Concurrent Engineering: An Enabler For Fast, High-Quality Product Realization

David A. Gatenby
Paul M. Lee
Randall E. Howard
Kaveh Hushyar
Rich Layendecker
John Wesner

Concurrent engineering (CE) is a proven approach for product realization that results in reduced time to bring a product to market, improved product and service quality, and reduced life-cycle costs. Time-to-market improvements of 30% to 60% are typical of a disciplined approach to concurrent engineering. Concurrent engineering integrates and synchronizes activities and the information required to define, design, produce, deliver the product or service, and to maintain the product or service over its life cycle. This paper reaches beyond a simple explanation of CE and provides examples of how powerful CE implementations can be. The paper:

- Describes the elements of an infrastructure and supporting technologies for a CE-based product realization process (PRP),
- Provides guidance for deploying CE by explaining a broad-based CE implementation process, and
- Shares tips and ideas on how an individual or small team can catalyze CE in an organization.

Introduction

Competition, product time-to-market, cost, and quality are today's critical concerns when introducing products and services. This paper presents a systematic approach to product realization that addresses these drivers, namely concurrent engineering (CE). In the CE approach, a cross-functional team of individuals continuously creates and uses a body of knowledge to optimize quality, cost, and the time to get a product to market.

A widely accepted definition of CE was published in 1988: "CE is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the product developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements."[1] Our interpretation of this CE definition includes the up-front conceptual product definition processes as part of "design." This definition applies to services, software, or manufactured products. We consider all associated documentation, such as customer training materials, as part of "products."

CE focuses on the product as used by the customer.[2] This approach requires striking a balance among functional disciplines. In CE, cross-functional teams are formed to provide a forum in which the individual expertise of its members melds to create and deliver a more competitive product. The CE team has considerable power to affect the success or failure of a product when it operates as a single entity, and the team has complete end-to-end control over the product life-cycle. The unified, cross-functional team uses its knowledge to assure that all considerations are incorporated into a product early in its development. This includes performance and functionality, as well as Design for X (DFX)[3] considerations. Real-time collaboration on these considerations saves considerable time and can improve product quality—in contrast to sequential, decoupled reviews.

The Basic Elements of CE

The combination of six fundamental elements of CE characterize and differentiate

Panel 1. Acronyms and Terms Used in This Paper

BCS — Business Communications Systems

BU — Business Unit in AT&T

CAE/D/M — Computer-aided engineering/design/manufacture

CE — Concurrent engineering

CFT — Cross-functional teams

CPM — Critical path method

Critical path — The sequence of activities that consume the most time in a process

DFM — Design for manufacturability

DFS — Design for simplicity

DFX — Design For X, where X stands for manufacturability, installability, reliability, safety, serviceability, and other downstream considerations beyond performance and functionality

DFT — Design for testability

GBCS — Global Business Communications Systems

GBS — General Business Systems

ICE — Interactive collaborative environment

IPM — Integrated project management

IS — Information systems

MSD — Market service description or definition

PDI — Product design information

Policy deployment — The technique of establishing goals at the highest levels of a business (policies), and "cascading" them down throughout an organization, so that all hierarchical goals and objectives are consistent with the policies "deployed."

PQMI — Process quality management and improvement

PRP — Product realization process

Product realization — All activities, from concept through production, required to create and introduce a new product

Product — Any service, software, or manufactured product

QFD — Quality function deployment

QUEST — Quality, Engineering, Software, and Technologies; a consulting organization in AT&T Bell Laboratories

R&D — Research and development

it from traditional product development.[4] The six elements are cross-functional teams, concurrent product realization process (PRP) activities, incremental sharing and use of information, integrated project management, early and continual supplier involvement, and early and continual customer focus. See Figure 1.

Cross-Functional Teams. CFTs have representation from many or all functional areas across the entire PRP for manufactured, software, and service products. This representation includes marketing, systems engineering, design, manufacturing, purchasing, field services, and even customers and suppliers.

Concurrent PRP Activities. PRP activities are executed in parallel, with some or all of the activities occurring simultaneously, rather than sequentially. Examples include:

- Performing simultaneous product and assembly process design,[5] rather than waiting for a fully completed design.
- Developing part of a technical prospectus when feature descriptions are available from the market service description (MSD).

Incremental Information Sharing and Use. In each of the above examples, information is shared incrementally, as soon as it becomes available, which allows immediate feedback. This is in sharp contrast to waiting for a transfer of a complete set of information in the classic "over-the-wall" mode. Examples of incremental sharing include:

- Performing material planning and procurement activities, using a subset of the material needed as specified in the early design information.
- Determining the technical feasibility, using a subset of the customer requirements extracted from market research information.

Integrated Project Management (IPM). When a CE approach is taken, project management changes in four major ways:

1. Project management is integrated to encompass end-to-end activities involved in the PRP. Milestones, and the responsibility for meeting them, are shared by all members of the concurrent engineering team.
2. Tracking mid-activity status becomes critical, since incremental information sharing can trigger other activities.
3. Target dates and knowledge about the PRP's information flow are used to prioritize work in each functional area.
4. Greater emphasis is placed on change management, since concurrent activities place considerably more stress on the management of information.

Early and Continual Supplier Involvement. Involving selected suppliers early on enables the CFT to better understand and design to the suppliers' capabilities, take material off the critical path, and leverage the design capabilities of the suppliers.

