The Impact of E-Commerce on Education for Distributed Engineering Processes

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Abstract

The rapid growth of e-commerce technology and the movement toward expanded outsourcing of product development place significant challenges on the research and education of engineers. This paper outlines some of the facets of a future distributed concurrent engineering environment and illustrates some of the research and education issues that must be done to cope with this future.

Introduction

In recent years, there has been an explosion of capabilities in e-commerce driven by the rapid expansion of Internet and web technologies. The result has been a trillion dollar a year business conducted via e-commerce processes. At the same time, engineering companies have been outsourcing extensive portions of the work on major products such as automobiles, aircraft, ships and electronics. To date, most major products are developed by teams distributed over large geographic areas and suppliers are assuming a growing proportion of the development effort and decision-making. Major companies are now looking more carefully at the supply chain management approaches to effectively develop quality products at reduced cost and time.

These two trends of e-commerce growth and distributed developments greatly complement each other but place significant challenges on engineering research and on the education of future engineers. The tools that facilitate rapid seamless integration of distributed engineering activities are not well developed. Furthermore, the tools provided by Internet developments are not tailored to support engineering functions and processes. Prime developers often off-load key design decisions to suppliers at remote sites and cannot interact with them in an appropriate manner to support key design decisions. Engineers trained in today's engineering education programs are also not experienced in distributed design strategies and the CAE/CAD tools that would support them.

This paper discusses the current trends in linking e-commerce with distributed development and describe some experiences by the authors and other in demonstration projects that help to illustrate issues. It also describes experiences in extending CAE/CAD based courses to distributed engineering design. Finally, the paper identifies several areas where research is needed as well as how engineering education should be extended to meet the needs of a future engineering development in an e-commerce supported distributed development environment.

Perspective on Electronic Commerce

Electronic Commerce and its associated strategies, tools and technologies represent a fundamental change in the manner in how we conduct business in the 21st century global markets. The opportunity for a synergistic integration and amalgamation in the flow of goods and information is reshaping the fundamental processes and infrastructure governing the efficient and effectiveness of such strategies as e-business, supply chain management, collaborative/distributed engineering and other e-strategies. The traditional paradigm of mass production and economies of scale is being replaced by outsourcing, time-based competition, economies of scope, and mass customization or one-to-one marketing such as business-to-consumer (B2C) and business-to-business (B2B).

In the new millennium, enterprise operations will become more competitive for meeting the demands of delivering customer specified products and services with high quality, fast speed and low cost. Companies distributed by space, function, capability and ownership join together for delivering products and solutions to service the global marketplace. Teams distributed over large geographic areas will develop most major products and suppliers will assume a growing proportion of the development effort and decision-making. The trends for virtual corporations, distributed and collaborative engineering and e-commerce, and increasing global networking of economies will accelerate. In this rapid changing business environment, it is critical to integrate and synthesize information from various enterprise components for identifying a company's competitive edge and business opportunity and for efficiently managing corporate resources to gain market share.

With the advent of the Internet and its impact on e-commerce, the influence of this dynamic on the economy in general over the past few years and into the 21st century, and business practice in particular, has been tremendous. Changes are happening extremely fast and the scope is breathtaking! Internet e-commerce technology tools have forced companies to redefine their business models so as to improve the extended enterprise performance linking e-commerce with distributed development, which is properly called e-business. The focus has been on improving the extended enterprise transactions including intra-organizational, B2B and B2C transactions. This shift in corporate focus has allowed a number of companies to introduce a new *supply chain paradigm* using e-commerce tools as enabling technologies in developing new business models. For instance, the Direct-Business-Model employed by industry such as Dell Computers and Amazon.com, enables customers to order products over the Internet and thus allows companies to sell their products without relying on third party distributors. Similarly, business-to-business e-commerce, which is predicted by Forester Research to skyrocket from $500 Billion in 1999 to $1.3 trillion in 2003, promises convenience and cost reduction. The Internet economy accounted for 33% of US economic growth in 1999 representing 8% of jobs.

