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COMPUTER AIDED ENGINEERING (CAE) OVERVIEW

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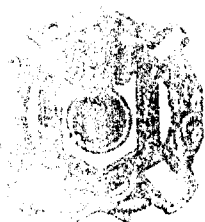
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13. ABSTRACT (Maximum 200 words) Computer aided engineering (CAE) refers to a collection of software and hardware tools integrated into a system (a computer) that is providing the circuit designer and circuit troubleshooter with step-by-step assistance during each phase of the design and analysis cycle, as well as during development, documentation, and maintenance. Under the CAE umbrella a number of commonly called "automated design tools," which are the software components of CAE, are revolutionizing and transforming engineering environments from the "hands-on" way of conducting business into a virtual or simulated "hands-on" mode of operating; and are having a tremendous impact throughout all engineering disciplines. They have not yet displaced breadboarding and other methods of developing circuit boards yet but are making their presence known to the point of being totally necessary in the design of certain devices. It is the intention of this report to promote the use of these tools in the government by providing engineering management with an overview of the hardware and software products available for electronic simulation, while covering trends, new technologies, and costs.				
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INTRODUCTION

In Computer Aided Engineering's (CAE) earlier days, only selected organizations in large companies and government could afford the systems required to automate, design, and/or manufacture an end-item. The majority of midsize and small organizations were shut out from taking advantage of technologies because of exorbitant costs and lack of qualified personnel to help them undertake such transition. Breakthroughs in integrated circuit (IC) technology and programming have now opened up the doors of CAE to more modest companies and applications, even to one-man firms and hobby electronics enthusiasts.

CAE At Work

At work, the simulation of an electronic circuit in a CAE system begins with the schematic capture of a circuit, where a complete description of the circuit in computer language is created (often times called a "net-list"), which is the data used to analyze, troubleshoot, and print or plot the results.

Schematic Capture

Working in 2-D, designers create circuits using lines and component models. Rather than redraw a component, a circuit or a section of circuitry used in other areas can easily be duplicated using the copy and grouping function.

When a CAE package is integrated in an environment where parameters and blueprints are constantly changing to reflect new product capabilities and improvements, modifications are quickly made without having to recreate the entire drawing.

These and other techniques accelerate the analysis of any design which could include a large number of subassemblies. The experience in many companies is that productivity had doubled since the systems were installed (ref 1). In the past, engineers worked with huge drawings that made the analysis of a particular circuit area very cumbersome.

Electronic Design and Analysis

Design engineers using a CAE or a computer aided design (CAD) system don't have to depend on a drafting technician to present a layout of the most current design, since the data base is automatically updated every time a circuit modification is performed.

Applications ranging from 10 to 100, to 1000 transistor boards can be simulated in a CAE system for a personal computer (PC), where the number of transistors that can be handled is constantly increasing as prices of more powerful PC drop. The limit is 10,000 discrete transistors at a time, 1991. Although there are other discrete components that are included in analog and digital libraries, the number of transistors that an electronic software package can handle is a figure-of-merit, and is something to look at when choosing a CAE package.

Working with Simulation Packages

A simulation package can not as yet replace the engineer. It can compute the voltage, the current, and other electric parameters at virtually any point in the circuit, but it can't communicate to you exactly what to do with them or how to achieve a certain response from the circuit. A CAE package is intended as a design aid and will do only what it is asked. The right questions have to be asked before every characteristic of the circuit is known. For example, in power dissipation if you try to dissipate 2 W into an 1/8 W resistor, the simulation program probably would not raise a flag, but will give you a value if a query is made.

This example is not 100% right. As a matter of fact, a package called Smoke Alarm®¹ will now raise a flag (in the form of a puff of smoke) on the screen next to the component in trouble, to indicate that it has exceeded its ratings. Thereby simulating the actual operating constraints of the circuit.

An electronic simulation program will also warn of simple problems such as short circuits and other extraordinary conditions, that often times are the culprit in malfunctioning.

More Simulation Less Breadboarding

In a typical design cycle, breadboarding (physical wiring of a circuit in a test board) has to be kept to a minimum in order to produce a cost effective board, which in this case is the product. The optimal process is to use simulation at various times throughout the development process (trying different formats) to achieve a reliable, producible design that meets specifications. Experienced designers advise the use of some level of circuit simulation in the early design stages to learn more about the circuit before breadboarding. For the case of high bandwidth components, or high frequency, the introduction of parasitic inductance and capacitance usually requires the construction of production quality prototypes. Simulation will reduce the number of time consuming breadboarding iterations required to complete a design.

