APPROACHES TO BRINGING INFORMATION TECHNOLOGY TO SMALL BUSINESS APPLICATIONS

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ABSTRACT

The development of major engineering products such as automobiles, aircraft, computer and energy systems involves not only large highly visible developers but also an array of small businesses to carry out their specific tasks. These small businesses may be responsible for over 50% of the design/manufacturing effort. The large developers are moving rapidly toward the use of information technology to improve productivity, but the small businesses often lag behind. ARPA has established a network of eleven Electronic Commerce Resource Centers (ECRCs) specifically tailored to help small and medium sized enterprises (SMEs) use information technology to integrate with major developers. This integration can lead to major advancements in concurrent engineering, distributed databases, design for manufacturing, product data modeling and linking business and technical data. This paper reports on a study of some of the new research issues that result from the use of information technology by SMEs, and approaches to addressing those issues.

INTRODUCTION

Today's industrial complex is characterized by a multitude of conflicting demands: smaller lot sizes, increased product flexibility, higher product quality and shorter delivery times. Even in traditionally mass production industries such as the automobile industry, manufacturers are tailoring cars to diverse customer preferences. A variety of makes, models, colors, engines and options are available. To compete successfully in such an environment, industries have to respond efficiently to the rapidly changing demands of consumers by producing high quality products in the shortest possible time at competitive prices.

It has been estimated that 20% - 30% of total product cost comes from repetitive inputting of information and 75% of all computer entry comes from other computers. On an average, there are 14 information exchanges per shipment, most of which are through the postal system. RJR Nabisco estimates that using the current paradigm, the cost of processing a purchase order is $70. Through the use of information technologies such as Electronic Data Interchange (EDI), the cost is reduced to a mere 93 cents [ECRC National Program Brochure, 1995]. Thus, the key to success in today's market is the effective harnessing of information technologies, i.e., a move towards Electronic Commerce (EC). This is particularly true for the engineering industry which deals with large quantities of digital data.

Engineering products such as automobiles, aircraft and computers consist of many subsystems, each subsystem consisting of many parts. Often, smaller and more specialized engineering firms are involved in the design and manufacture of the individual parts. For instance, in the automobile industry, the frame, the chassis, the trim, the doors, etc., are all obtained from specialized parts manufacturers and assembled at the various automobile plants. Over the past few years, downsizing and streamlining by the large manufacturers has resulted in shifting of even more of the work to the specialized small and medium sized enterprises (SMEs). Currently over 50% of the design/manufacturing effort occurs in the SMEs.

The major engineering product developers are rapidly moving towards the use of state-of-the-art EC technologies to achieve the desired QR (Quick Response) capability, flexibility and enterprise integration. This requires perfect coordination between not only all the internal organizations of the large developer, but also with the SMEs. Total enterprise integration necessitates that the relationship between the large organizations and the SMEs be such that they are nominally independent but are working as though they are part of the same company. However, due to limited finances and resources, the SMEs lag behind in implementation of the required technologies and are often the weakest link in the chain.

To help promote awareness and implementation of EC and related technologies into the civil-military industrial base, Advanced Research Projects Agency (ARPA) has established a network of eleven Electronic Commerce Resource Centers (ECRCs). The ECRCs are specifically tailored to help SMEs use information technology and integrate with major product developers.

We begin this paper with a discussion on EC, its components and its future. We then discuss the role of the ECRCs and the approaches used to usher the SMEs into the age of EC, thus integrating them with the major developers. The current paradigm for development of major engineering products and its problems are discussed. We then present the EC-based paradigm associated with integration of SMEs with the major product developers. The paper concludes with a report on some of the new research issues that result from integration and use of information technology by the SME's, and approaches to addressing those issues.