We believe that supply chain agility is going to provide businesses with a competitive advantage compared to firms without it in the first decade of the 21st century. We also envision an increase in the emphasis on managing the linkage between global product platform development and global supply chain issues, wherein the customer is involved during development, delivery, usage, and disposal (cradle to grave). The supply chain strategy for firms will comprise a seamless integration of the knowledge chain strategy that involves deployment of virtual processes and resources that is information technology driven and the supply chain strategy, which involves deployment of physical processes and resources. In parallel, the Internet and the emerging e-business models have produced expectations that many supply chain problems will be resolved by virtue of these new technology and business models. E-Business strategies were supposed to reduce cost, increase service level, increase flexibility and of course profits sometime in the future. However, the reality has not been as kind to these hopes as many of the new E-businesses have begun to flounder or, at best, not reach their full potential. In many cases the downfall of some of the latest high profile Internet businesses has been attributed to poor business strategy planning.

One of the most profound impacts of e-business technology has been the facilitation of the virtual enterprise. The Internet and e-business technologies have enabled profound changes in how products and services are created and delivered to customers. Many of the "new" decisions faced by firms are fundamentally the same as pre-"e" decisions. For example, improved information processing capabilities can reduce replenishment lead times resulting in a shift of the cost versus service tradeoff curve. While it is clear that e-business capabilities are responsible for the shifting curve, the fundamental decision is still choosing the appropriate point on the curve. This is not to say that e-business has not radically changed many business decisions by enabling new kinds of solutions. It has! One of the most profound impacts of e-business technologies is the facilitation of the "virtual" organization. That is, software and information infrastructure, which permits many, firms to be efficiently and tightly linked.

In summary, to compete successfully in the global market, companies need to re-examine the strength and weakness of their operations and restructure their business objectives to adapt to the changing environment in the trading marketplace. E-commerce, supply chain, distributed engineering and e-business strategies are critical in support of a viable strategic tactical and operational plan. To gain a competitive edge, many companies may need to outsource a part of their operations and integrate their trading partners in supply- and selling-chains to create a virtual enterprise for delivering customer specified products and services with high quality, fast speed and low cost. Facing these demands, product and service innovation and time to market are crucial. In both a traditional company and virtual enterprise operations, it is critical to integrate information from various business components for identifying business opportunities and for efficiently managing a companies resources to gain market share using e-commerce, supply chain management, collaborative/distributed engineering, outsourcing and other critical strategies.

Team Integrated-Electronic Response (TIGER) Project

DARPA-sponsored a collaborative engineering project denoted TIGER. (Team Integrated Electronic Response) which demonstrates advanced engineering collaboration between primes and suppliers using standards-based design and manufacturing tools. This $1.4M program was carried out from 1995 - 1998 under funding from DARPA BAA 95-23. In the TIGER scenario a large manufacturer provides its suppliers early printed wiring assembly/board (PWA/B) design information in a standard STEP format (AP210). Suppliers use the TIGER toolset via an Internet-based engineering bureau to supplement this information with their process expertise. Descriptions of their manufacturing capabilities are represented using STEP

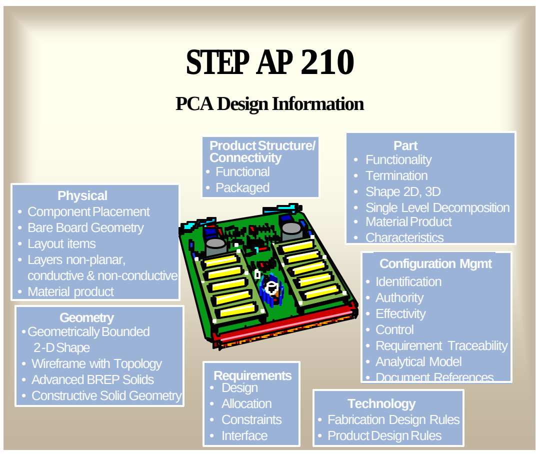

Figure 1

AP220 (figure 1). They then perform a variety of process-specific design checks, including design-for-manufacturability (DFM) and thermomechanical analyses. As members of the product team, supplier's feedback structured design improvement suggestions via a Negotiation Facility. The TIGER scenario was tested with Boeing and Holaday Circuits as a representative prime and supplier, respectively. Other team members were Arthur D. Little, Atlanta Electronic Commerce Resource Center, Georgia Tech, International TechneGroup Inc., and SCRA (the project management lead)(figure 2).

