An Overview of the COMBINE project

Godfried Augenbroe
Faculty of Civil Engineering, TU Delft, The Netherlands

ABSTRACT

An overview of the COMBINE project is given. COMBINE (Computer Models for the Building Industry in Europe) is an international project with at present 11 partners from seven countries. The project is funded in the JOULE rational use of energy program in the framework of European Union R&D funding. Its objective is the development of future intelligent integrated building design systems (IIBDS) through which the energy, services and other performance characteristics of a planned building can be analyzed. This will be accomplished through the use of standardized IT solutions for data integration emerging from the ISO-STEP standardisation effort. The research concentrates on establishing a data infrastructure and tools for managing the information exchange in a building design team, with emphasis on the energy and HVAC consultant. This will enable better and more efficiently designed buildings, especially from an energy conservation, building quality and heating and ventilation perspective. Results from the first will be summarised, whereas the set-up and technical issues and objectives of the ongoing second phase will be discussed.

1. INTRODUCTION

Many studies have identified building design as a multi-actor cooperative process which could greatly benefit from IT as the key-enabler of integration of an, at present fragmented industrial process. Among these we mention two studies, recently commissioned by the Commission of the European Union i.e., (Dupagne, 1991) and (Augenbroe and Laret, 1989). The latter led to the initiative by the EU Comission’s Directorate General XII to launch the COMBINE project in 1990 as part of the JOULE program.

COMBINE's goals are not to add to information technology as such, rather it targets efficient use of advanced Product Data Technology (PDT) in the building industry showing its potential to the end user community. It attempts to provide the first operational prototypes of the next generation of intelligent integrated building design systems (IIBDS). For the time being the emphasis will be on the integration hence we will target the IBDS level first, dropping the first I. The overriding perspective of the research is to apply emerging STEP technology (ISO-STEP, 1992), and reuse (not re-engineer) existing design applications in an integrated framework lending them added value.

The first phase of COMBINE (1990-1992) has concentrated on data integration based on the concept of a set of separate actors shared around a central common data repository (Augenbroe, 1993). It's deliverables comprise the first large conceptual building model

(IDM), an IDM implementation and a standard STEP interface kit supporting STEP neutral file exchange. Six, mostly existing, design tool prototypes were interfaced to demonstrate the concepts. A final workshop and seminar held in Stuttgart in November 1992 marked the end of the first phase (COMBINE, 1992).

The present second phase builds upon the above deliverables by combining them into an operational integrated building design system (IBDS) according to functional specifications resulting from particular building project-partner settings in practice. These specifications are drawn up in close collaboration with local end users who will also act as field testers of the deliverables at the end of the project. The extension of the suite of interacting design tools will be based on a configuration of existing tools in the areas of costing, HVAC-CAD, component databases, daylighting and energy, CEC standards and building regulations. Additionally, off-the-shelf and widely used architectural CAD tools will be incorporated. Whereas extended intelligent design support features and full coverage of concurrency issues is not within the scope of the project, the resulting IBDS prototype will primarily be configured to support robust multi-actor data exchange in specific engineering design office settings. Some added features of future IIBDS's will be explored in a separate prototype, e.g. an intelligent project supervisor will be developed using a blackboard approach.

At the start of the project, relevant types of building projects were selected to drive the specification effort. They will also serve to act as blue prints for potential field testing of the resulting IBDS prototype. The second phase will result in:

- one of the first actual multi-actor IBDS prototypes - thorough specifications of the type of IBDS's that can be absorbed in practice (i.e., in real-life enterprise project settings)
- exploration of necessary features of an IBDS through field testing.