ELECTRONIC COMMERCE

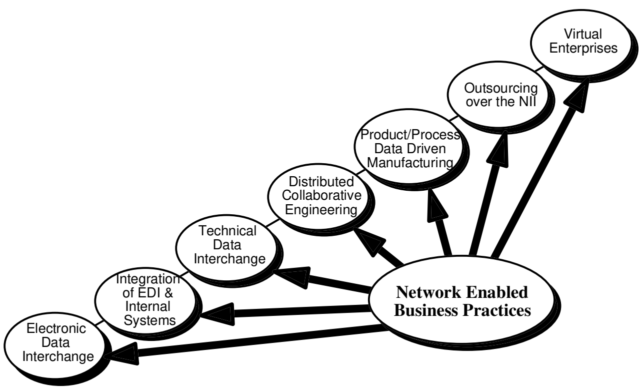

FIGURE 1. The Electronic Commerce Technology Ladder

Electronic Commerce (EC) is a broad term describing business activities with associated business and technical data that are conducted electronically. Through the use of computer technology and standards, information and activities can be taken care of remotely, automatically, and electronically. The essence of EC is data survivability, which is the concept of having data created, modified, and saved in such a way that it can be used throughout the life cycle of a manufactured product. The concept of data created once and used many times epitomizes EC. The goal of EC is to mold the vast network of SMEs, government agencies, large corporations, and independent contractors into a single community with the ability to communicate and work with one another seamlessly across any computer platform [ECRC National Program Brochure, 1995].

EC leads to the following benefits: increased sales, reduced costs, reduced errors, improved customer relations, improved document processing, reduced order cycle, reduced manufacturing time, reduced inventories and improved manufacturing. Outstanding EC success stories already exist. Operation Desert Storm found the benefits of EC when its parts backlog was reduced from 24 months to 2 weeks. The shipbuilding industry also experienced success using EC when the USS Theodore Roosevelt was completed 17 months ahead of schedule and $80 million under budget [ECRC Training Text, 1995a]. It is no wonder that all the major industries are rapidly embracing EC technologies and forcing their trading partners to follow suit.

The EC technology spectrum (Figure 1) [SOL BAA 95-23, 1995] encompasses a wide variety of concepts and technologies with EDI at the lower end of the ladder to virtual enterprises at the higher end. As a company progresses up this ladder, it becomes more integrated within and with its trading partners. All the major product developers are currently practicing EC to some extent or the other. The important point to note is that all of them, without exception, are implementing programs to move up the EC ladder while a majority of their trading partners, the SMEs, are struggling to catch up. Let us now examine each rung of the EC technology ladder in turn.

EDI

EDI is described as the application to application transmission of business documents in a standard format. The traditional paradigm for exchange of business documents, say a Purchase Order (PO), involves printing the PO from the computer system of the major manufacturer, mailing the paper copy of the PO, handling at the SME, and re-entry into the SME's computer system. This process takes a few days at the very least. The EDI paradigm consists of sending the PO in a standard EDI format (such as the X12 or the UN/EDIFACT standard) through a VAN[1] to the SME, a process that takes a few minutes. Due to its obvious advantages, almost all the major corporations have chosen EDI as a fast, inexpensive, and safe method of sending purchase orders, invoices, shipping notices, and other frequently used business documents.

EDI has been used by large corporations like Motorola and Apple Computers since the early 70's. However, it is over the past couple of years that there has been a sharp increase in the EDI growth rate. This can be attributed to increased pressure from large corporations, availability of low cost hardware, software and VANs, and maturing of EDI standards. To be globally competitive, it is projected that 50 % of all U.S. companies need to be EDI capable by the year 2000 AD. Realizing the potential of EDI, Congress passed the Federal Acquisition Streamlining Act of 1994 (FASA) which is designed to simplify and streamline the Federal procurement process. FASA establishes the Federal Acquisition Network (FACNET) requiring the government to evolve its acquisition process from one driven by paperwork into an expedited process based on EDI. Therefore, SMEs are currently facing pressure to be EDI capable from the government as well [ECRC Training Text, 1995a].

[1] VANs (Value Added Networks) are digital repositories whose primary purpose is to store EDI documents for companies in electronic mailboxes for future retrieval by the concerned trading partners.

