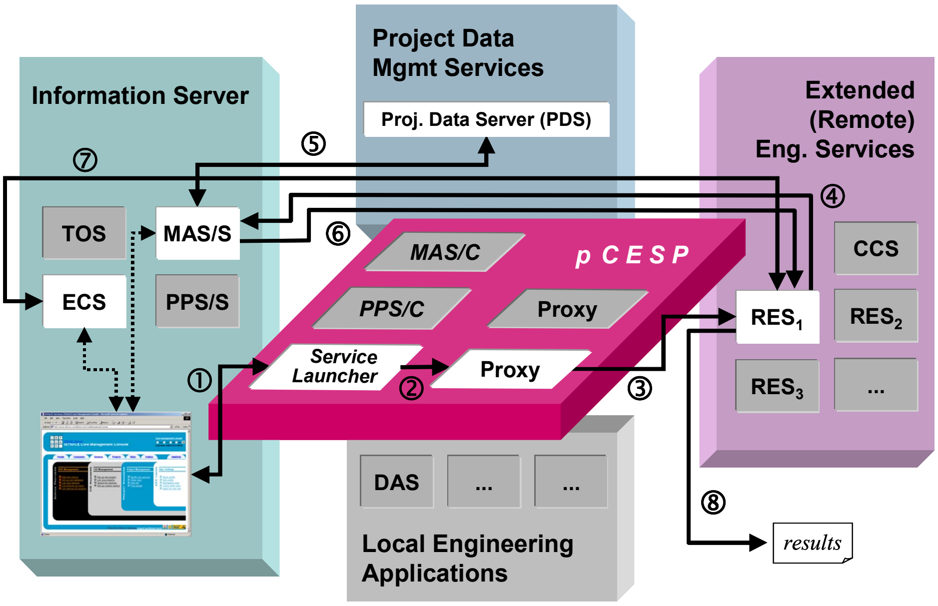

Fig. 9: Principal interoperability at business level 1 "Integration of services and project data" for the case of accessing the project data repositories by a remote engineering service.

Business level 2 exposes the full features of the platform. It further extends level 1 by additionally enabling multi-project workflow and information support. Here the user has *both a project and an enterprise role*. All services are accessed through the workflow client (PPS/C), and tasks can – ideally - be fully coupled with project data support.

At this level, all components and the related interoperability aspects come into the play (see Fig. 10). However, at this level, too, transactions are based on the common well-defined interface specifications and are generally not visible to the end user who can concentrate on his/her actual practical tasks.

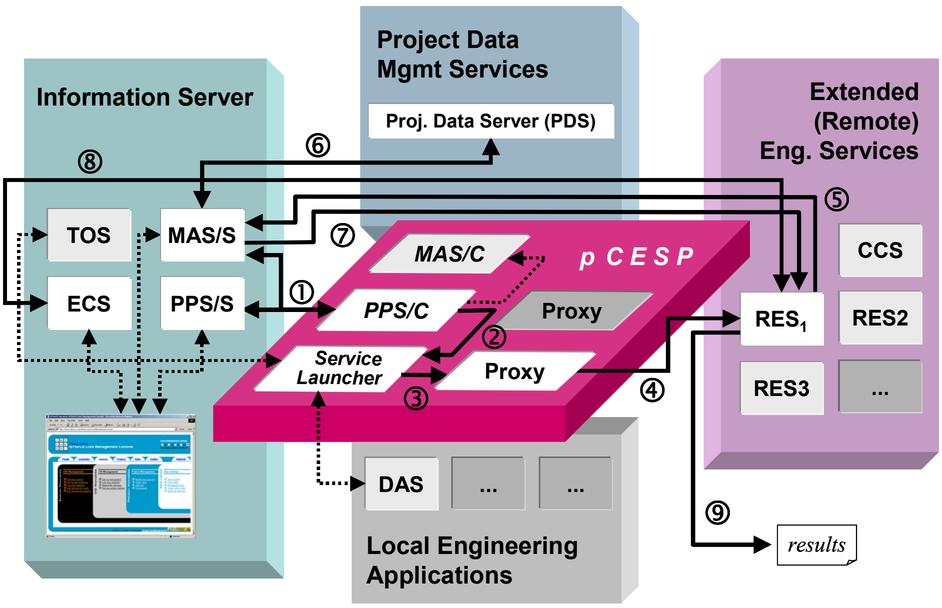

Fig. 10: Principal interoperability at business level 2 "Virtual enterprise". At this level the full functionality of the environment is used.