2. PROJECT DATA

The total man power spent in the first two phases is approximately 70 manyears equally divided over both phases. The main contractor is TU Delft, Faculty of Civil Engineering. Contributing partners are:

- TU Delft, Faculty of Civil Engineering, NL (also coordinator)
- University of Newcastle upon Tyne, Department of Architecture, UK
- University College Galway, CATERU unit, IE
- TNO-BOUW, Delft, NL
- CSTB, Sophia Antipolis, FR
- SBI, Statens Byggeforskningsinst., DK
- Fraunhofer Institut, Stuttgart, D
- VTT, Technical Research Center, Espoo, F
- ERG, University College Dublin, IE
- BRE, Garston, UK
- University of Strathclyde, ESRU unit, UK

The following partners only took part in the first phase:

- University de Liege, LEMA unit, B
- University of Edinburgh, EdCAAD unit, UK
- CoSTIC, F
- University of Ulster, PROBE unit, UK
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The composition of the team reflects the expexted synergy of two disciplines, i.e. partners with IT expertise and more specifically experience in the use of STEP technology on the one hand and partners from the application field in energy performance, building engineering services and design on the other. One group of partners is identified as ‘design tool suppliers’. Their role is to interface and adapt existing design tools (mostly for performance evaluation) and thus prepare a strategy to interface a large population of design tools after the project has ended.

All partners come from the field of building engineering. The nature of the research is a pre-competetive one - no industrial ‘clients’ are involved in the project at the moment. The project is due to end with conditioned exposure to practitioners which will provide an effective transition to follow-up projects with the objective to develop productive systems with involvement of industrial partners.

The COMBINE consortium issues a regular newsletter and maintains an anonymous ftp server for easy distribution of deliverables. The ftp site can be reached at: dutct05.tudelft.nl, internet address 130.161.136.37. The final report of the first phase (Augenbroe, 1993) is also available on the site as postscript document.

3. COMBINE - FIRST PHASE (1990-1992)

The seminar mentioned in the introduction marked the end of the first phase with a number of prototype deliverables demonstrated to the targeted audience. A workshop was organised alongside to confront a number of leading design professionals with the resulting prototype. This prototype consisted basically of a data-exchange infrastructure through which a number of "accidental" design tools were able to communicate, or rather design tools were able to download building data subsets from the central data repository and submit updates at the end of a design tool session. The workshop discussions provided important input to the preparations of the second phase of the project which is building upon the above deliverables by combining them into an operational system, according to functional specifications derived with the aid of practitioners in typical design office settings.

3.1 Survey of deliverables

The conceptual and software architecture of the "delivered" system of the first phase of the project are diagrammed in figure 1. It can be viewed as an off-line data exchange system for a limited number of design tools. The data exchange system prototype consists of a set of design tools, logically shared around the common conceptual data model. An interface executes the mapping between the central integrated data model (IDM) and the aspect model of the design tool. The six design tool prototypes that are interfaced address the following tasks:

Design Tool-1:	Construction design of external building elements
Design Tool-2:	HVAC-design
Design Tool-3:	Dimensioning and functional organization of inner spaces
Design Tool-4:	Thermal simulation tool in the late design stage
Design Tool-5:	LT method in the early design stage
Design Tool-6:	Radiator network design