Integration Of EDI With Internal Systems

Despite the obvious advantages of EDI, it's full potential can only be realized by integrating EDI and the internal computer systems of the company. It is this integration that poses significant challenges to the SME community because, not only does it involve restructuring of the company's computer applications systems in which the core business procedures and supporting software are reworked, but also requires changes in internal business practices. Because this kind of integration affects almost all the internal systems and personnel of the company, it requires cultural changes and a strong commitment from all levels of management in order to succeed. While basic EDI capability costs very little and can be obtained in a few days, complete integration of EDI with internal systems requires significant investments in time and money. In an EDI integrated organization, incoming orders are received electronically and the information goes not only to production, but to the other subdivisions such as shipping, billing, and inventory systems, automatically, without any human intervention [ECRC National Program Brochure, 1995].

Technical Data Interchange

While EDI is used for the transfer of business documents, CALS (Continuous Acquisition and Life-cycle Support), is used primarily for the exchange of technical data. CALS can be defined as an industry and government strategy intended to enable more effective generation, exchange, management and use of digital data supporting the life cycle of a product, through the use of international standards, business process change, and advanced technology application. Though CALS was initially intended to support the DoD, today its principles are applicable to all enterprises that make, distribute, or support a product.

One component of CALS defines standards for exchange of the various types of technical data: IGES (Initial Graphic Exchange Specification) format for transmitting CAD/CAM files and vector graphics, SGML (Standard Generalized Mark-up Language) for the transfer of technical manuals, CGM (Computer Graphics Metafile) for data files containing a mix of both text and illustrations, the STEP (Standard for the Exchange of Product Data Models) standard for developing product data models, raster data standards and the IETM (Interactive Electronic Technical Manual) standard. Although the CALS initiative has been focused towards large corporations, the growing availability of powerful, low cost PCs and PC based CAD/CAM software is bringing this technology to the SMEs as well [ECRC Training Text, 1995b].

Distributed Collaborative Engineering

Distributed collaborative engineering extends the concepts of Concurrent Engineering (CE) through the use of information technologies. CE is a systematic approach to the integrated development of a product from various related processes, e.g., issues dealing with the later stages of product development such as manufacturing and quality control are dealt with during the design phase itself. Therefore, CE requires the coordination of data and personnel from all the stages of the product life cycle. Using information technologies such as distributed databases, video conferencing systems, technical data interchange, and workflow management, the CE team can work together and make modifications to the same electronic copy of a design, even if the individual members are geographically dispersed.

Product/Process Data Driven Manufacturing

For large companies and their SME partners to be efficiently integrated and function as a single unit, technologies and standards should be available to represent product and process data in machine interpretable form which can be exchanged electronically and modified in a controlled manner by all members of the team. The product/process data driven manufacturing approach requires product and process specifications (right down to process parameters like tool selection, feed rate, manufacturing time, etc.) of each individual component of the final product to be developed through a collective effort of all the members of the team prior to manufacture. Examples of mechanisms that provide this capability is the IDEF (ICAM DEFinition) family of tools for process and data modeling and the STEP standard for representation of the developed models in a neutral format. In this paradigm, since all the data is in a standard format, the large corporations and the SMEs can simultaneously go through the iterative design process till it satisfies all the parties involved.

Outsourcing Over The National Information Infrastructure (NII)

As products and systems become more sophisticated and complex, more and more SMEs are becoming niche specialty suppliers. Larger prime contractors and higher tier subcontractors are unable to internally manufacture most of the individual components that make up the final product, at a competitive price. Also, globalization of the marketplace brought by advancements in information technologies are allowing companies to outsource to suppliers from any part of the world. Therefore, outsourcing over the NII is the wave of the future and SMEs will have to possess the capability of effectively utilizing the NII for exchanging business and technical data, or a competitive disadvantage will result.

Virtual Enterprises

Virtual enterprises are teams wherein suppliers of products and services, big and small, are linked together and develop and manufacture major engineering products. In a virtual enterprise the geographic location of a member of the enterprise is inconsequential due to complete integration provided by EC technologies. A company can be a member of several teams, even competing teams. Virtual enterprises are seen as the future of business and are the end result of effective EC.

