INTEGRATED PRODUCT DEVELOPMENT IN VIRTUAL ENTERPRISES SUPPORTED BY WEB-BASED APPLICATIONS

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The era of information age and globalization has created a situation of increased international competition. In this scenario the tasks of design and manufacturing are executed by different facilities usually at different geographically locations and the information has to be passed among the different phases of product development. In order to support better all the Product Life Cycle activities, modeling tools and computer applications have been created. On this research project Web-based applications have been developed between UC-Berkeley and ITESM to demonstrate how virtual collaborative product development can be achieved in Virtual Enterprises. A case study is presented to demonstrate how collaborative design for High Tech Products can be undertaken.

1. INTRODUCTION

Integrated Product Development integrates all the activities, methods, information and technologies to conceive the complete Product Life Cycle (Tipnis 1999). In the modern scenario, most of the activities in the Product Life Cycle are executed on different geographical locations and the information has to be passed among the different phases of product development.

In order to support better all the Product Life Cycle activities, information models have been created to share information and knowledge. Two key concepts have been developed Product Model (Krause et al. 1993) and Manufacturing Model (Molina and Bell 1999). Product Model allows engineers to represent the important aspects of products: function, geometry and engineering data. Manufacturing models capture the capabilities and capacities of manufacturing processes and resources of a particular facility. Also computer based information systems have been introduced to support Integrated Product Development. A classification of the system can be as follows: *Function oriented systems* that support engineers in specific task: CAD, CAM, CAE and Rapid Prototyping (Kochan 1995);

Coordination systems to support sequencing of activities and flow of information: workflow and project management (Barclay and Dann 2000); *Collaboration systems* to foster cooperation among engineer i.e. CSCW - Computer Supported Cooperative Working (Woodcock and Scrivener 1999); and *Product information management systems* to enable the exchange of product and manufacturing information (Hanneghan et al. 2000).

Virtual Enterprises (VE) is a temporary network of independent companies linked by information technology that share competencies, infrastructure and business processes, with the purpose to fulfill a specific market requirement. Therefore product development activities in VE requires of virtual collaborative environments. The future and success of a global collaborative environment for Integrated Product Development in VE will rely on Web based applications and e-technologies. The research reported in this paper describes how a virtual collaborative environment has been designed and implemented, and a case study is presented to demonstrate its benefits.

2. VIRTUAL COLLABORATIVE ENVIRONMENT

2.1 Description

A Virtual Collaborative Engineering Environment results from combining a collaborative environment supported by Web based applications and e-technologies. Partners on different geographical locations can interact and work together, contributing their competencies and abilities to reach a common goal. This is important in a Virtual Enterprise because product development is carried out by different partners in distributed locations. A system based on the groupware technology was developed in order to allow the members to: organize common research and development activities; establish coordinated actions and enable remote communications; participate in creative ideas across distances; keep up-to-date information to support members' research in a fast and collaborative way using cyberspace; and share information and knowledge (Molina et al. 2001).

2.2 Technical Description

In the early stages of the project, a complete development of the collaborative environment was carried out. The selected technologies were Hypertext Preprocessor (PHP), MySQL and Apache Web Server. When this system was tested several limitations were found. A Webmaster must be constantly coordinating and maintaining the system, increasing costs, and reducing efficiency and autonomy for the software users. As a consequence, a new research about collaborative applications was done and some standard applications were analyzed. The chosen application was phpgroupware (<http://phpgroupware.org/>) because it offers a standard collaborative environment, which can be personalized, that is, it can be reprogrammed to be adjusted to the application.

2.3 Functionality

The Virtual Collaborative Engineering Environment was created (Figure 1) and it is

supported by a generic product development methodology. In agreement with the proposed methodology, the environment is divided in four stages:

- Ideation. It is the systematic search for selection and development of promising product ideas.
- Basic development. This phase involves the collection of customer requirements, identification of design problems and search for appropriate solution principles. The result is a conceptual design.
- Advanced development: This is the phase in which the arrangement, form, dimensions and surface properties of all individual parts are finally laid down and drawings and other production documents are produced.
- Prototyping. The prototype is constructed and tested.