3.4. Interfaces and interactions of the components

A Web Browser with possible standard plug-ins (e.g. VRML) and extension languages (Java, JavaScript) is the main interface that the platform provides to the human users. However, the four actors shown above have each their unique adaptable user interface (see Section 4, Fig. 13).

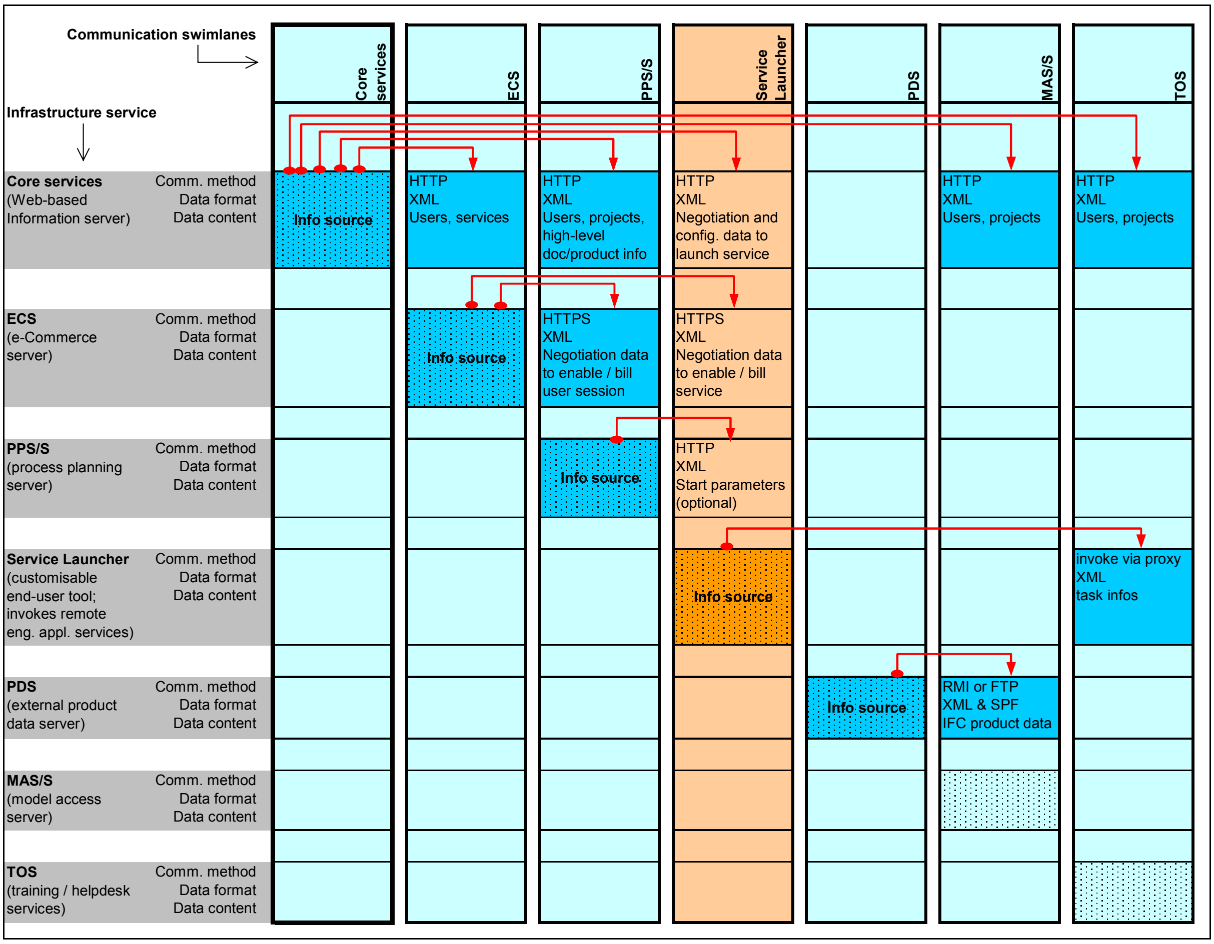

Fig.11: Interaction matrix for the CESP infrastructure services. Arrows denote the principal information flows.