THE ELECTRONIC COMMERCE RESOURCE CENTERS

Realizing the urgent need to address the specific needs of the SMEs, Congress established eleven regional ECRCs (Figure 2) to accelerate deployment of the latest EC technologies to the SMEs, which represent about 98% of all DoD and U.S. industry procurement transactions. The centers are funded by the DoD Advanced Projects Research Agency and the U.S. Navy Office of Naval Research. The ECRCs work closely with the DoD CALS/EDI office, the DoD Electronic Commerce in Contracting

Program and the multi-association CALS Industry Steering Group.

The mission of the ECRC Program is to promote awareness and implementation of EC and related technologies into the U.S. integrated civil-military industrial base and create a world class supplier network by linking U.S. industry to the NII. While its current focus on migrating small businesses to EDI, each of the country's eleven ECRCs can provide education and training, consultation and technical support for each rung of the EC technology ladder. Thus, they are helping to lay a solid foundation on which SMEs can build to become contributing members of future large virtual enterprises.

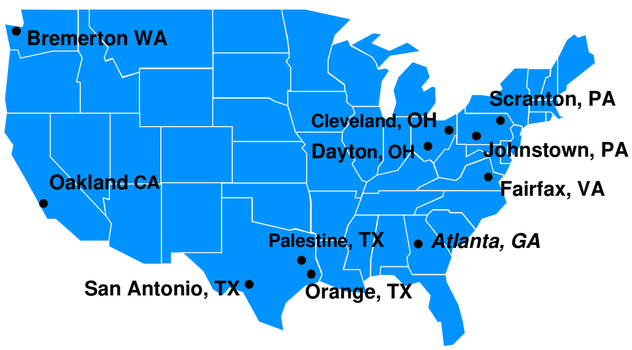

Figure 2. The Eleven Regional ECRCs

Though all the ECRCs cover the broad spectrum of EC, some have emphasis in selected areas. For example, the Atlanta ECRC emphasis is in engineering product and process data exchange and CALS standards. It has a vast experience base in IGES based exchange of 3-D product data between CAE/CAD tools. However, all the ECRCs are linked together as a cooperative enterprise that allows the expertise at any center to be called on as needed by any other center. Collectively, the ECRC network provides nation-wide services. An ECRC Technology Hub in Johnstown, PA monitors rapidly changing technology, keeps the other ECRCs informed on the changes, coordinates regional ECRC projects and provides access to the results for the civil-military industrial base [ARPA Press Release, 1994].

The ECRC Approach To Bring Information Technology To SMEs

The ECRCs use a three pronged approach to help customers, as shown in Figure 3. Customers, though primarily SMEs, include government prime contractors, government agencies involved in acquisition, educational institutions and manufacturing extension providers such as SBDCs (Small Business Development Centers) and PTACs (Procurement Technical Assistance Centers). The customer presents problems to the ECRC through Outreach or Education & Training activities. These activities may lead to assistance from ECRC teams in the form of Consultation and Technical Support. These teams then give the customer the knowledge and skills to insert the technologies into their businesses.

Outreach provides the initial contacts with SMEs and results in customer awareness of the potential of EC. It is intended to lead to Consultation and Technical Support.