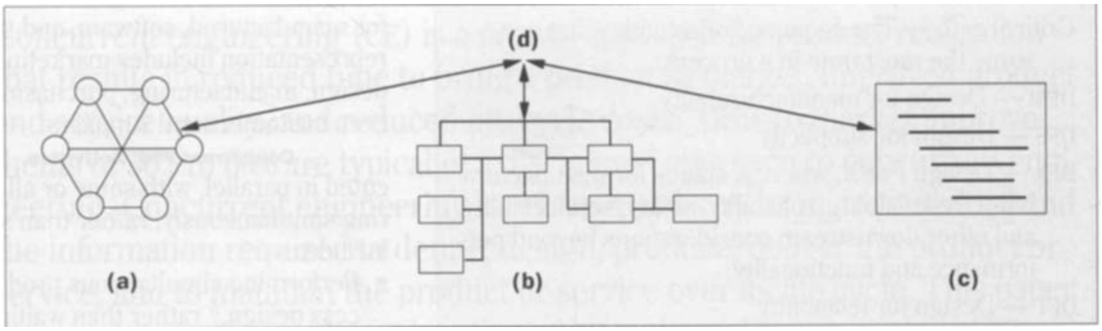

Figure 1. In a concurrent engineering environment, the cross-functional teams (a) perform concurrent product realization process activities (b), which are managed with integrated project management techniques (c), using incremental sharing and use of information (d). During this entire process, the customers and suppliers are involved early and continually.

Early and Continual Customer Focus. CE focuses the team on customer needs by providing an opportunity to absorb and act on customer inputs. This ensures that design and test decisions, beyond high-level requirements, are made with the customers' viewpoints in mind.

Communication in a CE Environment

A successful implementation of CE requires excellent communication between all elements throughout the PRP. More specifically, this can be achieved because:

- The use of CFTs is aimed at articulating and using knowledge from functions across the PRP.
- Concurrent PRP activities require real-time communication during simultaneous activities, and clear, unambiguous sharing of incremental information.
- IPM hinges on the communication of the status of activities, resource information, and priorities.
- Early involvement of customers and suppliers increases the frequency and quality of communications with them to accelerate and enhance the PRP.

Why Use Concurrent Engineering?

Studies of many different implementations of CE have consistently indicated the substantial advantages of CE in bringing lower-cost, higher-quality products to market faster. This section describes CE benefits and presents data from AT&T and other companies.[1,6-10] Here are some results from CE implementation:

CE benefit	Reduction/Improvement
Time to market	30-60%
Product life cycle costs	15-50%
Engineering changes and rework	55-95%

Time-to-market is reduced through many CE mechanisms: activities are coordinated in parallel rather than serially; rework loops are much shorter; and with constant communication, the cross-functional team and PRP are able to react to changes more quickly. Cost benefits are the result of lower-product costs, which CE reduces by forcing effective decision-making early in the PRP—where up to 90% of the life-cycle costs are determined.[3] Development costs are reduced due to shorter intervals, less rework, and lower costs for product changes.

A study on the cost of engineering changes[11] found that the cost of change increases by a factor of 10 through the phases of design, design checking, reviewing, pre-production, production, and, finally, use in the field. (See Figure 2.) The quality of products and services can be increased dramatically through a CE-based PRP, because the CFT is more creative and effective at realizing a product that satisfies customers' performance and function needs, as well as meeting DFX considerations—especially with early customer involvement.

Several AT&T Business Units have employed CE successfully over the past several years, achieving some of the results discussed above. Global Business Communications Systems (GBCS) has implemented CE broadly, and we discuss this successful implementation next.

Systematic Implementation of CE

This section describes a systematic Business Unit (BU) level transformation to a CE paradigm. The CE effort between the Denver Works and its three major design laboratories began in 1988, when "concurrent engineering" was then becoming more prominent in the engineering literature. Two of the design laboratories were part of one BU, Business Communications Systems (BCS), and one was part of another BU, General Business Systems (GBS). One lab was co-located with manufacturing, and two others were remote locations. All three labs introduced designs to a common manufacturer, the Denver Works.

Since this effort was relatively complex to coordinate, involving four organizations, two co-located and two remote, we are confident the steps outlined here could apply to any BU-level transformation to a CE paradigm. To add context to the description of the transformation, the steps that GBCS went through are described in more detail in this section. Since the particular execution of each step depends on the culture and resources of the organization making the change, the reader is urged to consider the essence of each step, while viewing the specific techniques only as an illustration of one way to achieve the transformation. Other techniques might be more optimal. The section, "Barriers to Implementing CE," provides information on building the initial commitment to CE, and offers additional ideas on taking the steps below.

Transformation Steps. Adhering to a *rigorous* process-management method ensures that process improvements are driven by facts, not guesses. These are the steps taken in the GBCS project:

- Step 1 - Benchmark and establish performance targets,
- Step 2 - Establish the structure for breakthrough improvements,
- Step 3 - Characterize the current process,
- Step 4 - Create the target process,
- Step 5 - Verify all new processes,
- Step 6 - Implement new processes across the entire set of product lines, and
- Step 7 - Measure the results and continuously improve.