¹Cadence Design Systems, San Jose, CA.

The consensus among engineers using CAE packages is that breadboarding still gives a closer representation of the final circuit for low frequency designs, but not for high frequency designs. They also agree that simulation works well in some cases but not for others. For example, simulation for designs using complimentary metal oxide semiconductor (CMOS) provides a good correlation to the hardware, but bipolar designs do not offer such a close match.

Spice Simulation. Most analog simulators use Spice² or a derivative. The newer derivatives are constantly improving the shortcomings in equation convergence that the original had, by modifying Spice's model equations.

Spice simulates a device using both modeled equations and modeled parameters. The first describes device types and technologies [CMOS, field effect transistor, transistor, transistor logic, etc.], and are part of the simulation software and the user typically cannot modify them. The second one models specific device types within a technology (from data books e.g. S_n , i_n , β , etc.). The user can alter these.

Mixed-mode Simulation. Mixed-mode simulation (ref 2) is on the rise, with more than a few vendors now offering it.

Because even systems that are mostly digital systems have to sooner or later interface in the real world (the analog world), both analog and digital simulation capabilities are needed to simulate an entire system. It is a big plus to have the two simulation packages integrated into one, where simulation by parts is no longer the only means to accomplish a circuit simulation.

Mixed-mode simulation is especially important for circuit designs that have feedback paths linking analog and digital circuits. For example, motor or engine controls, where analog sense or drive circuits and the control equations are implemented digitally, would be difficult to simulate without mixed-signal simulation. Breaking up the analog and digital sections does not result in an effective simulation of the control loop.

Mixed-mode simulators (ref 2) typically comprise separate analog and digital simulators that run in unison. These separate simulators need the net list split into analog and digital sections before they can run the simulation. A good integration of the two simulators will handle the net list split internally. The separate analog and digital simulators operate independently except when an analog input to a digital device crosses a threshold or a digital input to an analog device changes state.

²Berkeley Spice created in May 1975 by professor L. Nagel.

Other Simulation Packages. Simulation packages dedicated to specific design specialties are becoming widely available, and should ideally be compatible with other electronic design automation (EDA) software.

Temperature-stress analysis packages are becoming popular in engineering environments because of valuable information about actual working thermal distributions. In military applications, where working temperatures are usually higher than for commercial applications, it is usually imperative to support a design with considerable analysis, and to show that the circuits will work over a range of temperatures.

EEsof and Compact Software are two simulation vendors that have developed tools dedicated to radio frequency (RF) and microwave design. These packages have extensive military applications and are capable of covering most frequency ranges.

Analogy's SABER is a simulation package that is more than just an electronic simulator because it can use both standard electronic device models and standard mathematical equations to define elements (electronic, mechanical, and chemical) of a complete system.

Monte Carlo and Sensitivity Analysis. Monte Carlo analysis has the ability to simulate process-variations (fluctuation in the manufacturing yield) effects and although an experienced designer will design a circuit to minimize these effects, the simulation of such variations can result in a better design evaluation.

Sensitivity analysis is used to tighten the performance spread of a circuit. This simulation package will help to determine which part variations have the most effect on a circuit, or how sensitive the circuit performance is to the change in component value. Sensitivity analysis lists components starting with those that have the most effect on the circuit, and calculates the worst-case outcomes.

In system-level circuit design, Monte Carlo and sensitivity analysis will graphically indicate which components are being excessively stressed; and in addition, it will list in descending order the percentage of time that each component is used in the circuit during normal operating conditions. This knowledge will allow relaxed performance specs and still meet overall performance. It would also prompt the use of premium parts only where they are absolutely needed to keep cost down and increase reliability in the long run.

Library Models

A simulation package is limited only by the accuracy of the models that are used. In the early stages of design, a simulation package enables the user to view, understand, and analyze a circuit's response as the circuit is created. The use of these model libraries does not immune anyone from related modeling problems. A

few things need to be kept in mind when using these libraries, i.e., if the necessary model parameters are not available in the library, they will have to be filled in from data books and parametric analyzers (programs that help find the optimum parameter for the given application of the circuit). Also, when a part is modeled for a specific application, factors can be included that are important to that model. For example, if a quick response is desired from a threshold detector or an amplifier, the slew time becomes a factor that should be closely looked at and modified if necessary in the library models. When simulation vendors develop parts libraries, they have to satisfy everyone's needs, which can result in models that are a compromise. A model that oversimplifies an important effect being sought will cause trouble. On the other hand, a more detailed model will always make the simulation run slower. In addition, there are some variations in the quality of models available, so an assessment of the limitations of the models to be used is needed.