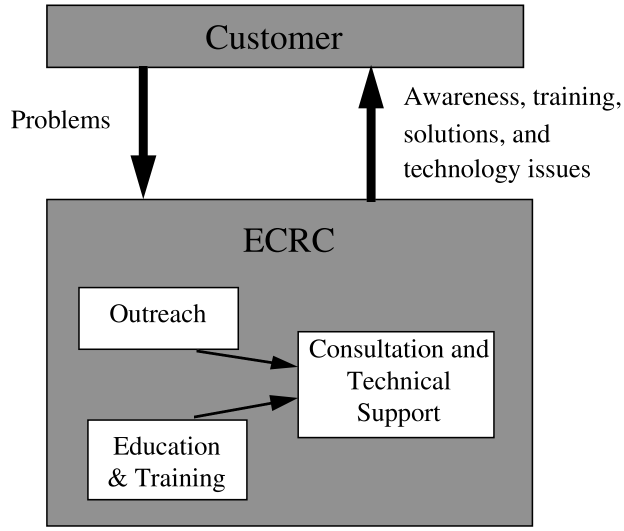

Figure 3. Regional ECRC Activities

Education & Training provides free or low cost training courses to SMEs wanting to learn more about information technologies. This also leads to Consultation and Technical Support. All the ECRCs provide a wide range of courses that cover all aspects of EC. Some of the courses currently offered are:
- CALS Orientation
- EDI Orientation
- Issues in EDI Implementation
- Technical Data Exchange
- The CALS Initiative and Integrated Manufacturing
- Legacy Data Management
- Business Needs Analysis
- Concurrent Engineering
- Data in a Business Environment

Consultation and Technical Support start with analyses to develop a baseline understanding of a company's needs and operations, and to identify problems that can be resolved by EC technologies. After a baseline is defined, a list of candidate technical support projects and recommendations are presented. Once the consultation leader recommends a company to receive technical support, a consultation team conducts a detailed analysis of viability. This is critical, as technical support activities may include substantial in-plant effort by an ECRC team. If technical support is warranted, the technical support team develops a detailed list of solutions and an application plan for the company.

Thus, the ECRCs provide technical assistance and furnish technology-based training on EC at little or no cost to U.S. manufacturers, helping them maintain a more competitive posture in the global marketplace. The ECRC support is especially beneficial to the SMEs who have limited finances and resources and find it a gargantuan task to climb the EC technology ladder by themselves [ARPA Press Release, 1994].

RESEARCH ISSUES THAT RESULT FROM SME'S USE OF ELECTRONIC COMMERCE

Figure 4 shows the paradigm currently used for the development of major engineering products. The product development process begins with the customer submitting a set of product requirements to a major product developer. In cases such as the auto industry, the product requirements are generated by the auto manufacturer based on inputs from the end users (i.e. car buyers), market trends, etc. This major product developer called the Prime, is typically a large corporation with a turnover of greater than $2 billion per annum. The Prime is responsible for the overall design and integration of the product and bears ultimate responsibility for satisfying customer requirements. The Prime may also manufacture selected components in the product.

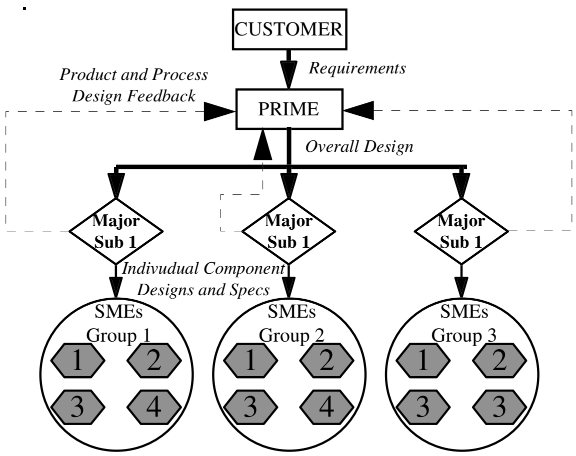

Figure 4. Product Development-The Current Paradigm

The Prime subcontracts the major subsytems of the product to smaller corporations (turnover of around $500 million per annum) called the Subs. Typically, each Sub is responsible for one large subsystem of the end product and obtains the initial design and specifications of the subsystem from the Prime. The individual components of each system are manufactured by specialty SMEs, a majority of which are shops with 10-50 employees and a turnover of less than $1 million. Even though nominal design is performed by the SMEs, in a majority of cases, the job of the SME is solely to manufacture its subcontracted component according to specifications.

In this current operating paradigm the center of gravity of design activity is the Prime, with limited feedback from the Subs (depicted by broken lines in Figure 4). In the recent past, Primes have been implementing programs to integrate product development with the Subs. However the SMEs are still very much out of the development loop. There is negligible design feedback from the SMEs to the Subs and the Prime. The key point to note in the current paradigm is the conspicuous lack of flow of product and process data from the SMEs to the higher levels.