Services also need to talk to each other. Due to very different requirements, the lowest common denominator is TCP/IP networking. Some services may use standard protocols (e.g. ftp or http), some proprietary solutions. The core services themselves will use operating system and other server resources, such as a database engine and basic Internet services like e-mail, DNS and ftp. However, even more important than these technology issues is the common commitment of the services to a lean, easy to implement high-level communication language based on a *system-wide ontology* (Guarino, 1998), which is consistently provided in ISTforCE in terms of XML (Katranuschkov, 2001; Katranuschkov et al., 2001).

Thus, the interactions between the CESP services, as well as the use of remote (rental) applications follow well-defined communication and data exchange patterns, widely based on HTTP and XML, as shown on Fig.11 and Fig. 12 below by means of an adapted version of the Generic Process Protocol approach (Kagioglou et al., 1998).

Fig.11 illustrates the principal interactions between the infrastructure services of CESP which can be (and are) developed as independent servers. It shows also the inter-relationships between the infrastructure services and the *Service Launcher*, a local end-user tool enabling the individual customisation of the environment in accordance with the specific end-user needs. This approach is different from the personification methods used by most commercial project hosting sites which basically rely on server-side customisation and a Web Browser as the user's front-end tool. It emphasises the benefits that can be achieved by the use of shared project information through a specialised tool with clearly defined interfaces to the platform's servers.

Fig. 12 illustrates how remote application services are plugged into the platform with the help of the core services – providing the needed services specifications, and the Service Launcher – enabling the appropriate remote service invocation. Each remote service may additionally use the features of the platform for querying / retrieving project data and for authentication / billing purposes, provided that it implements the respective APIs. Optionally, the on-line support system can also be called by the PPS client, by the Service Launcher, or even directly by the remote application (not shown on Fig. 12 for simplicity).

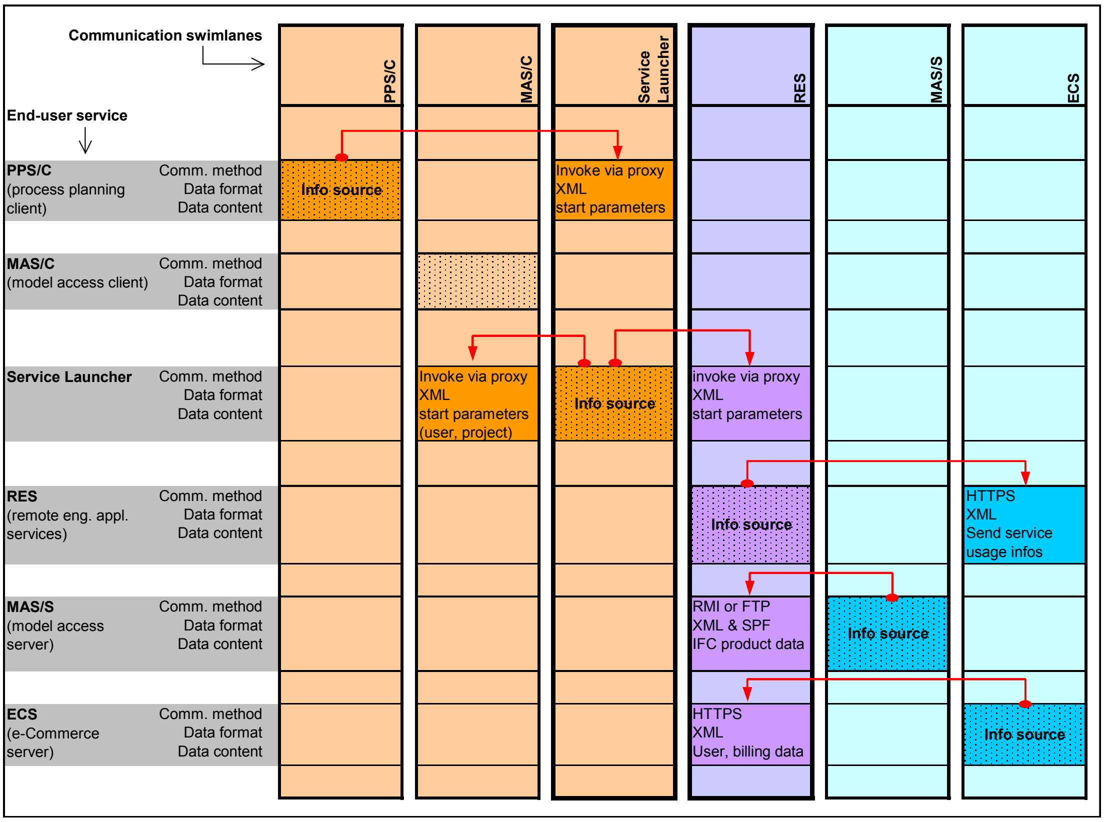

Fig. 12: Interaction matrix showing the invocation and the principal information flows for the remote (rental) engineering services.