Component models probably present the biggest problem for most users. In the Military, where the critical components are custom made for the application or project at hand; the biggest problem is the modeling of components or availability of library parts. This fact alone can render big complex simulation packages to no more than a "ball park figure getter." The solution to this problem is to contract it out to simulator vendors or companies that are dedicated to the modeling of electronic devices, or to create your own models using the simulator's features in house. The latter needs specialized training investment, but is the most efficient, cost wise, and rather applicable when dealing with confidential or secret parts.

Model needs vary greatly from user to user; and no one model can satisfy every application, because a given device can be modeled at several different levels of complexity. A transistor model may have less than a dozen or as many as several dozen parameters (a graduate level electronics test book (ref 3) lists 23 parameters for a typical bipolar transistor).

Valid Logic Systems (now Cadence Design Systems), for example, publishes data books along with its models that show characteristic device curves. The books detail what effects have been factored in and those that have not. The system permits making parametric changes quickly.

As new devices are introduced, simulation users must either obtain or develop models of the devices. The best solution is to have the device vendors provide models of new parts as they are introduced. Needless to say, device vendors are already doing just that since it makes their parts more attractive to the even larger community of designers that use simulation as a designing tool.

ADVANCED COMPUTER TECHNOLOGY

The technology that promised to change the engineering industry as we know it, is delivering. Constant new versions and new generations of hardware and software, specially in the CAD arena, are commonplace and affordable to virtually all engineering organizations.

New Personal Computers

PCs are no longer a weak platform. The days when PCs were used when nothing else could be afforded are history. The latest and more powerful PCs offer the processing power, graphics, and memory that are required to tackle a good share of the CAD and CAE software in the market today.

More Powerful Hardware

After the introduction of PCs in the mid-seventies, the computer industry has seen many changes. Today's PCs have the power of mainframes of not too long ago. These days PCs are rather inexpensive if compared to the cost of . . . let's say, sending someone on travel for a few days or buying a conference chair. PCs lend themselves well to expansion and upgrades. More memory can be easily added. Faster and higher resolution graphics can also be installed. Lately, some manufacturers have developed adapted versions of newer generation microprocessors that can be mounted in old computers; more specifically, in old "mother-boards" (main electronic board that basically contains the bus system and the microprocessor), making the upgrade alternative even more cost effective.

Expanded memory (more RAM readily available for the operating system's use during processing), coupled with newer and better operating systems like Unix³ and operating system/2 (OS/2)⁴, that are capable of multitasking (the ability to run more than one program or application at the time), are making PC-based tools the engineer's workhorse for even more complex design tasks.

According to Byte magazine (ref 4), there are more engineering groups that have bought tools that run on an IBM PC and its clones than any other platform.

Automation tools for PCs are relatively inexpensive when compared to tools that run on the Sun, Hewlett Packard (HP), or Silicon Graphics station; and automation tools for PCs would certainly provide a training vehicle before investing far larger sums for workstation-based tools.

³Operating system developed at Bell Labs in the early 70's capable of addressing more memory at a time than DOS, and based on a more efficient 'higher language, "C".

⁴Similar to Unix OS, but developed at IBM in the early 80's.

Vendors of workstation-based engineering design automation (EDA) tools are looking to these new powerful PC as the future platform for their software package, and as a way of reaching more and more engineers. PSpice⁵ and MatLab⁶ both have versions for PCs and workstations running on Unix.

PC-based tools can handle the same types of design tasks as workstation-based EDA tools but on a lower scale. They can handle schematic capture or drafting, logic and analog simulation, signal processing, IC design, and PCB design.

Newer Operating Systems

DOS can only access 640 Kbytes of memory. Because of this memory addressing limitation, the so called DOS extenders were created. They allow software developers to bypass the memory limitation and make full use of the 32 bit microprocessor machines now widely available. The latest generation of operating systems like OS/2 and Unix, also Windows NT, for new technology that is due out at the end of 1993, provides multitasking and overcomes the serious limitations of DOS. It removes the 640 Kbytes barrier, provides 16 Mbytes of addressable memory and 48 Mbytes of virtual memory (memory that resides in the hard drive but is looked upon by the microprocessor as RAM memory available for the operating system to be used when application programs.