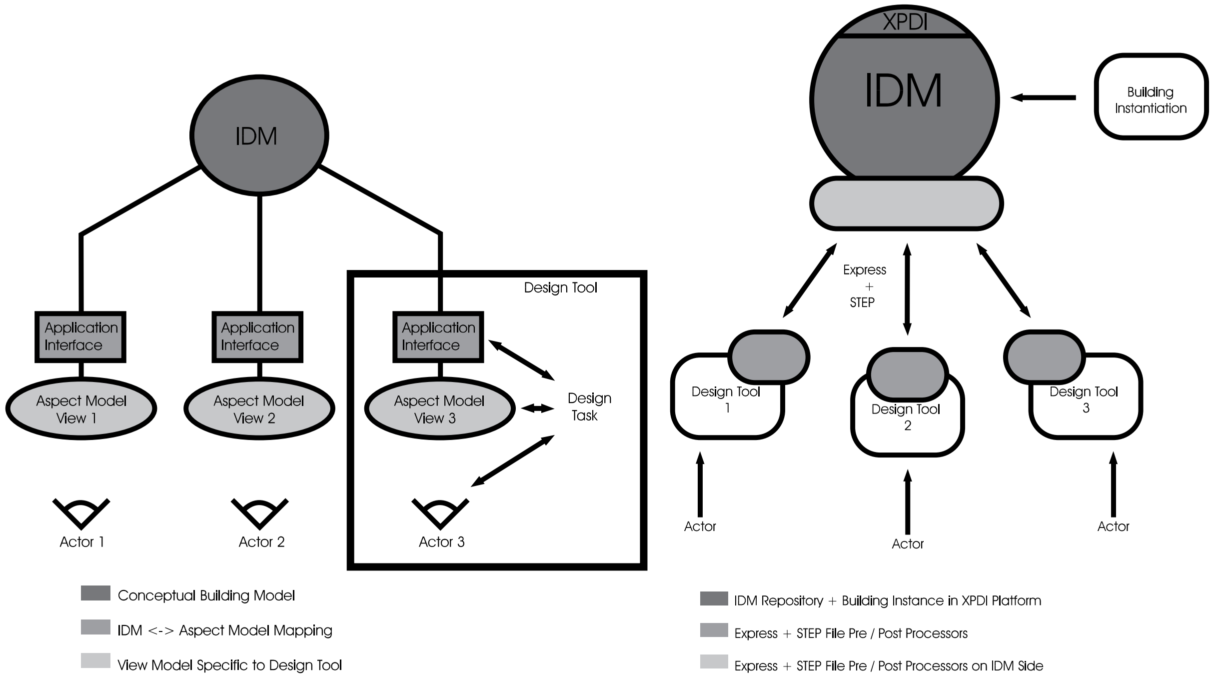

Figure 1. COMBINE 1 conceptual architecture and prototype implementation

The data exchange is realised through the following deliverables:

- a conceptual building model (IDM) that integrates all actor views.
- implementation of the conceptual building model in the XPDI software platform.
- data exchange facilities through which the design tools can communicate with the common building model, delivered as a STEP-based interface kit.

The actual communication was accomplished through STEP neutral file (ASCII) exchange.

3.2 Discussion of deliverables

The integrated building model (IDM) was a key-output of the COMBINE-project, as the IDM must enable the integration of all communicating actors (Dubois, 1993). A challenging and time-consuming effort concerning the data modelling and integration of the six actor-views resulted in a generic conceptual building model. NIAM was chosen as modelling language, supported by dedicated data dictionaries. It should be stated that the present IDM could only meet a few of the long-term requirements on ultimate building models; the output reflects the present state of the art. For easy access to the resulting model, an EXPRESS browser was provided. The browser enables easy navigation between entity definitions, with access to EXPRESS text and dynamic updates of user-defined concepts and creation of new entities.

The implementation of the IDM relied on the XPDI software environment used to rapidly prototype the exchange facilities (Poyet, 1993). Through the addition of XPDI functions for NIAM generation, NIAM to EXPRESS translation and generation of STEP files according to IDM subschemas defined in EXPRESS, the basic functionality of the data exchange facilities were supplied. The implementation has mainly served to provide a proof of technology solution to the the type of subschema based exchange of STEP files that was chosen for the final demonstration.

At the design tool side an interface development kit was provided to application developers to interface their design tools to the central building model. This so-called COMBINE interface kit offered generic STEP file read and write operations and a C++ binding to add interface specific mapping operations (Plokker et. al. 1992).

The development of the six design tools concentrated on building adequate interfaces with the aid of the interface toolkit. The approach generally followed these steps:

- define the design-related function that a certain actor can perform and specify a design tool with which to perform it
- define the actor's view of the building, hence specify and formalize it into a formal conceptual model, called Aspect Model, which describes the semantical meaning and relations of all input and output concepts. In the project NIAM was used throughout as data model and a customized data description form was used for adding additional semantics.
- specify the design tool functions in a formal way, e.g. relate these functions to the overall building design process (external link) and decompose them into the granular functions that are performed internally, e.g. by embedded evaluation and analysis tools.
- define the mapping between the integrated building model and the view models and give feedback to IDM-team on encountered problems. This process enabled an iterative refinement of the IDM.