Experiences indicate TIGER leverages the expertise of suppliers to provide certain design checks that are more precise than those typically done by primes. The Internet-based engineering bureau offers these checks to suppliers on a cost-effective basis ranging from self-service (for highly automated product-data driven routine analyses) to full-service (for challenging new analyses). This paradigm provides suppliers advanced capabilities without requiring expensive in-house tools and expertise. Other accomplishments include the world's first usage of the STEP draft standard for PWA/Bs (AP210 DIS) to drive DFM and finite element analyses - all using live data that originates in the Mentor Graphics circuit board layout tool. Overall, the advantage of TIGER techniques is the effective inclusion of suppliers in the product team, resulting in cost-saving design improvements and reductions in design iterations from days to hours.

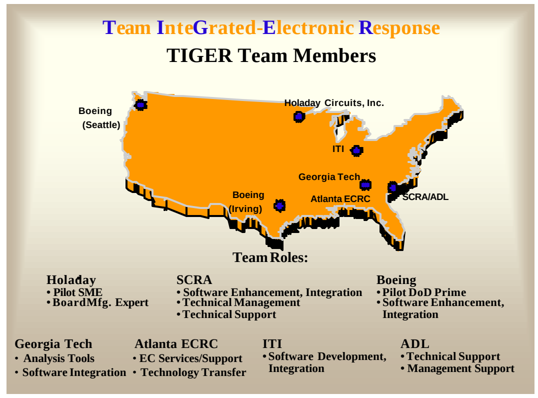

Figure 2

Some observations from the study were: (1) that the supplier was often able to participate in the total design if given the opportunity, (2) that the prime had downloaded to the SME key decisions that could affect the reliability of the total system, (3) that suppliers would like to do analyses of their components if give the tools and access to system design definition.

Product Data Modeling Fosters Collaborative Engineering

With rapid advances in material development, manufacturing processes, computational resources, and information technology, it is becoming less common for a single company to do everything from conceptual design through detailed design, analysis, manufacture, assembly, testing and qualification. Increasingly distributed collaborative multi-disciplinary teams, geographically dispersed and located in different enterprises, and work together in building components and assemblies. Such a multi-site, multi-disciplinary approach to product development is found to be efficient, cost-competitive, and strategic in industry sectors such as microelectronic, automotive, aerospace, consumer, and military. The Boeing Commercial

Airplane Group made headlines and history by designing and developing the 777 model aircraft from concept to reality in a virtual environment using CAD/CAE/CAM tools. The backbone of this project was a Product Data Management (PDM) system that enabled engineers to track the mountain of information and millions of parts. Not only can Boeing realize the effects of making a design change in a matter of hours (reduced from months), they can also respond faster to customers requests for changes in airplane features and functions. Our purpose at the university level is to prepare students to enter the commercial arena by emulating and improving upon industry practices.

Background

The ME 4041 course (Interactive Computer Graphics and Computer-Aided Design) at Georgia Tech is targeted at junior and senior level students of the George W. School of Mechanical Engineering. The objective of this course is to provide hands-on exposure to computer-based modeling, design, and analysis techniques in addition to theoretical formulations. Three hours of lectures every week introduce them to the principles of geometric modeling and the finite element method. Two hours of weekly laboratory gives them practical applications using the I-DEAS Master Series suite of CAD/CAE/CAM tools by Structural Dynamics Corporation (SDRC) of Milford, Ohio. The students demonstrate their learning with a group design project involving CAD and CAE applications in thermal and mechanical design.

Computing environment

Two strengths of I-DEAS Master Series 7 make it well suited for this project. First is its cross platform ability. I-DEAS runs on many flavors of UNIX and Windows NT. Second, I-DEAS features a centralized relational database system called the Team Data Manager (TDM) that provides a mechanism of centrally locating design data with extensive capabilities for storage and retrieval of design documents, check-in/check-out, assembly modeling, and data exchange with others. SDRC also released a Student Edition of I-DEAS, which is bi-compatible with the commercial version run in the labs.

We setup the I-DEAS Team database and files on a SUN workstation in the A. French building of the College of Engineering. The I-DEAS executable files are loaded locally on (figure 3):

- 16 PCs in the MRDC building of the School of Mechanical Engineering running Windows NT
- 16 SGI workstations in the A. French building running UNIX.
- 25 SUN workstations in the A. French building running UNIX

All of these facilities, including the student dormitories located on the west campus and the GT Motorsports (GTMS) labs, are connected via a T1 ethernet network. When a student logs into a workstation, the I-DEAS Team directory is automatically network mounted to their computer. By storing part models in the library (the I-DEAS Team directory), the students have access to them from any computer on campus. I-DEAS TDM handles the data, the data conversion processes (from UNIX to NT and vice-versa) and file locking. As students build parts, others can conduct the assembly process and other tasks (e.g. finite element analysis) working on referenced parts with read-only privileges.