Powerful Engines

Central processing units (CPU) are indeed the computer's engine, and already a 32-bit CPU based machine running at about 66 MHz is currently available for less than \$15,000.00. These systems are more than 25 times faster than the original PC of the early seventies. Intel and Motorola are at the forefront of the microprocessor race. They are constantly announcing a new generation of microprocessors every year, breaking new grounds in transistor density and processing speed. The Intel's 80486 or i486, and Motorola's 68040 contain over one million transistors. The next generation of these chips is rumored to contain about three times as many transistors.

Although Intel-based computers or IBM-compatibles have a bigger share of the PC hardware market, and of the software market, Apple computers are promising a good fight. Because of great reviews received about newer micros from Motorola, Apple computers (which use these new micros in its systems) are poised to stand their own ground in the competitive PC arena bringing higher powered and cheaper units in the future.

⁵A mixed-mode electronic simulation package by MicroSim Corp.

⁶A mathematical and signal processing program by Math Works Incorporated.

Workstations

Workstations have become the platform of choice of CAE users. The machines' multitasking Unix operating system, huge memories, built-in networking and fast graphics, along with usually large high definition (a 1024 by 760 pixels is considered a high definition monitor) monitors make them ideal for CAE applications.

Workstations are known for their ability to run large programs, with great speeds (in the range of tens of millions of instructions per second), having virtually all manufacturers offering network and interfaces to numerous computer environments. These machines can also be enhanced by adding more memory, dedicated graphics, or floating point processors.

Low-end workstations in 1990 could be acquired at a price of about \$3,000 to \$10,000⁷. These machines are often monochrome, and are used for drafting, some electronic design, and various graphic applications. A step up from that are machines that provide color and have faster processors equipped with at least 32 Mbytes of RAM. These usually handle 3D modeling and analysis of all types. They sell for \$10,000 to \$30,000, but the prices are less than a year ago and they keep coming down due to stiff competition among workstation vendors as well as competition from high-end PC. The drop in unit cost is perhaps the most significant development in workstations as their performance continues to increase.

Responsible Technologies

What has made these high powered computers available at low costs are two developments: a reduced instruction set computing (RISC) architecture and an emphasis on user interface graphics for which new programming techniques and faster hardware are responsible.

RISC Architecture

The developers of the RISC architecture derived the fundamental concepts of this design philosophy after analyzing millions of lines of existing computer code. This analysis testified to the fact that most of the software in use at the time (late seventies) did not employ the then de facto computer architecture complex instruction set computing (CISC) in a very efficient manner.

The term reduced instruction set computing does not manifest its true characteristics. The goal of a RISC architecture is not to reduce the number of executable instruction in its instruction set but rather to speed up the processing by making the

⁷All monies from FY 90.

compilers (original to a particular computer hardware, it is a program in read only memory that is the intermediary between software and hardware) and processors match. When developing RISC architecture developers had at their disposal, due to advances in the field of electronics, wider bandwidths at higher frequencies and faster memories that, along with the newer 32 bit CPU, allowed them to cram more information in every instruction with the objective to accomplish an instruction of a fixed length (32 bits) with every cycle. These days a typical RISC architecture machine would usually include: a single-cycle instruction execution, a fixed length instruction, larger register sets, and would support the so called "high-level" languages like Unix.

In a CISC processor there is a control program called microcode, which interprets and supervises the incremental instruction execution, playing the role of "middle man" between the compiler and the CPU. A RISC processor has no microcode. The machine's instructions, now crammed with more information, become the microcode. Consequently, the theoretical achievement is one instruction per clock cycle; however, no μ P has yet attained that goal. It has achieved an average of close to a one instruction per cycle.

X Window System

As workstations become more popular users are demanding that they be as easy to use as PC. Vendors of these systems have come up with what has become a standard user interface, namely X Windows, not to be confused with Windows from Microsoft.

The X Window standard, in simple terms, provides a method for displaying multiple applications simultaneously on screen. At the same time, as a side benefit, it provides one with a standard format to port applications to other systems.