Figure 1 – e-Engineering collaborative environment-
<http://csim.mty.itesm.mx/grupos/e-engineering>

To fulfill all of the above, the system developed offers different applications on each stage of the project, divided into the next categories: Functional, Collaboration, Methodological, Coordination and Information management. The members can access these sections and contribute as they please. To support two key activities in product development, two web based application were designed and implemented: MAS and SMT – Advisor.

3. MANUFACTURING ADVISORY SERVICE (MAS)

3.1 Description

When developing a consumer product, 70% of the costs of materials, human labor, and equipment are actually set during design (Ullman, 1992). During the early stages of product development two disparate groups exist that often have completely different views of the part to be fabricated: designers and manufacturers. The designers have the functional requirements of the part in mind, along with dimensions, quantities, and customer needs. On the other side are the manufacturing sites, staffed by engineers and technicians who must build tooling and operate production equipment during fabrication. However, constraint resolution can only take place when the language of the designer matches the language of the manufacturing engineer. A shared view of the component must be established. The

MAS provides this common language, at the concept level, allowing a designer to describe a part so that an expert system can decide which manufacturing processes can produce the desired part, in the desired time, with the desired quality (<http://cybercut.berkeley.edu/mas2/>).

3.2. Technical Description

The MAS is a Java™ applet freely available via the World Wide Web. It is interlinked with web pages of instructions, tutorials, and references explaining the program, fabrication processes and material choices. The MAS performs its calculations using capability data from a remote database. The current version of the Manufacturing Advisory Service is located at: <http://cybercut.berkeley.edu/mas2/> (Figure 2).

Figure 2 – Manufacturing Advisory Service (<http://cybercut.berkeley.edu/mas2/>)

3.3 Functionality

The Manufacturing Advisory Service (MAS) is a concept level manufacturing process and material selection tool. The MAS generates a dialogue with the designer, inquiring about batch size, typical tolerances, size, overall shape, and cost requirements. At each step along the way, the user is presented with an updated, ranked list of manufacturing and material possibilities. The final result is a ranked list of viable combinations, obtained through a process/material pair optimization.

The MAS provides three different modes of information to aid a designer in preliminary process and material selection:

- Process search. On this mode the designer selects items from the requirement list, such as material, shape and dimensional tolerance, which MAS uses to make decisions and rankings in the process selection.
- Material search. This mode is almost the same as a process search, except that the options list now has materials, and the requirements, such as yield strength and Young's modulus, are material properties. After defining a set of desired material attributes, the user is presented with a ranked list of materials that match the properties.
- Results surveys. Switching to the Results Survey mode the MAS matches all of the candidate manufacturing processes with compatible candidate

materials, and presents the designer a final ranked list of material/process combinations.

Once the 'Result Survey' is complete, a user may follow-up with the MAS's optional cost estimation or process chain tools.

- Process chain generation. Process chain generation allows the user to define a rough 'global' tolerance, and match secondary operations to higher tolerance features.
- Cost estimation. If a model exists for the selected process/material combination, the user may click on the 'Cost Estimate' button. The user must then enter additional data for the part that is specific to the manufacturing process in question. Currently the MAS only implements two cost estimate modules (injection molding and sand casting).

4. SMT - ADVISOR

4.1 General description

The manufacturing model for the SMT line (Surface Mounting Technology Equipment) at CSIM, is represented (Molina and Bell 1999). The model identifies, represents and captures the data, information and knowledge describing the manufacturing resources, process and strategies of the SMT line.

4.2 Technical description

SMTAdvisor help users to analyze the manufacturability of the Printed Circuit Board (PCB) according to the capabilities from the SMT line at CSIM. The system prototype was developed in a web based platform (PHP programming) and supported by MySQL database and it is available (Figure 3).

Figure 3 – Mounting Technology Advisor (<http://csim.mty.itesm.mx/grupos/smt>).