A very specific feature of the ISTforCE approach is the use of the personal planning system client (PPS/C) on business level 2 which provides support for the user's activities in relation to an optimised activity plan (see Section 3.3). In this case, a user session is initiated by the PPS/C which enables the selection of the most urgent task and then activates the Service Launcher to choose and invoke the local or remote application tool(s) needed for the realisation of that task.

With these clear communication, data exchange format and data content specifications, a sound implementation basis for the naturally heterogeneous, distributed architecture of CESP is achieved.

4. PROTOTYPE ENVIRONMENT

The currently developed prototype environment includes the principal features of all infrastructure services, a set of three rental services exploiting different provider alternatives, and a few selected applications demonstrating the features of the system design concepts. Project model data are according to IFC 2x (Wix & Liebich, 2001) and the IAI ST-4 project (IAI, 2001; Weise et al., 2000). The high-end Web-enabled core infrastructure services of CESP have been encoded as a set of Perl scripts which are fully operational (see Fig. 13 and Fig. 14).

Fig. 13 shows the main page of the ISTforCE Web portal, providing the entry point for all four groups of users, and Fig. 14 shows the CIO interface allowing to create and reuse the various databases of the environment (users, organisations, projects, services, access control lists etc.).

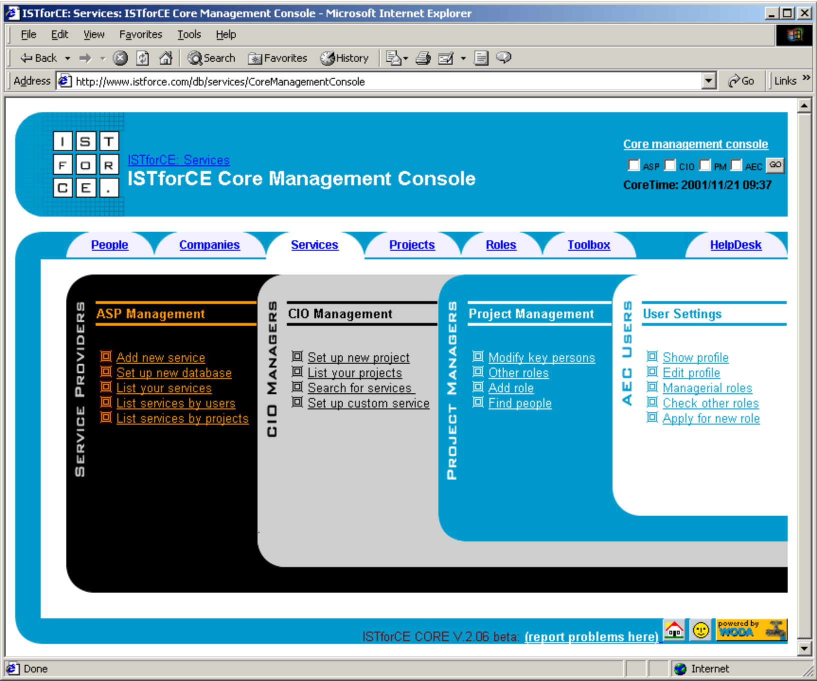

Fig. 13: Main page of ISTforCE. The four vertical tabs denote the four main groups of users. Clicking on each vertical tab opens up a specialised screen for the respective actor.