Step 1: Benchmark and Performance Targets. This step provides a clear imperative, or vision, for the project, based on a competitive reality. Benchmarks for design and the introduction of similar products showed that BCS and GBS products lagged behind best-in-class intervals of other companies by 30% or more. The team recognized that the reengineering process would be a multi-year effort and, therefore, set the breakthrough improvement target at a 40% improvement of their current performance. This target then became the rallying point for the entire effort. Although aggressive, this goal, in the absence of any knowledge on how to achieve it, forced the team to entertain some radical new thoughts, instead of employing the usual bromide of "just doing everything a little faster."

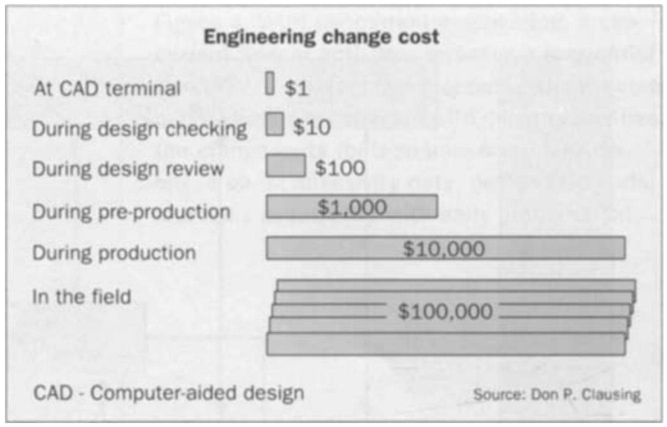

Figure 2. The cost of change increases by a factor of 10 through the phases of design, design checking, reviewing, pre-production, production, and, finally, use in the field.

Step 2: Breakthrough Improvement. Once the team established a benchmark that indicated the need for a major technological shift in how things get done, often called a "breakthrough improvement," mustering the resources to achieve the breakthrough became the critical need. A careful analysis of the driving factors influencing the project structure preceded any decisions on the structure. Three factors were:

1. Success required an unprecedented level of partnership between design and manufacturing,
2. The basic organization of the Labs and manufacturing could not be altered, and
3. Breakthrough improvement would require support of managers at least two levels above the working level, and preferably higher.

The project structure resulting from these requirements featured three groups:

- *Steering committee:* Mid-level managers from manufacturing and the design organizations met periodically to give and receive feedback on the progress of the

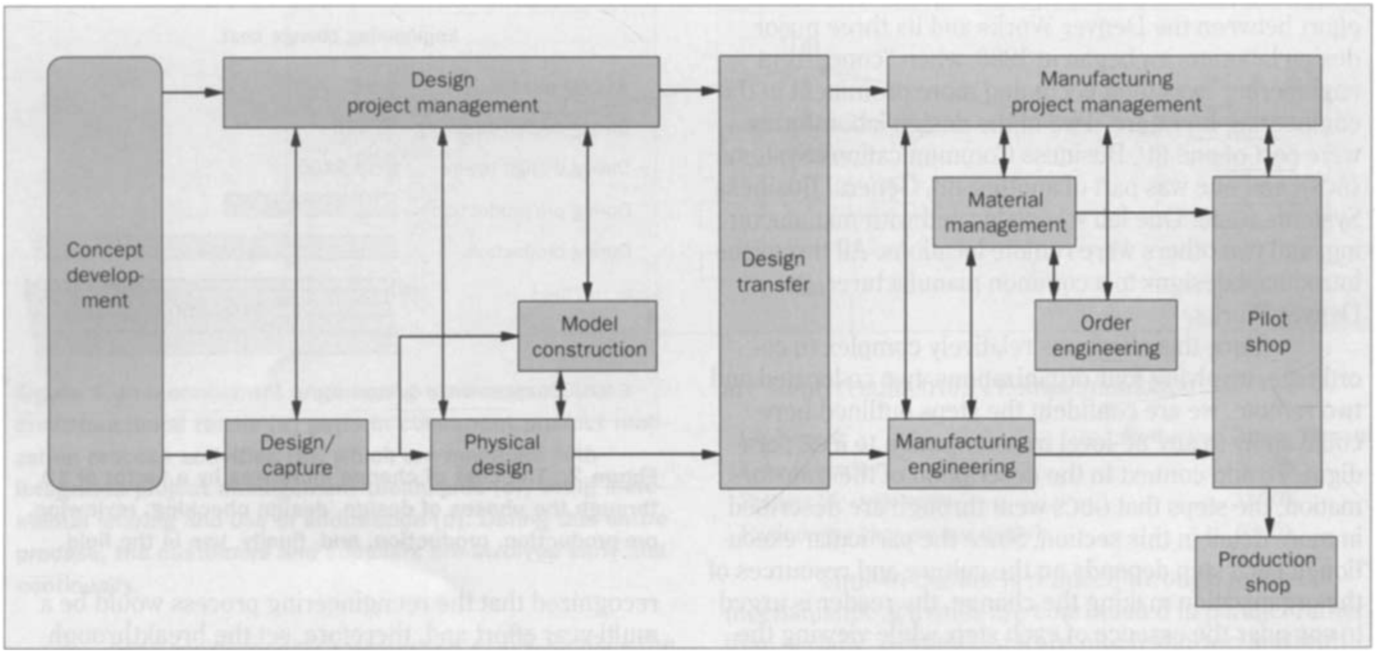

Figure 3. When design and manufacturing activities are performed sequentially, design transfer triggers both production activities and manufacturing-enabling activities, such as creating programs for assembly equipment, documenting assembly instructions for production operators, establishing bill of materials, and the creation of test programs. Procurement activities start so late in the product realization process (PRP) that material lead times are often on the critical path.

reengineering effort.