Each design tool supply team then built it's design tool prototype in the hardware/software environment of choice. No standardization of implementation approaches was required, as heterogeneity across the actor tools is one of the requirements.

It was found that the interface kit proved to be hard to use and lacked the full range of functions that were deemed necessary for the ensuing stages. That is why a new version of the interface kit was a priority in the follow-up stage of the project.

3.3 First phase results in broader context

In order to view the results of the first phase as an intermediate step, it is useful to distinguish three separate levels of functionality. COMBINE 1 showed how the data exchange "works" (*operational level*) through a common language (IDM) and data exchange facilities. No attempt was done to supply support on the *tactical level* where control over the data exchange operations is implemented in order to support cooperation among design actors, engaged in a building project. Even more out of scope were targets at *strategic level*, where additional design support is at stake. At this level common strategies and negotiaion among a team of heterogeneous actors should be supported to make coordinated design towards pre-set objectives possible. Ideally this should also deal with adequate enterprise integration and the provision of means to apply local configurations and company flavouring.

The first phase of COMBINE was intended to produce adequate functions on operational level, ie, getting relevant product data technology in place to effectively support the exchange of data in a heterogeneous system. On tactical level moderate goals were reached, in the sense that the demo showed the set of actors exchange data in the context of a simulated project, according to a hardwired pre-defined scenario. The primary aim was to be able to show one support layer of cooperative group work, ie, the data exchange layer, in action, be it in a laboratory setting. No attempt has been made to clearly define a project-setting, e.g. participating actors involved in a specific design task. As a result of this, the resulting suite of tools/actors represents a more or less random selection in a moreover unspecified design process and project environment. Support of the tactical level was identified as a priority for the next stage of the research.

Needless to say that the first phase did not target any additional functions on strategic level. It should be clear that the resulting COMBINE deliverables were exclusively on data-integration level, thus inherently very limited in their potential of providing dynamic design support.

4. COMBINE 2: TARGETS

After conclusion of the first phase a number of obvious extensions were identified. Among them the scope extension by taking a broader range of design tools into account which was vital to arrive at usable systems. As a result the integrated building model needed to be expanded and in fact re-tailored considerable, not in the least because shape description had to be augmented to reach a much richer level. The inclusion of on-line CAD actors among the integrated design tools was another major new direction in the project. Although the majority of design applications is still in the energy/HVAC engineering domain a number of tools ‘peripheral’ to that domain are added. This leads to the following scope of design tasks now supported:

- thermal/energy/comfort simulation
- HVAC design with HVAC CAD support
- lighting design
- shape design and space layout with architectural CAD support
- cost estimation
- building regulation checking
- component database access for HVAC and fabric components
- on-line document browsing

On the implementation side it was opted to steer towards robust implementation of the building model with persisitence support in an OODB and a re-engineered interface kit with enriched functionality.

Another major second phase extension steered towards delivering project support to real life project settings. This will predominantly address issues on tactical level by focusing on a number of project environments, identifying the actors in various scenario's and configuring the exchange system accordingly. The exchange control offered by the system will be of moderate flexibility, hence functionality on strategic level (assuming flexible and intelligent and eventually concurrent multi-actor control) will not be offered.

An important concept was introduced in the form of a “Project Window”. A project window delimits the "playing field" of a number of actors within a limited life-cycle span along the time axis. Data integration is usually built on the premises, that the exchanging actors operate only on predefined intermediate states of the product specification, whereas the semantic coverage in the conceptual model is mostly directed towards (rigid) product description, with little or no design support semantics. The project window metaphor is introduced to lend a context to the states of the product that are exchanged among actors. Moreover, within the limited span of a well defined project window, so-called on-line actors will have access to the building model to perform a number of predefined design operations. On-line actors will be applications typically built with a general purpose CAD system. A limited (conservative) form of concurrency will be targeted in the cooperation between off-line and on-line actors.