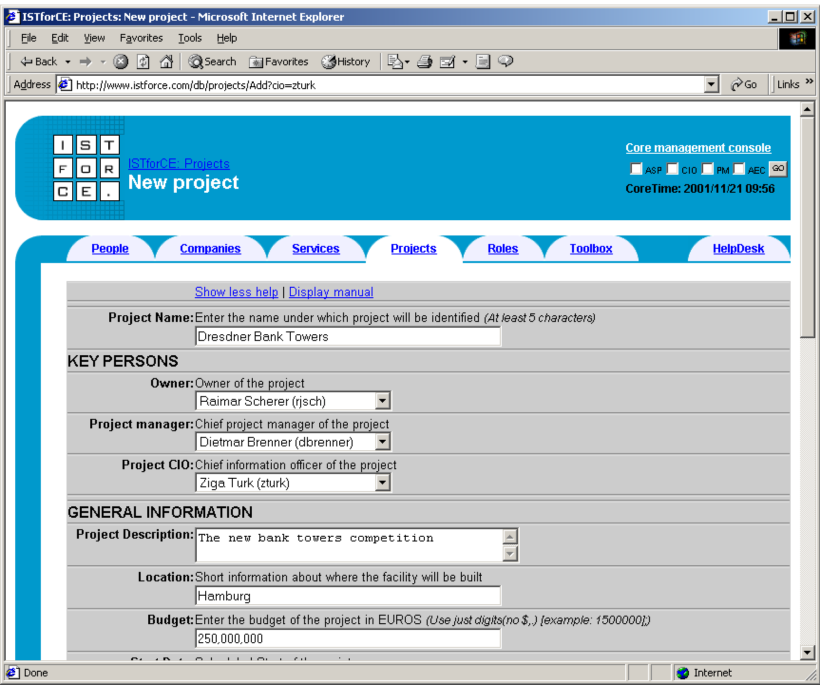

Fig. 14: CIO Manager interface allowing to create and reuse various databases.

On Fig. 15 the selection of a project with the Service Launcher is shown, and on Fig. 16 – the selection of one of the configured remote engineering applications. Both data are retrieved from the Information Server on the basis of the user's login authentication at the beginning of the session. In the case when the Service Launcher is invoked through the PPS client, the data are retrieved and forwarded by PPS/C and the respective service is immediately started, without exposing the GUI of the Service Launcher.

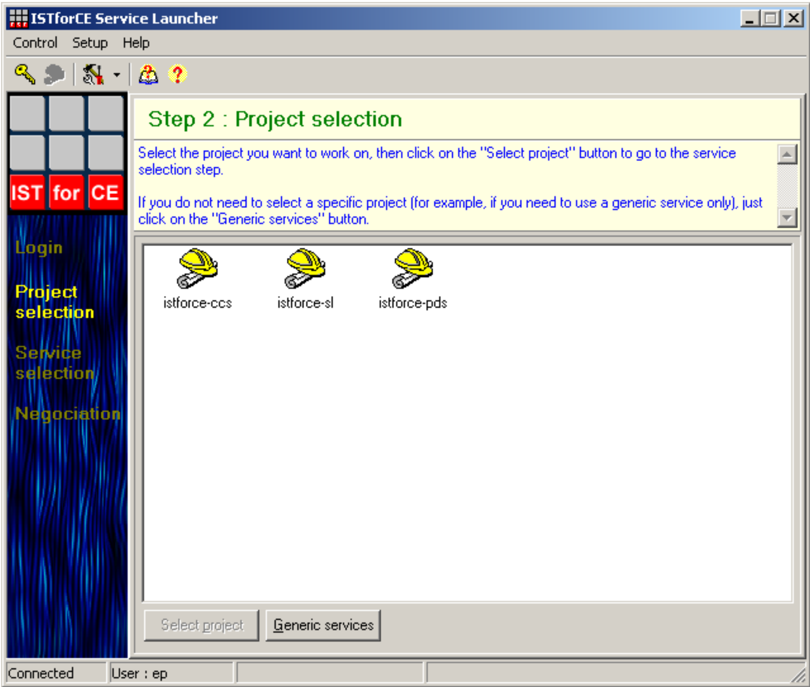

Fig. 15: Project selection through the GUI of the Service Launcher. The main Launcher frame dynamically creates references to the projects relevant to the logged in user.