- *Project office:* An engineering manager from the Denver Works teamed up with an operations analysis supervisor from the internal consulting organization, Quality, Engineering, Software, and Technologies (QUEST), to co-manage the project on a day-to-day basis.
- *Core team:* Engineers and analysts from the participating organizations worked under the guidance of the project office, and with the support of the steering committee, to complete the remaining steps.

Most core-team members became full-time participants, even though this effort required the inconvenience of extensive travel for some individuals.

Step 3: Characterize Current Process. The team gained intimate knowledge about the current process and its variations to prepare for the next step. This step also afforded the team the opportunity to build personal working relationships, understanding, and support among the various subject-matter experts across the PRP.

The core team characterized the PRP within the four organizations to gain insight into all PRP activities, with a special focus on activities that contributed to the product-introduction interval. Flowcharting techniques and root-cause analysis were used extensively to accomplish this. Figure 3 provides a high-level view of the PRP before reengineering it with CE.

We identified and quantified the following root causes for long product-introduction intervals:

- *Sequential design and manufacturing:* Figure 3 shows that the design and manufacturing activities were performed sequentially. Design transfer triggered both production activities and manufacturing-enabling activities, such as creating programs for assembly equipment, documenting assembly instructions for production operators, establishing bill of materials, and the creation of test programs. Procurement activities started so late in the PRP that material lead times were often on the critical path.
- *Focus on intermediate milestones:* Intermediate milestones, such as the design-transfer date, were a driver for design activities. The designers' performance was

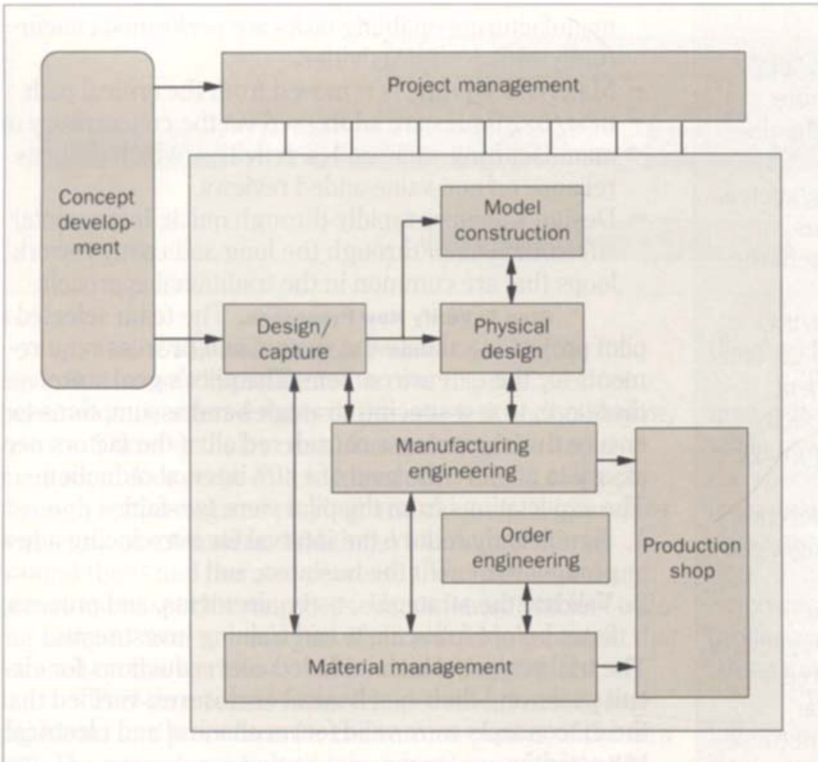

Figure 4. With concurrent engineering, a concurrent flow of activities replaces a sequential flow. For example, material-management personnel analyze, concurrently with design activities, the components for lead-time consideration, based on an effectivity date, design trade-offs, and risks associated with early procurement.

based on delivering a functional design by the scheduled transfer date. Additional time was then needed by manufacturing to compensate for a lack of consideration given to efficient production issues in the early stages of design. This resulted in long intervals that put the product at a competitive disadvantage.

- *Extensive queues without priority control:* Using a critical path method (CPM), we found that of the time these activities took, 80% of the total represented time in a queue, mainly because of numerous handoffs and ambiguous prioritization. This finding proved that the real problem to quickly introducing a product or service was managerial, rather than technological. This meant we could accelerate the PRP, without increasing the resources needed, by reorganizing project tasks strategically.
- *Multiple, unsynchronized data bases:* We also learned that vast amounts of redundant data were maintained in the design and manufacturing environments. This meant that data needed to be synchronized, typically manually, before products could be manufactured.

The result was a process that added significant time, labor, and errors to the PRP.