The exchange mode in COMBINE2 will be on-line data access to the IDM in an object based data server environment, paired with standard off-line exchange for those design tools that do not require "direct" interaction. Adequate data exchange tools will be provided following the STEP Data Access Interface specification (ISO-STEP Part 22, 1992).

The main deliverables of the present phase will consist of a generic data exchange system (DES) and three PW specific (I)IBDS prototypes. The project structure that was set up to reach these goals is presented in the next section.

5. PROJECT STRUCTURE

Figure 2 shows the six main tasks in COMBINE 2. The tasks and their interdependencies will be briefly described here.

Task1: Specification

With the involvement of building services design firms a specification of proposed IBDS’s is drawn up. The specifications take working practices and design tools used in the practices into account.

Task 2: Concept design

This task deals with all conceptual modelling activities that go on in the project. Three different levels are distinguished to structure the modeling process:

- Design Tool level: the development of the design tool's local 'Aspect Model', expressing the local data requirements (input and output)
- Integrated Data Model level: the central building model accomodating and integrating all local DT aspects and adding generic concepts to generalise all views into a common description
- IBDS level: at system level modelling activities are employed to capture the design tool functions and their dependencies, and control the flow of events of exchanging actors. A project window refernce model is defined and two example project windows are being developed.

Task 3: Data Exchange System (DES):
Concerns the development of the generic data exchange capabilities that an IBDS will be built around. The implementation will make use of a commercial OODB. The components of the DES will be a data exchange kernel, off-line and on-line data interaction managers and an event control module, called ExEx (Exchange Executive).