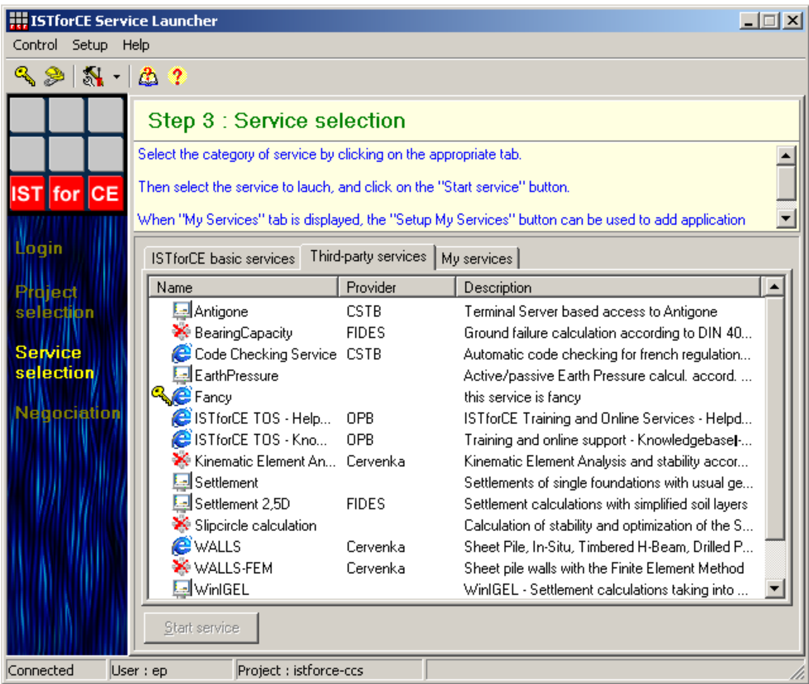

Fig. 16: Service selection through the GUI of the Service Launcher. Only services available to the logged in user

are shown.

At last, Fig. 17 shows an example screenshot of the VTLS application, integrated as a remote rental service in the ISTforCE environment by using the described approach.

More details w.r.t. the environment are provided in (Turk et al., 2000a). Full run-through examples will be available at the end of the project, in mid 2003.

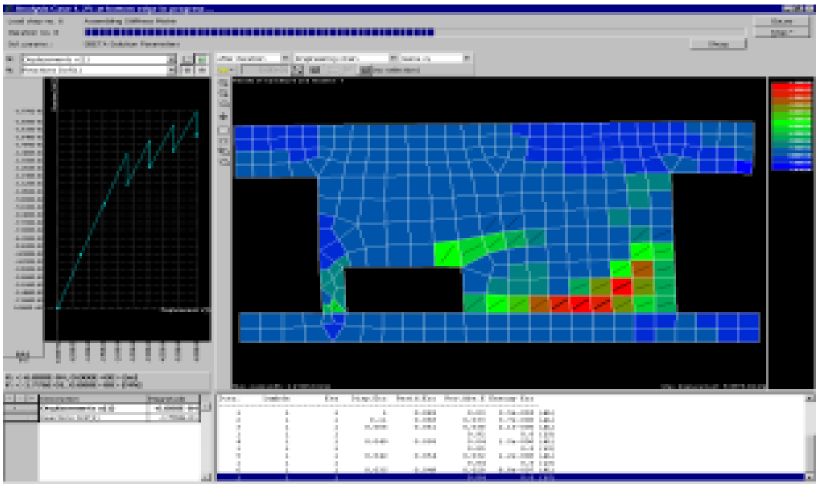

Fig. 17: Example screenshot of the GUI of the VTLS remote application service invoked by the Service Launcher and exposed at the user desktop via Microsoft's Terminal Server.

5. DISCUSSION

The ISTforCE project, within which the presented platform is being developed, is an on-going effort, currently at the end of the first implementation phase. The final results, including the integration and the co-related functionality of the application and infrastructure tools outlined in Section 2.2, will provide the basis for more comprehensive benchmarking and analysis of the benefits of the proposed approach, and for practical test-bed and demonstration examples. Below we perform a brief qualitative SWOT analysis of its main features.

Strengths. The developed approach, at least as envisaged conceptually, integrates the entire profession in which small and medium companies are in a large majority. It provides them with a new model of doing business and all the necessary infrastructure. Especially beneficial is the clear and easy method of integrating third-party engineering applications into the environment. Provided that an application is Web-enabled (for example via a HTML/XML user interface, or via Microsoft's Terminal Server), it is only necessary to configure its URL and invocation method and parameters at the Information Server in a way similar to the UDDI approach. This can be done even on-line by the service provider or the CIO, through the Web Browser interface of the Information Server. The customisation of the Service Launcher is achieved almost automatically, with the help of the specifications stored at the Information Server.

Weaknesses. The prototype is created using tools that allow for rapid prototyping but lack the robustness of the tools with which a professional platform would be built. Currently, we have not addressed sophisticated issues like security and privacy, except for the e-Commerce transactions supported by the ECS.

Opportunities. Central management of project information should result in a digital archive of previous projects. This could enable better reuse of old project data, analysis of the processes, as well as synthesizing new knowledge about construction. The data could be used to support the full life cycle of the structure. To service providers, a common point of entry for all users and a centralised user tracking could lead to better understanding of the users and their needs.