Step 4: Create the Target Process. The team took its time and focused its creative energies, and the insights gained from the previous step, to visualize the characteristics of the best process imaginable before subjecting it once again to reality. This approach provided team members with the freedom to think creatively, and helped them design a realistic plan. Three of the CE elements: CFTs, concurrency of PRP activities, and incremental information sharing and use, were used as fundamental principles in reengineering the PRP.

The objective of a 40% product introduction interval drove the team to be radically creative with reengineering ideas. The resulting process integrated design and manufacturing activities, eliminated the need for design transfer, and combined two project management functions into one driven by a single effectivity date (the date the customer needed the product) that drives all PRP activities. Figure 4 presents a high-level view of the concurrency that has been implemented. For example,

Panel 2. Technologies Supporting CE

The six concurrent engineering (CE) elements and communication can be supported by one or more technologies. (See Figure 5.) Examples of technologies supporting CE include:

- *Operations engineering* (OE) methodologies, such as the critical path method (CPM) that identifies specific parts of the process that would benefit the most from concurrency.
- *Product definition, design, and design for X (DFX)* methodologies, some of which overlap with CE (see Figure 6), such as quality function deployment (QFD), robust design,[15] and design for simplicity (DFS),[5] provide structure and a common language for specific PRP activities.
- *Telecommunications,* such as video teleconferencing, which enhances communications amongst geographically separated team members, and
- *Information systems (IS) and computer-aided engineering/design/manufacture (CAE/D/M)*, such as electronic mail, on-line DFX audit tools, shared product-information databases, product data managers, and work-flow managers. Some of these technologies can be combined effectively to support CE teams, such as CAD conferencing over telecommunications networks for automated CE/DFX reviews[16] and on-line collaborative design.[17]

material-management personnel analyze, concurrently with design activities, the components for lead-time consideration, based on an effectivity date, design trade-offs, and risks associated with early procurement.

A new information system (IS) to support the CE process became critical. The new system had to provide a common environment for information on both the product and manufacturing process, and make that information available to everyone involved in PRP.

In summary, the target process differed from traditional PRP practices in the following ways:

- Use of one end date, the effectivity date, to drive all PRP activities.
- Business needs, including time-to-market and costs, influence the design decisions—in contrast to product functionality as the primary driver.
- Design transfer does no more than trigger production activities, i.e., acquisition of long lead-time parts, since manufacturing-enabling tasks are performed concurrently with design activities.
- Material lead time is removed from the critical path.
- DFM/DFT issues are addressed via the concurrency of manufacturing value-added activities, which reduces reliance on non-value-added reviews.
- Design stabilizes rapidly through quick, incremental adjustments, not through the long and costly rework loops that are common in the traditional approach.

Step 5: Verify New Processes. The team selected a pilot project to validate the system and process requirements for the CE environment. The pilot's goal was, therefore, to test specific strategies and assumptions to ensure that the process considered all of the factors necessary to achieve the goal of a 40% interval reduction. The expectations from the pilot were two-fold:

1. Significantly reduce the interval for introducing a new product to benefit the business, and
2. Validate the strategies, IS requirements, and process flows before full-scale IS and training investments.

The trial project, which included cost reductions for circuit packs and their mechanical enclosures, verified that the CE concepts were valid for mechanical and electrical PRP activities.

The CFT included people from all functions that normally participate in product realization. The key differences were that all players were named at the start of the PRP, and that a facilitator, knowledgeable in CE, worked with the team to coach them through the process. A mockup of the target information-management system was used to validate that all necessary data elements, and their relationships, were clearly defined for all to understand.

The pilot demonstrated the basic soundness of the principles, and resulted in a significant acceleration of the product introduction. In the traditional PRP, circuit-pack realization took longer than mechanical-enclosure realization. In the pilot, circuit-pack realization accelerated more than mechanical realization. The pilot also revealed that tooling intervals for plastic parts are not amenable to acceleration through the CE techniques used. Also, the mechanical enclosure became a major controlling factor, or gating item, in the pilot, and highlighted a need to give enclosures an early start in the target process. The pilot led directly to full-scale implementation, which incorporated lessons learned from the pilot.

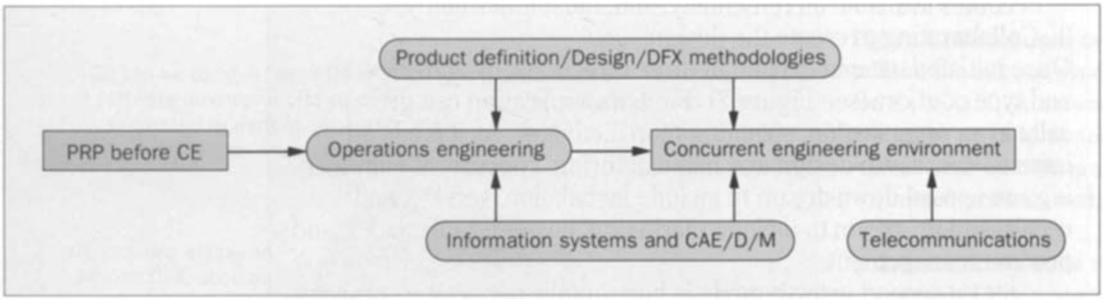

Figure 5. The implementation of concurrent engineering can be supplemented by a variety of technologies.

Step 6: Implement Across Product Line. As the CE environment was implemented across the BUs' product lines, we encountered many of the issues described below.