4.3 Functionality

The SMT Advisor is composed by the following five steps:

- Step 1 - Facility Strategies: the system evaluates basic and strategic concepts about the assembly of a PCB. This issue includes the type and volume of the PCB in order to establish if one prototype, a pre-production batch or a medium-volume batch will be assembled.
- Step 2 - PCB Specifications: the PCB specifications are evaluated in order to see if they match into the SMT line capabilities. Some aspects that are evaluated: dimensions, materials, component placement (top/bottom layer), fiducial marks for the board and for the components pads.
- Step 3 - Paste Printing Process: the SMT Advisor evaluates PCB specifications according to the capabilities of paste printing process such as stencil use and solder paste material.
- Step 4 - Component Placement Process: the system places questions regarding components package dimensions, fine pitch, components presentation and bill of materials to verify the manufacturability of PCB.
- Step 5 - Soldering Process: the setup information of the reflux furnace is solicited to have all the information ready for the evaluation process.

5. CASE OF STUDY

5.1 Product description

A Collaborative Design Process was executed to design and manufacture a prototype of electronic product used by students at ITESM: The Xceter. The ITESM work team was responsible of conceptual and detailed design stages of the case design and a team of Mechanical Engineering students at the University of California at Berkeley were responsible to manufacture the prototype (Figure 4).

Figure 4 – Xceter Design Process

From the conceptual design obtained in the first stage of the project, *Basic Design*, two key activities on the *Advanced Design Stage* were executed:

- Evaluate the product case requirements on MAS in order to determine manufacturing process and material. Results from this activity are shown in Table 1.
- Evaluate the electronic design on SMT Advisory in order to determine the manufacturing feasibility in the SMT line at ITESM. Results from this activity are shown in Table 2.

Table 1 - Results from the evaluation of Xceter case using MAS

	Process search	Material search	Results survey
Input data	Batch Size: 100 Bounding Box: 4.95" Dimension tolerance: 0.025 in Surface Roughness: 125 μ in Wall thickness: 0.1" Production Rate: 11 - 100	Density: 250 lbm/ft ³ Yield strength: 5 Ksi	
Output data	Injection Molding	Thermosets Thermoplastics Aluminum & Alloys	Injection molding + thermoplastics

Table 2 – Results from the evaluation of Xceter PCB using SMTAdvisor

Facility Strategy	PCB Specifications
Type: SMT Volume: Medium Volume Batch	Component placement: Top layer Material: FR-4, 0.062 in, 0.5 Oz, Cooper, Double sided Dimensions: x = 6.5 and y = 4.5 Fiducial Marks = 6 (all plated) Fiducial diameters = 0.028 – 0.125 mm List of components approved for SMT line

6. CONCLUSIONS AND FUTURE RESEARCH

6.1 Conclusions

- A Virtual Collaborative Environment was developed to manage the product development process across borders. It was possible to demonstrate how collaborative product development (from concept to prototype) of High Tech Products can be achieved by different teams in two countries.
- Web base applications were developed and tested: MAS and SMTAdvisor. This application supports specific activities at conceptual design stage in the Life Cycle Product. However other applications can be designed and developed to support other stages of this process. The use of this type of tools presented the following advantages: in a short time period of evaluation the designer has a feasible conceptual design product; information can be shared between the design and manufacturing teams; and designers can evaluate if a product can be manufactured at a specific facility.
- It was demonstrated how Web Base Applications support design activities of two companies (ITESM and UC) in order to share information, knowledge and infrastructure. Therefore the functionality of this Virtual Collaborative Environment can be extended to support the product development in Virtual Enterprises.
- Finally product development in Virtual Enterprises must be formalized in order to understand better the interactions between all the partners.

6.2. Future research

In this project new design tools were needed to allow designers from both a mechanical CAD environment and an electrical-layout CAD environment to work together on a design while resolving possible conflicts and constraints. DUCADE (Domain Unified CAD Environment) is a research project at the University of California at Berkeley. It has now reached a mature point in our research and it is being used as a web based environment created to aid designers from different engineering domains in the concurrent design of electro-mechanical products (Wright et al, 2002). In the future projects, DUCADE will be used to identify primarily geometric relationships between the printed circuit boards (PCBs), displays, I/O ports and the casing.

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