Threats. Companies providing core collaboration services could be tempted into using project data, either discretely or synthetically, to learn about the participants and about the ways construction work is done, and therefore exploiting the implicit knowledge of the construction companies using the services and benefiting from them. An open collaboration platform where many small providers of services and tools can offer these to construction professionals is also a threat to established players in the field, who are interested in exploiting collaboration platforms to extend their monopoly in one segment of the market (e.g. CADD or project planning) over the whole industry. Such portals are also threatened by the general lack of economic soundness on the Internet. In order to establish market shares, dotcoms are offering services nearly for free. Engineering consultants and software authors cannot operate at a similar price. In addition, the ease at which information can be exchanged digitally is likely to cause an information saturation and overload. Designers and planners will be receiving a growing number of messages, files, calls, just because sending out a digital copy of a floor plan is so much easier than drawing out a paper version and mailing it. Therefore, advanced filtering on both sender's and receiver's end will be required as well. All these threats include topics for future research.

Other open issues requiring further examination are the legal implications of using such an environment, the applicability of multi-project work in the cases where different project hosting sites are used, enhanced training facilities etc. Although the ISTforCE platform provides three levels of interoperability, most beneficial for the collaborative work in the virtual enterprise is the highest level 2. It is therefore interesting to examine if this level can be practically used in real-life environments on the basis of the upcoming IFC standard.

6. CONCLUSION

In the preceding chapters, the architecture and some of the prototype work on a novel environment for collaborative engineering on the Web has been described. It is not only concerned with the horizontal integration of the architects and engineers, but also with a vertical integration of all professions providing construction related services on-line.

The key component of the Web portal is a platform for the collaboration in construction projects, as well as a market place for selling construction related services, tools and knowledge. It allows for any construction service or software provider to take part in the new economy.

The key components of the infrastructure for collaborative work are information exchange and communication tools, and the key components of the infrastructure for the providers are service templates, e-Commerce tools and security tools, so that they can concentrate on their core knowledge and not on basic Internet technology.

Thus, compared to current Internet-based project hosting sites, such as Bricsnet, Buzzsaw etc., the developed platform establishes a basis for the achievement of more ambitious and challenging objectives to provide a much more encompassing system, taking into account both project, enterprise and individual user needs. However, the large scope of such an effort and the remaining open issues that need to be solved can take many more person years of development work until it is fully operationalised and deployed.

7. ACKNOWLEDGEMENTS

The presented research has been carried out in the context of the 5th Framework IST project ISTforCE, funded partially by the EU. The contribution of the funding agency as well as all the project partners - Obermeyer Planen + Beraten, the Dresden University of Technology and FIDES (Germany), CSTB (France), GEODECO (Italy), Atlante and APIF (Spain), AEC3 (UK), Cervenka Consulting (Czech Republic) and the University of Ljubljana (Slovenia) - is gratefully acknowledged.

8. REFERENCES

Bricsnet (2001). *Bricsnet Solutions* (http://www.bricsnet.com/about/solutions/default.jsp?site=1).

Buzzsaw Inc. / Autodesk Inc. (2001). *Project Point* ™ (http://www.buzzsaw.com/content/products_and_services/ProjectPoint/default.asp).

Cervenka J. & Pukl R. (2000). *Testing of Building Structures in the Web Towards Virtual Labs*, in: Goncalves R., Steiger-Garcao A., Scherer R. J. (eds.) Proc. of ECPPM 2000 "*Product and Process Modelling in Building and Construction*", 25-27 Sept. 2000, Lisbon, Portugal, publ. by Balkema, Rotterdam / Brookfield, ISBN 90 5809 179 1, 97-104.

Citadon Inc. (2001). *Collaborative Project Management* (http://www.citadon.com/product_center/index.html?pc_collab_proj_mngmnt.html).

Conject AG. (2001). *Conject* – Project Area (http://www.conject.de/english/index.htm).

Gehre A. & Katranuschkov P. (2000). *Engineering Ontology*, ISTforCE Report D5, TU Dresden, Germany, 31p.

Goldberg E. (2001). *Architectural Desktop Taps into the Internet*, CADALYST Magazine 3/2001 (http://209.208.199.147:85/solutions/adt/0301adt/0301adt.htm).