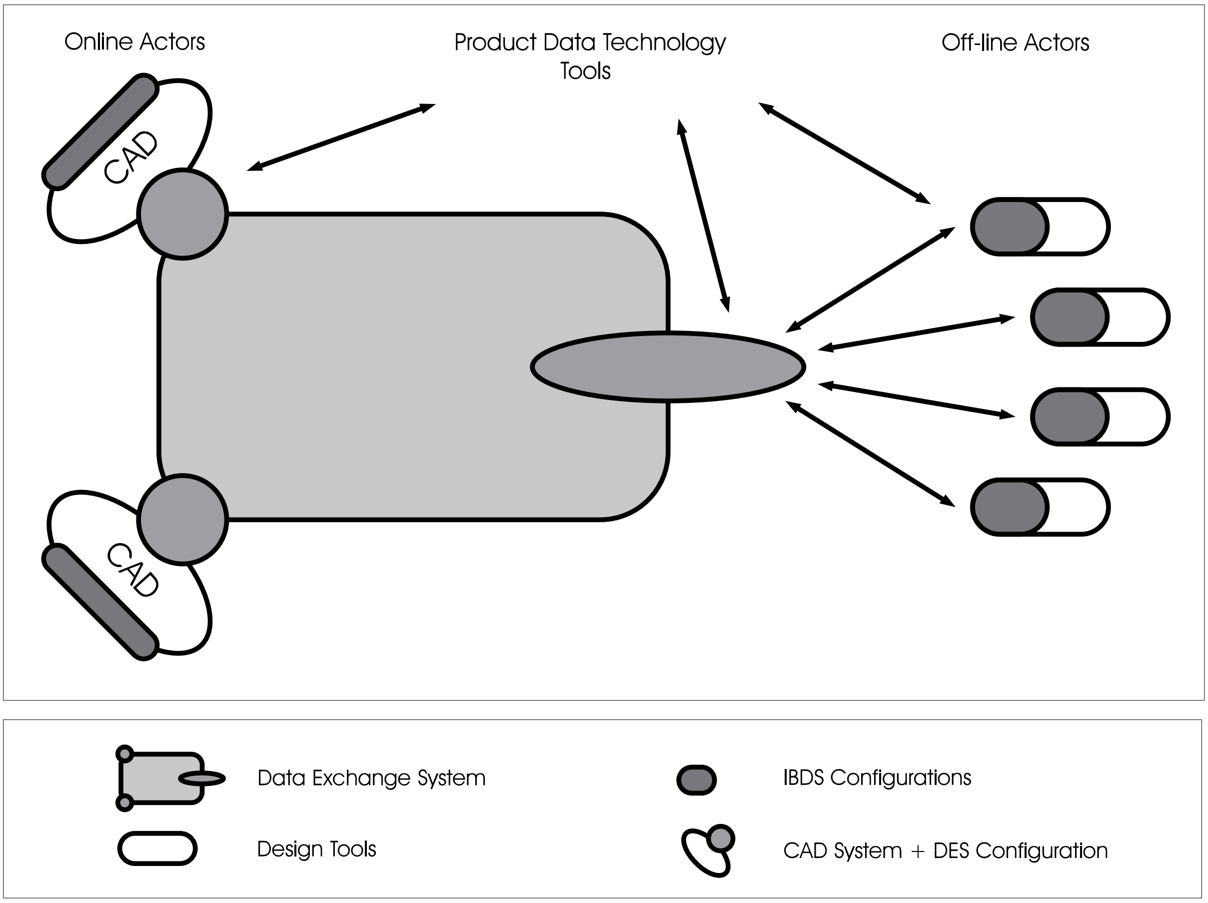

Figure 2. COMBINE 2 Task structure

For the efficient development of interfaces to off-line tools, an enriched interface toolkit is developed, compliant with the STEP-SDAI specification. The generic CAD functions and online connection to the DES are implemented in this task.

Task 4: Integrated building design system (IBDS):
This task deals with the composition and configuration of two IBDS prototypes according to the two PW models generated in Task 2. DT interfaces, based on IDM subschemas and associated mappings are defined and implemented. IBDS specific configurations are implemented on the DES and DT side. The on-line CAD tools are configured for the design functions they are designated to perform in the project windows.

The ExEx is'loaded' with the project windows execution control information and 'flavoured' with additional control aspects.

Task 5: Intelligent IBDS (IIBDS):
Based on a separate project window this task will develop another prototype system around the DES with a knowledge based supervisory module, called the actor interaction handler (AIH). The AIH will know about the design purpose of the individual actors and issue extended supervision accordingly. The AIH will use a blackboard approach.

Task 6: Field testing and dissemination
In the final phase of the project the delivered prototypes will be placed in several professional offices around Europe. A number of commercial architectural and enginerring practices will carry out field tests on projects they have already completed. Each test site will have individual needs and characteristics. A final seminar/workshop will demonstrate the deliverables and show the results of the monitored field tests.

The next section will give a brief overview of the remaining Tasks 4, 5 and 6 as they are not described in depth in the accompanying papers.

6. (I)IBDS PROTOTYPES

Basically we are targeting a number of real-life project environments which will then be used to drive the specification and ensuing configuration of the IBDS-prototypes that will result. Two project windows, PW1 and PW2 have been defined and modelled in a dedicated formalism developed in Task2.

IBDS1 and IBDS2 will be the prototypes developed for the two defined project windows.
A third PW will drive the development of Task 5, aimed at the IIBDS prototype.