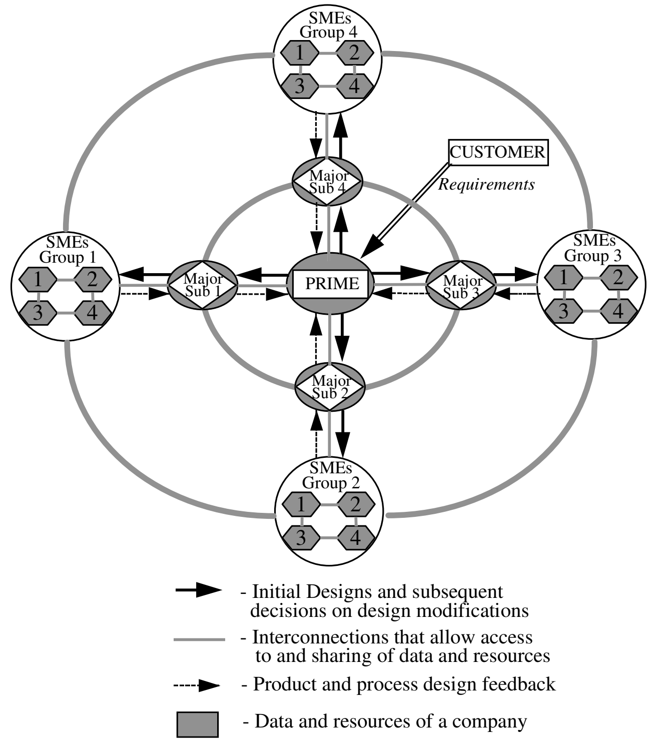

Figure 5. The EC Paradigm for Product Development

The current paradigm poses significant problems in the manufacturing stages of the product. Even though more than 50% of the manufacturing is done by the SMEs, they have no control over individual component design due to lack of effective feedback mechanisms to the Subs and the Prime. Even if some feedback does occur, it is normally too late to make design changes. Due to lack of integration of the SMEs into the development team, the specialty expertise of the SMEs is not exploited. Proper utilization of the specialty expertise of the SMEs could result in significant reduction in development time and costs. In some cases the component requirement and specifications might not even be reasonable, i.e., the SME might not be able to produce the parts on schedule due to design complications and/or production limitations that are recognized only by the SME. Situations also exist wherein the SME recognizes flaws in the design that can be rectified, but is not done due to inaccessibility of key tools and data by the SME. Another big problem in this environment is the absence of R&D (Research and Development) capability in the SME community. Even though they may possess the expertise to perform the R&D for their subcontracted components, they lack adequate tools and finances to do so.

The EC approach recognizes the inherent limitations of the current paradigm and focuses on integrating the SMEs into all stages of product development. Figure 5 shows the EC-based product development process in which all the companies involved (the Prime, the Subs and the SMEs) work as a team to develop the final product. This is possible due to the feedback and communication channels created by EC technologies such as EDI and technical data interchange. The dark arrows in the figure depict the flow of design decisions from the larger members of the team to their smaller counterparts while the dotted arrows represent the flow of information in the opposite direction. The EC paradigm is geared toward empowering the smaller companies in a corporate environment and allows the Prime to make use of the SME capabilities more effectively. This is made possible by providing the smaller companies with access to critical product, process, planning and tooling data early in the development cycle (shown by gray lines in Figure 5). The paradigm also provides the SMEs access to design and analysis tools to perform their R&D.