Training took several forms during the implementation. A concept course introduced the CE concepts through lectures, game playing, and videotaped interviews with early practitioners. Additional training, centered around the IS and the new processes, was developed and presented to specific members. Users found that tool training became more meaningful when placed in a context that focused on the workflow, and how tools support it.

Part-time teams formed to document new *operating norms and procedures* for the various phases of the new PRP. The procedures helped take advantage of the knowledge of experienced people in a usable format. It also provided input on where IS needed to be more flexible to accommodate the real-life variations in the process.

The *timing and strategy* of transforming organizations required extensive planning. The goal was to minimize, during the transition, the length of time any organization had to spend operating under both the old and new processes. Projects were begun in each of the design organizations as certain individuals in each of the functional organizations were dedicated to operating the new processes. Additional people were brought on board as the momentum switched to the new processes.

An *information systems* solution needed to be deployed to support full-scale implementation of CE. A team was formed with the charter of characterizing and recommending an appropriate solution. Three candidate solutions existed at the time:

- Expanding local software platforms,
- Adopting an outside IS solution,
- Using a software system developed at Bell Labs called "FOCUS-Prime."

A business case assessing the risk, cost, and timeliness showed that augmenting FOCUS-Prime to fit the target process best met the selection criteria.

The *core team* designed the IS to enforce a common set of concepts necessary for interval reduction, while trying to accommodate variations among users on the specific processes to follow. Project teams formed from designers and manufacturing engineers were encouraged to decide their own detailed operating practices, in alignment with the overarching concepts, to empower them to use their creativity in refining the basic processes. This approach required flexibility in the IS, and added complexity in its development and in training.

The *project structure* also changed to support full-scale deployment, maintenance, and support. An implementation team was added to partner with the core team. The implementation team contained people from various functional organizations. They were given in-depth training on the CE concepts and acted as facilitators as projects adopted CE. The implementors joined the CFTs during the product design and introduction, and acted as advocates for those teams when they returned to the core team to report progress and problems. The core team then responded by changing the CE processes to meet the operational realities.

Step 7: Measure Results and Improve. Results are given below for both a single-product CE implementation and a BU-wide CE implementation in GBCS. While a normal GBCS development took from 18-30 months, the development team of the 408 MLX unit completed the project in 11 months. This result was due to their clear team objectives, and their adherence to the six CE principles—especially the use of a CFT with end-to-end ownership. They went from three printed-board design cycles to just one, matching the benchmark for best-in-class companies for this critical path activity. Their greater than 35% reduction in interval was attributable to their being accountable for the entire project, and concerned with the overall success, rather than just doing

Panel 3: Scope of Concurrent Engineering (CE)

CE might begin as agreements between two people from different functions in the product realization process (PRP), such as a product designer and a manufacturing engineer, or a market researcher and a systems engineer. Within the relationship, the two can take advantage of CE by:

1. Identifying which activities they can perform in parallel,
2. Specifying how they will make use of the information that becomes available incrementally, and, most importantly,
3. Collaborating to create the design.

Once initiated, CE can expand in three directions: by activities, size, and type of effort (see Figure 7). First, its application can grow vertically in an organization, spanning more activities. As it feeds on internal success in design and manufacturing, concurrent engineering can spread downstream to include installation, service, and repair, and upstream to include marketing, customer interfaces, and product management.

CE's second growth mode is horizontally across the company. This may progress from a state of CE amongst individuals, to individual projects, to many projects, and finally, throughout an entire organization. We suggest that large-scale implementation of CE begin with individual projects, wait for some success, and then deploy CE systematically across your business.

Finally, CE can be applied in places other than hardware-product development. Any activity that requires serial hand-off of significant amounts of information is a potential application. Wherever downstream use of information could be enhanced or optimized by collaboration between users and originators, CE can apply. This means that business planning, market research, systems engineering, product management, software development, testing, product provisioning, service provisioning, service calls, and others can all benefit from CE.

their particular piece of the job.

The wide-scale systematic implementation of CE in GBCS showed similar results. It provided interval reduction results and productivity gains. Quantifiable benefits included:

- A 40% interval reduction from design through manufacturing ramp-up.
- Elimination of pilot shop operations, resulting in a 10% savings in the cost to introduce the hardware product.
- A 50% reduction in the rate by which new components are introduced.

Full deployment of the IS and the CE-based PRP took about one year. This period required work in training, enhancing the IS, and working through organizational friction created by the new operating model. At the end of this interval, most of the people who would be affected had experienced being on at least one CFT, and most functional areas were using the new mode of operation.

Projects took initiative to form cross-functional teams early in the design cycle. Some designers and manufacturing engineers adopted the combined role of physical designer and manufacturing engineer on their cross-functional teams, as stability in process norms and the IS emerged. A critical element was clear ownership for ongoing project management and staffing to support the maintenance and evolution of information systems and processes. A team consisting of process users and core team members analyzed the business results and documented the results summarized above. Even before the process and IS were stable, the business results became evident and were meeting original expectations. Part of the continuous improvement strategy included assigning the core team a role in strategic planning. The team realized that product technologies and information-systems technologies would create the need to revisit the new process, periodically, to look for even better performance from the PRP.

How Does a Business Unit Get Started?