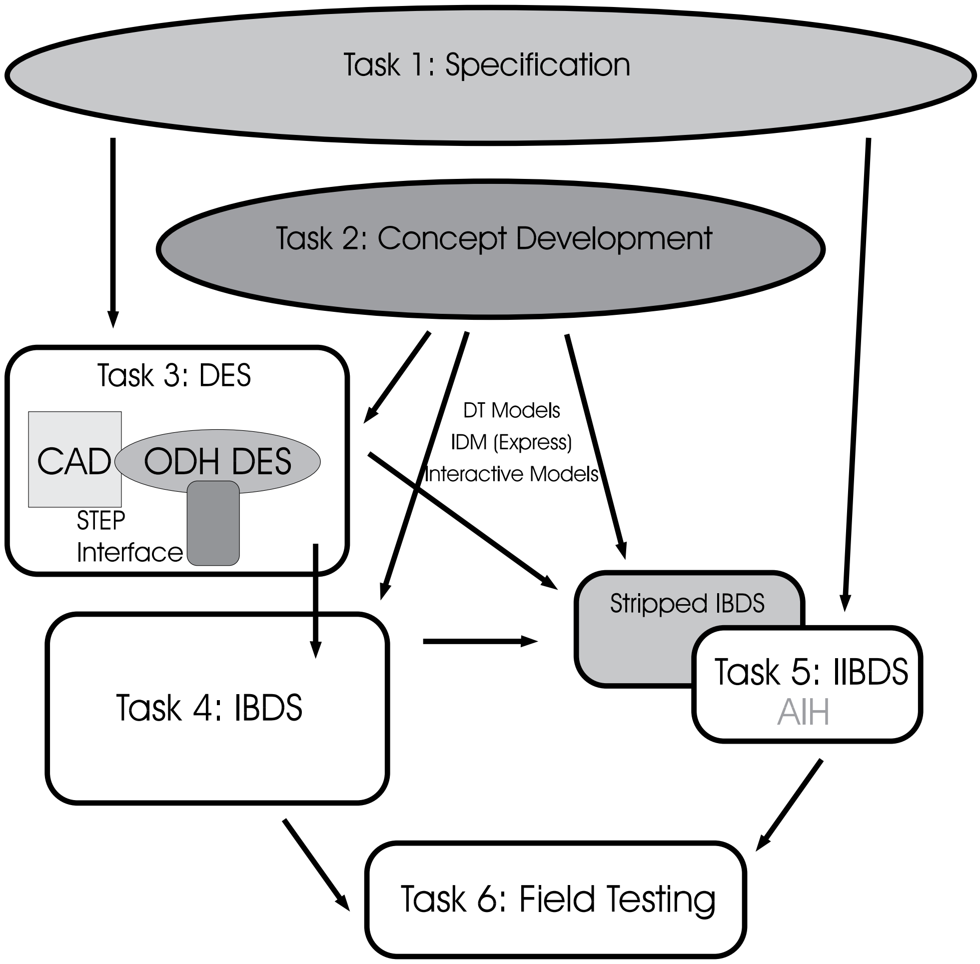

Figure 3. IBDS Architecture

A project-window and it's related IBDS support a connected string (scenario) of real life design activities by a number of actors. This is an essential requirement to be tested on a real project be it only in the 'controlled' environment of a conditioned field test. Field testers will have to be able to further adapt the IBDS to make this possible. For a realistic test in practice a number of functions must be offered in addition:

- adequate functions to "start up" a project, ie, at the front of the time window covered by the IBDS one must be able to populate the building data base with all upstream information already available,
- adequate functions to "export" to the downstream design activities beyond the backend of the IBDS time window,
- the ability to embed existing tools of current practice,
- pair added design support (through online actors supported by CAD systems) and data exchange support for "external" evaluation (through off-line actors with STEP interfaces).

Each IBDS contains at most two CAD-based online actors and an approximate number of five off-line actors. The two CAD based tools will address architectural design and HVAC design. A novel approach is developed concerning the embodymentof the online CAD tools in the DES. The global software architecture of DES and IBDS prototype is sketched in figure 3.

7. CONCLUSIONS

The COMBINE project is making an effort to develop new building design systems that have a credibility potential to be absorbed into practice. The following deliverables will result:

- an extended conceptual building model with broad coverage of energy, HVAC and related aspects and a rich topology,
- generic data exchange facilities in the form of a robust Data Exchange System (DES) supporting on-line data sharing with off-the-shelf CAD systems and off-line STEP file exchange with a variety of actors. The DES will be a full implementation of the building model in an OODB,
- several prototypical IBDS's tuned to specific project environments consisting of the DES core, configured design tools and other IBDS configurations such as interaction controls, data management, etc.
- exploration of enhanced extended intelligent support in an experimental IIBDS

Through these deliverables, COMBINE seeks to play the role of intermediate between emerging product data technology and the supply of tools that use (but hide) this technology in an industrial setting. The targeted field testing in these settings by practitioners will be the ultimate test on acceptability and absorptability at this time.

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