Guarino N. (1998). *Formal Ontology and Information Systems*, amended version of a paper in Guarino N. (ed.) "*Formal Ontology in Information Systems*", Proc. of FOIS'98, 6-8 June 1998, Trento, Italy, publ. by IOS Press, Amsterdam, 3-15.

Hannus M., Karstila K. & Tarandi V. (1995). *Requirements on Standardised Building Product Models*, in: Scherer R. J. (ed.) Proc. Of ECPPM'94 "*Product and Process Modelling in the Building Industry*", Dresden, 5-7 Oct. 1994, publ. by Balkema, Rotterdam, 43-51.

IAI (1999). *An Introduction to the International Alliance for Interoperability and the Industry Foundation Classes*, IAI Publ., Oakton, VA, 21 p.

IAI (2001). *ST-4 Structural Analysis Model and Steel Constructions* (http://www.iai-ev.de/projekte/documents/pdf/IFC_ST4.pdf, http://cib.bau.tu-dresden.de/icss/structural.html).

Kagioglou M., Aouad, G., Cooper R. & Hinks, J. (1998). *The process protocol: process and IT modelling for the UK construction industry*. in: Amor R. (ed.) „*Product and Process Modelling in the Building Industry*", Proc. ECPPM'98, Building Research Establishment, Watford, 19-21 Oct., Clowes Group, Beccles, Suffolk, UK, 267-276.

Katranuschkov P. (2001). *Interface Specification for the C/S-based CESP/MAS Project Data Services*, ISTforCE RFC-TUD-1, TU Dresden, Germany, 56 p.

Katranuschkov P., Gehre A. & Eisfeld M. (2001). *Engineering Ontology, Part II: Formal Representation of the Data Structures*, ISTforCE Report D5-2, TU Dresden, Germany, 97 p.

Mangini M. & Protopsaltis B. (2000). *E-Commerce: A New Frontier for Engineering Software and Services*, in: Goncalves R., Steiger-Garcao A., Scherer R. J. (eds.) Proc. of ECPPM 2000 "*Product and Process Modelling in Building and Construction*", Lisbon, Portugal, 25-27 Sept. 2000, publ. by Balkema, Rotterdam / Brookfield, ISBN 90 5809 179 1, 137-145.

Ouzounis V. (2001). Analysis of Distributed Technologies for the Usage in the Context of Virtual Enterprises. COVE News 1/2001, ISSN 1645 0582 (http://www.uninova.pt/~cove/newsletter.htm).

Scherer R. J. & Katranuschkov P. (1999). *Knowledge-Based Enhancements to Product Data Server Technology for Concurrent Engineering*, in: Proc. 5th International Conf. on Concurrent Enterprising, ICE 99, 16-17 March 1999, The Hague, Netherlands.

Scherer R. J. (2000). *Towards a Personalised Concurrent Engineering Internet Services Platform*, in: Goncalves R., Steiger-Garcao A., Scherer R. J. (eds.) Proc. of ECPPM 2000 "Product and Process Modelling in Building and Construction", Lisbon, Portugal, 25-27 Sept. 2000, publ. by Balkema, Rotterdam / Brookfield, ISBN 90 5809 179 1, 91-96.

Turk Z., Scherer R. J. & Katranuschkov P. /eds./ (2000a). *Requirements, Specifications, Architecture and Rapid Prototype of CESP*, ISTforCE Report D6, 118 p.

Turk Z., Wasserfuhr R. & Katranuschkov P. (2000b). *Environment Modelling for Concurrent Engineering, Int. J. of Computer Integrated Design and Construction /CIDAC/ 2(1)*, Special Issue on Concurrent Engineering in Construction, SETO, London, UK, 28-36.

Weisberg S. (2001). *i-Collaboration - State of the Industry*, CADALYST Magazine 9/2001 (http://209.208.199.147:85//features/0901icollab/0901icolab.htm).

Weise M., Katranuschkov P. & Scherer R. J. (2000). *A Proposed Extension of the IFC Project Model for Structural Systems*, in: Goncalves R., Steiger-Garcao A., Scherer R. J. (eds.) Proc. of ECPPM 2000 "*Product and Process Modelling in Building and Construction*", 25-27 Sept. 2000, Lisbon, Portugal, publ. by Balkema, Rotterdam / Brookfield, ISBN 90 5809 179 1, 229-238.

Wix J & Liebich T. (2001). *Industry Foundation Classes IFC 2x* (http://www.iai-ev.de/spezifikation/IFC2x/).

Note: All URL references last accessed in Sept. 2001.