This system was developed at the Massachusetts Institute of Technology (MIT) with assistance and support of Digital and IBM. X Window is a network transparent windowing system. This means that X Window is not tied to any given network protocols. In turn, this means that you can run applications on any machine on your network and control them from individual windows on your terminal. These applications don't even have to be made by the same manufacturer or be running on the same operating system. They just have to be in your network and running X Window. X Window is basically software independent at the user's graphical display end.

This new graphics interface promises to bring the look and feel that is common to all workstations. This means pull-down menus, dialog boxes, icons, and other elements that the user can come to expect from every application.

JUSTIFYING AND PURCHASING

As workstations become the platform of choice, the abundance of ways to buy a CAE system is making the selection process more complicated, and justifying the cost for an entire CAE system is not easy. This technology is very new, and as such, it produces a level of uncertainty and mistrust in management levels of most engineering organizations.

In the government, as in most engineering organizations, the promise of an automated solution also seems and feels like an unlikely proposition.

The requirements in a military scenario are, although very related to private industry, a bit more demanding and so are the CAE systems to be justified for purchase.

System Costs

CAE has costs that are hidden and those that are obvious. The sticker price of hardware and software for a modest system is in the tens of thousands of dollars. Less obvious are expenses for maintenance, training, and even loss of productivity during the transition period to an automated system.

Initial acquisition costs vary widely depending primarily in the software that one intends to use for a given application. The hardware part, most commonly known as the platform, is usually not as great as its software counterpart; in part due to the fierce competition in the market for such products and because of mass production of key components like memory chips and newer generation microprocessors that are becoming common in the market place.

Operating Costs

Annual operating costs tend to follow initial acquisition costs. In a study of 300 firms, conducted in 1990 by Practice Management System Ltd., Newton, MA, it was found that median annual operating costs were \$47,775. These costs included hardware and software, maintenance and upgrades, system operating costs of training, and other costs (space, utilities, insurance, and supplies).

It has to be pointed out that the costs of a CAE system are specially significant when considering that the average life of hardware is 24 to 30 months. This means planning ahead for replacing a updating obsolete and outdated systems.

User Training

This is an important but often neglected element in the purchase decision. Organizations often succeed in selecting a good system from a reputable vendor at a fair price, but fall short in budgeting for appropriate training. To use CAE as an effective engineering tool, proper training available from different sources is a must if a CAE system is going to be something more than a "dust collector".

Vendors of the software to be used are usually the best qualified to provide basic and advanced training; although there are training companies that can provide training for almost all the software available in the market. Some software vendors have on-going training on advanced concepts that are usually provided for an extra fee.

Upper management should realize that one or two training courses will not produce immediate CAD/CAM/CAE experts but will, however, give employee's the confidence to go on learning the technology.

Real Benefits

The benefits of a CAE package are more difficult to quantify than costs. One can easily say that such a system decreases the time to design or troubleshoot a circuit, but it is more difficult to say by how much and what cost savings that implies, or how much return the investment is paying-off. The payback of CAE can be, and usually is, quantified by how well it increases productivity or how significant it reduces the product development cycle. Processing engineering change proposals (ECP) is one way in which engineering groups have already reaped benefits from their investment.

It should be understood that high productivity gains are not going to be accomplished by acquiring expensive systems and using them for drafting or just simple ECP processing. It is in design, troubleshooting, and in circuit optimization that a CAE package gives you tangible benefits.

Another well defined benefit is the shortening of the development cycle. Commonly, all the different phases of development are performed independently and usually involve some degree of effort and resource duplication. A CAE system can take the task of putting all the pieces together in one data base. This would shorten the time to market of a commercial product or would cut the time of first fielding in the military. It is indeed this ability that makes a CAE system a vital tool in all engineering organizations.

Attention should be focused on the early stages of the design. Design for performance, manufacturability/producibility, and concurrent engineering are techniques that attempt to change CAE into a system that describes costs, features, specifications, design intent, and ranges of performances. Also, beyond accelerated aging models, there are attempts to simulate the deteriorating effects of dormant storage; that is a major concern in the Military.

The Purchase Decision

Selecting a Vendor

Standardization of hardware platforms has benefitted users who now have more choices of CAE systems. Most companies and organizations begin the process by forming a CAE acquisition committee which requests proposals from various vendors, and would sometimes bring them in or go out for demonstrations of the packages that seem to fit the intended applications.