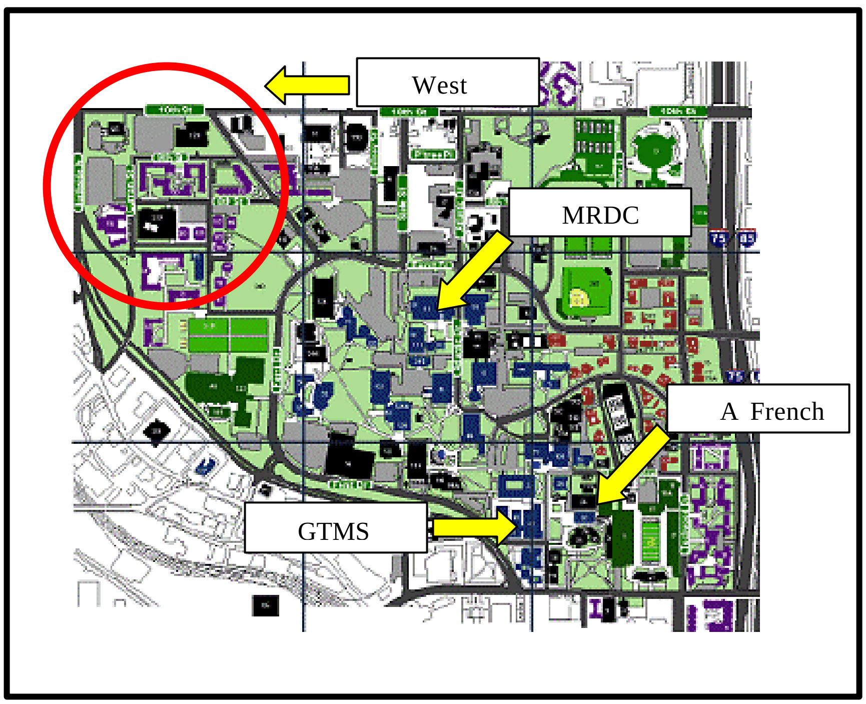

Figure 3

Collaboration: Computer project

In the fall 2000 semester, 8 students formed groups of twos to design a computer. Two groups were given the task of designing and building the chassis of the computer. One group was assigned to build the motherboard and the other group was assigned to build internal peripheral drives. At the initial meeting, the groups decided on the interfaces and standards that all must adhere to (Figure 4):

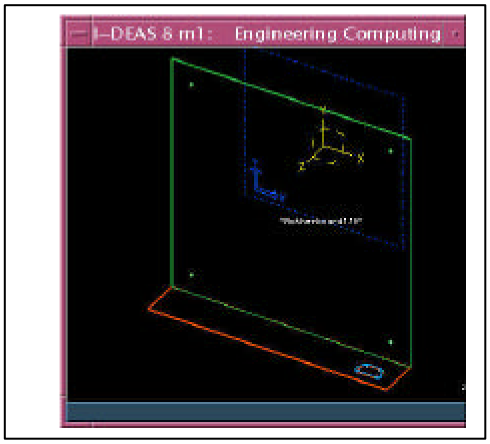

Figure 4

- Only 0.125 inch diameter screws are to be used.
- Motherboard
  Integrated motherboard must contain I/O ports and sockets (utilize technology similar to ZIF [zero insertion force] sockets) for:
  - Video
  - CPU
  - Memory
  - Sound
  - Network (Ethernet/COAX Cable/Modem/etc.)
  - Utility (SCSI/Firewire/USB/etc.)
  - Mouse
  - Keyboard

  Motherboard must also have connectors for peripherals and power. Motherboard should fit in 1' x 1' x 2in volume with one face (1' x 2in) exposed for i/o ports.
- Chassis
  Chassis can be made of any material and must house motherboard and 3 peripherals. Motherboard must be bolted by 4 screws with one face (1' x 2in) exposed for i/o ports. Peripherals must be bolted by 4 screws with one face (1-1/2 x 5-1/4 inch) exposed for I/O. Power supply is integral to chassis.
- Peripherals
  Design 3 storage devices that fit internal to the computer. Devices must fit in 1-1/2 x 7-3/4 x 5-1/4 inch volume.