The first thing a Business Unit (BU) needs to do to get started is to make the commitment to implement CE throughout the organization. This commitment must be made by top leaders of the BU, or it will not be viewed as belonging to the entire BU. This initial commitment

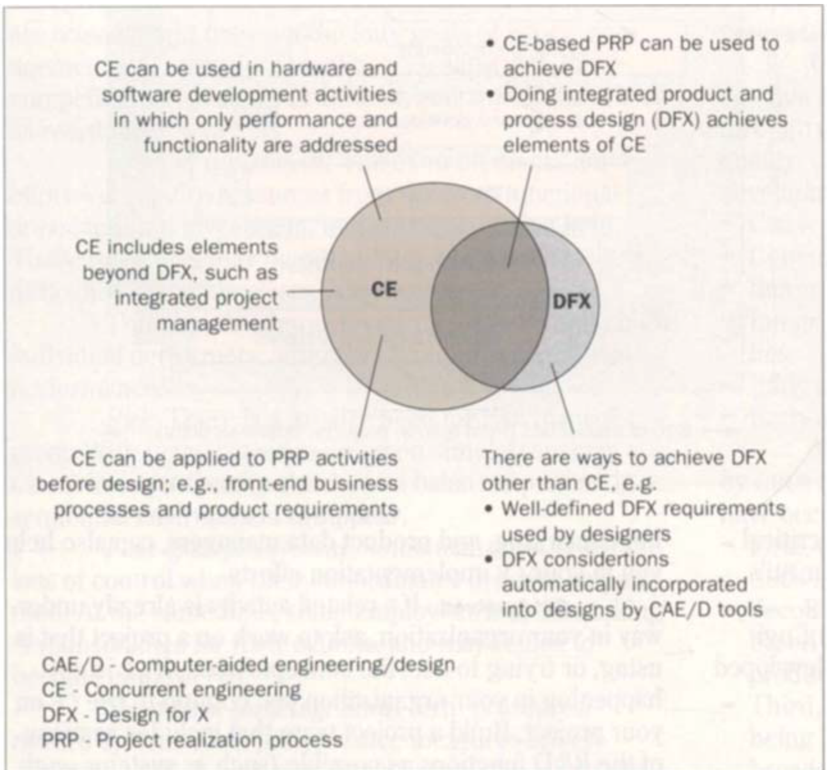

Figure 6. Concurrent engineering (CE) is related to, but not synonymous with, Design for X (DFX). DFX differs from CE in that there are other ways to accomplish DFX:
- **Well-defined DFX requirements from the X (manufacturing, installation, etc.) used by the designers.**
- **Automatically build the functions into a computer-aided engineering/design (CAE/D) tool.**

Concurrent engineering is more comprehensive. It includes many pre-design activities, is more tightly coupled with both process management and project management, and requires greater coordination.

will require four up-front steps before the message can begin to be deployed through the BU:

1. Train the top leadership team in the concepts of CE and process management,
2. Develop a vision and goals to provide a foundation for using CE,
3. Name management champions from different functions, and
4. Allocate funds needed to support the start-up activities.

In developing a CE plan and seeking support within your own project, there is no need to "go it alone" during this critical start-up period. Much help is available within your BU from people with CE experience or knowledge, from internal and external consultants specializing in CE, and from other BUs with CE experience. If you believe that you can make the start using your own resources, consider using some of the references listed at the end of this paper, for example, for doing a CE assessment on your product development environment.[12] The authors of this paper also can provide assistance.

Once the top leadership team is committed and prepared, deployment can begin. Three key early activities are discussed next. These steps should be integrated with the existing BU management system and infrastructure, such as policy deployment.

Publicize your Vision and Goals. Once you have the foundation in place, you need to draw everyone—the entire BU community—into the CE effort. Begin by sharing your vision and goals with everyone, and use whatever publicity you can, such as newsletters, flyers, announcements, e-mail, or videos.

Train the Rest of Management. While the message of vision and goals is being cascaded step-by-step through the organization, use every opportunity for management at each step to train the rest of management in the concepts of CE, and process management and improvement.

Name the Responsible People. Establish a core team of skilled "experts." These may be the people you found when you were looking for help, or they may be a core group of people trained by others. Once you have gained commitment, follow the seven steps described in the section "A Systematic Implementation of CE" to