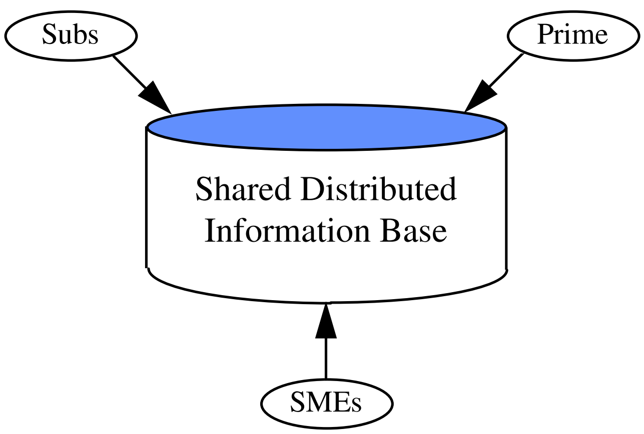

Figure 6. End Result Of Effective Integration Using EC

Cross communication channels between the SMEs of the same group is required to understand the implications of design modifications by an individual member of the group. Similarly communication between groups is also required. The communication channels provided by the EC paradigm also enables the SMEs to understand the impact of their suggested design modifications on the overall quality of the final product. Hence, concurrent engineering is possible in its purest form and QFD (Quality Function Deployment) techniques will be extremely effective in improving product quality. The end result of effective integration using EC is shown in Figure 6. Each product development member (Prime, Subs or SMEs) will, have access to the subset of information and tools it requires from the same product information base, even though the data itself is distributed.

One of the basic problems of the EC approach is the lack of advanced information technology skills at the SME. While the Prime and the Sub possess an array of programmers and information technology specialists, the trade school type skills normally possessed by the SMEs prove to be inadequate. Therefore, the integration of SMEs into the corporate world raises significant research issues in information technology that needs to be addressed for this paradigm to succeed. Some of the relevant research issues are as follows:

- User interface design for databases, communication software and analysis tools, needs to be researched keeping the trade school type skills of the SME personnel in mind. Effective use of multimedia approaches have a high potential to solve this problem
- Robust, low cost, high speed networks need to be developed for this intricately networked environment. The speed issue is particularly important because technical data is typically voluminous, e.g., the surface model of a medium complexity part could be up to 50 megabytes. Therefore, the current modem-based technologies used by SMEs might be inadequate. More efficient data compression algorithms also need to be developed.
- The EC paradigm necessitates the access of critical process, product, planning and tooling data by the SMEs. But, how does one partition all the data in the distributed environment such that each SME has access only to that subset of the data that it requires? Significant advances in distributed databases are required to solve this complex problem.
- Research also needs to be conducted in security issues in a networked environment. This is particularly relevant to DoD projects wherein all the partners may have access to databases containing classified or competition sensitive data.
- Research efforts are also required in the Standards arena. Even though there has been a lot of activity in this area over the past decade, all the data associated with design, analysis and product development cannot be adequately represented using the current standards. Standards are particularly important considering the transmission of extensive technical data in the EC environment. Globally accepted standards along with low cost mechanisms and software for implementing those standards need to be developed.
- The ability to link business and technical data is a must for a networked business environment. An example of this concept is the 841 transaction set of the X-12 standard. Using this transaction set, technical data such as CAD models can be sent over a network to a trading partner as an EDI transaction. However, this area is still in its infancy and needs to be researched.
- An important difference between SMEs and the larger corporations lies in the type of computer platforms used. While the larger corporations perform their design and development mostly on UNIX-based workstations, the SMEs primarily use PCs for their business operations. Therefore, issues relating to transfer of business data with associated technical data between the two platforms need to be investigated. In particular, effective mechanisms need to be developed for transmission and use of STEP data linked with EDI in a PC/UNIX Workstation network.

All the above issues are currently being researched to some extent or the other in the corporate world and academia. The key point being made is that the research efforts need to acquire a new flavor keeping the integration of the SMEs in mind. Such research will lead to a new generation of hardware, software and communication networks that will facilitate the success of the EC paradigm.

CONCLUDING REMARKS

Advances in information technologies are ensuring that EC is the wave of the future. SMEs will have to posses the capability to integrate with larger companies and participate in virtual enterprises. Initiatives such as CALS need to be pursued at the national level and more organizations such as the ECRC are needed to provide help to SMEs and usher them into the age of EC. To succeed, the SMEs will have to rethink and reengineer their business practices to facilitate integration with information technologies. As suggested in this paper, significant research efforts are also required in areas such as distributed databases, user interface design, product data modeling and networking. These research efforts need to be directed towards facilitating integration of the SMEs with their trading partners.

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