From these directives, the motherboard group built a rectangular object, inserted the 4 holes and checked it into the I-DEAS team library. The chassis teams could then reference the motherboard and build around it. As the motherboard team made changes to the motherboard, the other teams were alerted and could choose to update their referenced copy as needed. The same procedure occurred for the peripheral team. Communication was accomplished via emails and the once a week laboratory sessions (figure 5). A static webpage was created and pertinent information was posted as necessary.

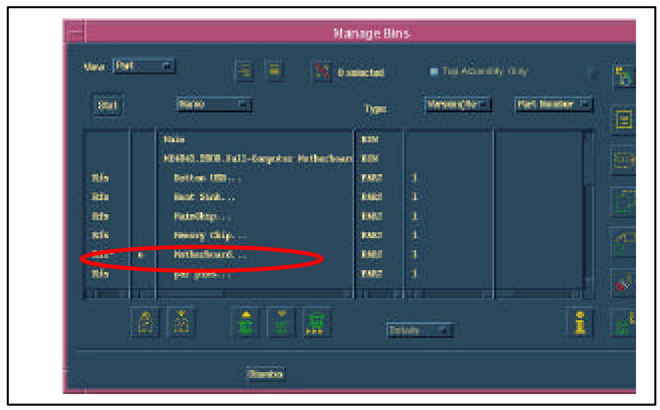

Figure 5

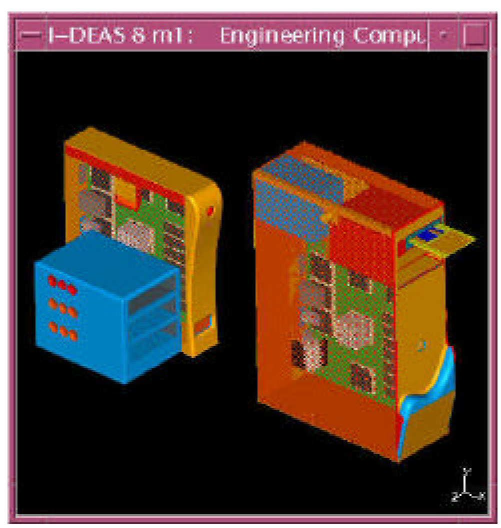

Figure 6

Result was two computers using the same motherboard and internal drives (Figure 6). More on this project can be reviewed on the web at http://www.cad.gatech.edu/courses/me4041/2000/fall

Collaboration: Formula SAE project

The Formula SAE project was a far more ambitious project conducted in the summer of 2000 with 18 student groups. The goal was to virtually design and build a mini-Formula SAE car. Groups were formed and the project was divided into the following subsystems (Figure 7):

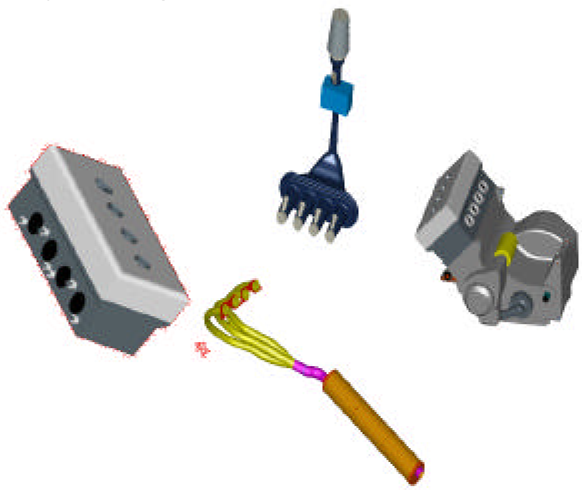

Figure 7

- Engine
- Intake system
- Exhaust system
- Chassis
- Front suspension
- Front brakes
- Rear suspension
- Drivetrain
- Steering and pedals

At the initial meeting, the interfaces between each group were decided. These were items such as; where boltholes were located and which groups were dependent on others for dimensions. For example, the engine team immediately built a block to represent the engine head. The Intake and Chassis team referenced this part from the library to build their components. As the engine team put more detail on the head, the other teams could update their referenced part to get the lasted modifications.

A parts numbering schema was created to keep track of the numerous parts involved. This was especially useful to distinguish between parts and assemblies and to determine what is the top-level assembly. A static webpage was created and pertinent information was posted as necessary.