Vendors would then come back with questions relating to the company's needs and practices. Some of the questions may include:

- How many users (engineers, technicians, analysts, drafters, programmers) will be using the system?
- Are you a research, industrial, or a military concern?
- Do you have an investment in existing hardware and software that will need to be taken into consideration.
- Are other corporate or organizational divisions using CAE equipment? If so, what kind?
- What is done more of: electronic analysis, printed circuit board layout? design integrated circuits, millimeter wave, application specific IC (ASIC), etc.? statistical, or other specialized simulation as temperature analysis, or VH application specific IC (VHSIC) and hardware description language (VHDL)?
- Are you interested in analog or digital simulation? both? mixed-mode?
- How much time or what percentage of time is spent generating new drawings? revising existing drawings?
- What is your procedure for generating bills of materials or parts lists? technical illustrations? bids?
- Finally, and invariably, how many dollars are to be invested?

This and other pertinent information helps vendors understand the operation, and makes it possible for them to make recommendations on the optimum system configuration for each particular need.

Evaluating Vendors

It is important to buy a system that is fast enough to handle the needs of the intended applications, and the relative speeds of the hardware to be acquired will probably have to be discussed using 'benchmarks' as figures-of-merit.

Benchmarking Systems. Benchmark tests are "canned" programs that are used for measuring computer speeds. These may or may not demand the same capabilities from a computer that the applications do; therefore, it is also important not to select a vendor based solely on favorable scores of formal benchmark tests.

A well known benchmark figure is millions of instructions per second (MIPS). This widely used number is the rate at which the computer can move bytes of information around and perform simple arithmetic on them like addition, subtraction, and multiplication. The performance of a DEC VAX 11/780 as 1 MIP has become a standard, and performance in MIPS is quoted relative to it. In theory, one can obtain this value by multiplying a processor's average instruction time (AIT) by its clock rate, assuming that the processor operates in a zero-wait-state (given that the processor does not have to wait for data to be fetched from memory and that it has all the information it needs readily available for its use) environment. Another often quoted benchmark figure is the Linpack, which measures floating-point performance by having the computer solve a 100 x 100 algebra matrix. If the application requires mostly integer manipulation, a fast Linpack rating is meaningless; hence, the only truly useful evaluation of a computer is to put it through its paces processing intended applications.

CONCLUSIONS

If one thing can be said about a computer aided engineering (CAE) system, it is that it had thus far brought results to the great majority of users who ventured resources in CAE. Companies of all sizes report increased productivity, reduced design and manufacturing costs, and work of better quality. CAE tools are the fastest growing applied technology in the world. With combined sales of hardware and software projected to reach the 10 billion dollar mark by 1994 in the United States alone, CAE and design is one of the leading causes of profit reinvestment in industry, and a major source of new white-collar employment.

It is anticipated that in the immediate future hardware will be sold directly by computer vendors or their dealers. The most popular operating systems will be the ones available for multiple platforms. Specialized applications software will be sold by its developers, and some may be sold by computer vendors.

What's in store for CAE in the 90s? More changes. For instance, 'open' systems will dominate making files easily accessible regardless of platform. The newly implemented computer aided design (CAD) framework initiative (CFI) expects to define a fully integrated electronic design automation (EDA) environment. In this environment, tools from different vendors will work together. Every tool will have the same look and feel. Although CFI appears free of problems, it still has some critical aspects to work out. When the electronic design interchange format (EDIF) was demonstrated at the 1988 design automation conference (DAC), several vendors proved it was possible to pass design information from one vendor's tool to another. All the designer needs is an EDIF writer to translate design information from one EDA vendor's format into EDIF, and an EDIF reader to translate design information into the EDA vendor's format. Problems arise when vendors support reading, but not writing EDIF. In other words, vendors support the flow of information into their environments from other's vendors' tools, but users can not transfer design information out to use with competitor's tools. At this point in time there are more EDA companies supporting only an EDIF reader, and not an EDIF writer.

The affordable price/performance ratio of workstations and personal computers (PC) has brought new users into the market at all levels and users in the industry as well as in the Government, have a wide selection of platforms, operating systems, and engineering software.

The electronics industry is not, by any means, the only one that has benefitted from the CAE technology; as a matter of fact, virtually 100% of all industries have been touched or influenced, for the better, by the CAE revolution. In the mechanical and electronics industry the applications are even more influential, to the point that none of these businesses could survive and thrive in the highly competitive industrialized world without the aid of CAE.

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