Although the designs were based on an actual physical car, the car was in England for a month forcing the students to rely on photographs, spare parts, non I-DEAS CAD drawings/models and dimensions received other team members (Figure 8).

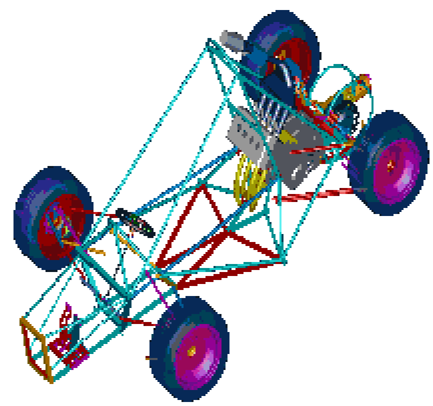

Figure 8

Results of this project can be reviewed on the web at http://www.cad.gatech.edu/courses/me4041/2000/summer

Enhancement Plans

The past concurrent engineering activities with ME4041 involve very limited distributed engineering. All students involved in the projects were located on the campus of Georgia Tech. The distributed aspect of the project involved linking multiple labs and student PCs in campus dormitories. Students met face-to-face at least once a week in facilitated meeting that gave them the opportunity to discuss their issues and concerns.

The next phase of this project is to conduct a true distributed collaborative engineering initiative involving students from Georgia Tech and Kettering University in Michigan showcasing the next release of I-DEAS. Dubbed “Meta-I-DEAS”, TDM (which was design for engineers on a local area network) will be replaced with subsets of Metaphase, SDRC’s Product Information Management tool. We will also enhance the collaborative environment using web-based video and audio conference tools. The proposed curriculum development aims to simulate the geographical dispersion of teams through collaboration both on campus and with other universities and programs.

Concluding Remarks

The above examples indicate that future concurrent engineering design of major projects will be carried out by remotely located teams composed of primes, partners and suppliers linked electronically with the latest electronic commerce tools. They will have to meet both the contractual and technical needs of the projects in rapid response through electronic commerce paradigms. Both contractual and technical information will have to flow freely in real time to reduce the total time to design and produce the products. The process must reduce both the time to carry out contractual actions as well as the time to design such products. In fact there will have to be better ways to exchange preliminary technical information that conforms to acceptable contractual procedures.

Some issues that must be addressed by future engineering research and education include, but are not limited to, the following:

1. Create strategies for defining and developing products at the early stages of design sufficient to support real time exchange of its evolving definition among all partners in the development
2. Create ways to manage and define subsystems and components of a product such that the subsystems and component can be designed concurrently with free exchange among team members as the product and process evolve
3. Develop methods to better understand how to address critical total system reliability and performance issues that now are often unwittingly off loaded to small suppliers who have little or no appreciation for how their design decisions can impact overall system reliability
4. Create new product data modeling methods and concurrent engineering procedures which are targeted to support concurrent engineering paradigms in a distributed e-commerce based environment
5. Create new and more user friendly ways to better link engineering analysis and design to facilitate rapid design decisions among geographically dispersed team members
6. Provide convenient and inexpensive tools to allow SMEs to use e-commerce as part of their standard operation
7. Provide an extensive suite of user-friendly tools to small and medium minority enterprises (SMEs) that allow such firms to participate with primes as full partners in the design. Of particular interest is the availability of user friendly tools to analyze and/or design their respective supply items within the context of the overall system definition
8. Advance international information modeling standards such as STEP (Standard for Exchange of Product) data models to include the ability to link a large suite of engineering analysis procedures to product data models and to allow product definition to grow and evolve as the design matures
9. Expand and/or restructure engineering computer aided analysis and design courses in colleges to include significant data modeling and exchange and partnering among design teams that are geographically dispersed
10. Incorporate product data management tools into undergraduate and graduate design courses to provide the types of experiences to be faced in engineering practices in industry
11. Provide convenient and inexpensive tools to allow SMEs to use e-commerce as part of their standard operation
12. Expand engineering undergraduate and graduate programs to encourage more in-depth knowledge of information technology through certificates, minors or other mechanisms

Summary

In summary, the rapid growth of e-commerce technology together with the trends in product development for expanded outsourcing to suppliers place significant challenges on the research and education of engineers. This paper has outlined some of the facets of a future distributed concurrent engineering environment and illustrated some of the issues that must be addressed to cope with this future. In particular the paper describes several efforts that need to be initiated in research and education to support a future of distributed concurrent engineering.

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