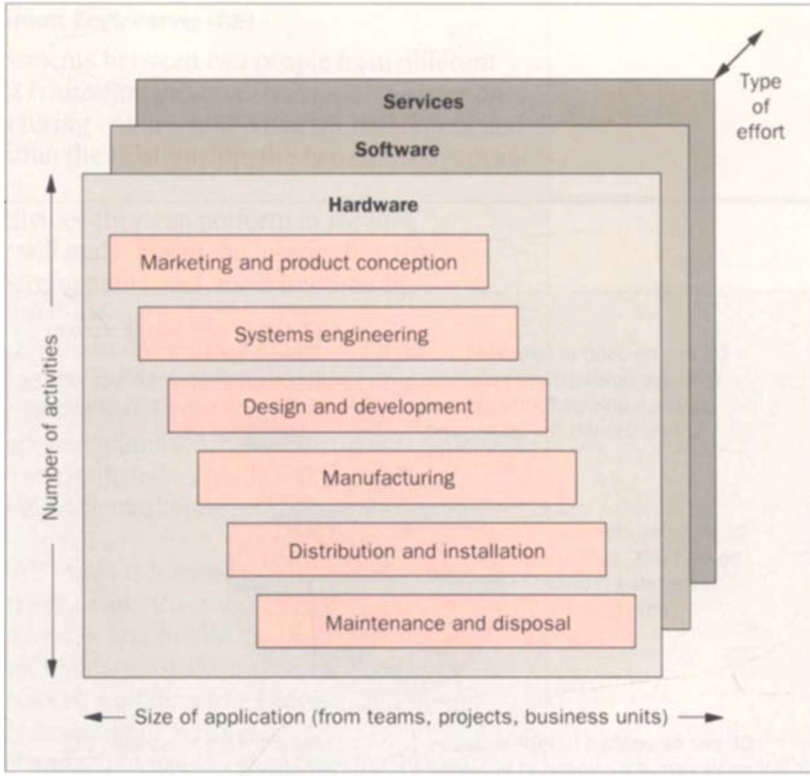

Figure 7. Concurrent engineering can be expanded into three directions: The number of activities in the development process, the size of the effort, and the types of product—hardware, software, or services—being developed.

implement a CE environment. Each step plays a critical role. You can tailor their execution to match your BU's needs and situation, and implement CE to varying degrees. See "Panel 3: The Scope of Concurrent Engineering (CE)" to determine how it can best be developed in your organization.

What Can I Do To Get Started?

What if you, the reader, see the value of implementing CE in your organization? Is it necessary to go to the head of your Business Unit to make something happen? The answer is clearly "No!" At some point the support of top management becomes critical, but it is possible to start locally, and still show success.

Network. Share this article with your coaches and colleagues, to build local interest. Ally yourself with others in your organization who have similar interests and goals:

- A desire to bring R&D and manufacturing closer together,
- A need to develop better processes for quality, interval, and cost issues,
- Local champions for "Design for X," since the people working on them are likely candidates to become your allies.

Train. Next, acquire a basic set of relevant skills and knowledge by taking courses or attending conferences. Look at internal courses, at universities, and at professional societies. Learning about some of the methods and tools mentioned throughout this paper, such as policy deployment, quality function deployment (QFD), benchmarking, and product data managers, can also help you in your CE implementation efforts.

Get involved. If a related activity is already underway in your organization, ask to work on a project that is using, or trying to use, the concepts of CE. If CE is not happening in your organization yet, commit to use CE on your project. Build a project team that includes as many of the R&D functions as possible (such as systems engineering, circuit design, mechanical design, software design, system assurance, etc.), as well as manufacturing personnel (such as factory process engineers, materials planners, etc.). Start working together to consider early on the many life-cycle design issues—all the "Design fors." If you can do this, you will have taken the first important steps toward adopting concurrent engineering as a way of working.

What are the Barriers to CE?

Along the way, you may encounter several barriers to implementing CE in your organization.

Commitment/Culture. You may find that resistance centers around cultural differences and individual and organizational commitments:

Lack of commitment from engineers: The philosophy of optimizing the end-to-end effort, while de-optimizing local efforts, can make it difficult for functionally-focused high performers. There will be skeptics who defer joining in because they believe that this is only one more "initiative du jour," which will soon pass and be replaced by another quality/process fad.

Middle management resistance: Middle managers are often caught between the lofty goals of upper management and operational realities. Dealing with these competing perspectives is difficult, and appears to others as resistance.

Up-front investment: The CE implementation effort will require resources from different functional areas, training investment, and perhaps outside help. These resources may be difficult to obtain because it is difficult to "guarantee" specific results.

Training: Academia prepares students to be high individual performers, whereas CE requires high team performance.

Risk: There is a greater need for risk management. With many activities going on simulateously in a CE environment, many checks and balances present in a sequential environment disappear.

Fear of empowerment: Some managers resist the loss of control when their subordinates become empowered. At the same time, some employees may fear taking responsibilities for their actions, and may refuse to become empowered.

Short-term thinking: Short-term pressures, reward systems, and performance measures are all designed to elicit high performance from the scope of a process covered by measures.

Organization. Organizational issues might adversely affect implementing CE:

Structure: The structures of normal functional organizations cause the resulting reward structure to center around performance inside each functional organization. This causes employees to work for the good of the functional organization, rather than for the good of a product.

Physical/geographic separation: Where permanent co-location is not feasible, CE implementation is an even bigger challenge, because significant informal communication cannot occur.[13]

Technology. Basic communications may also present problems:

Infrastructure: A poor communication infrastructure will hamper the implementation of CE. While phones are ubiquitous, e-mail, video conferencing, and computer networking may not be well entrenched. IS and process infrastructure may also require further development to best support CE. While these are not required, this infrastructure helps make CE much easier to do. See CALS[14] for further discussion on this issue.

Conclusion

Concurrent engineering is an enabling technology that offers a pathway to increased profitability through reduced time to market, lower costs, and higher quality. CE varies from traditional product or service development by virtue of:

- Cross-functional teams,
- Concurrent product realization process activities,
- Incremental sharing and use of information,
- Integrated project management for concurrent activities,
- Early and continual supplier involvement, and
- Early and continual customer focus and involvement

Work on improving the processes implemented by GBCS continues. Three exciting developments that have occurred since this work began:

- First, the GBS and BCS business units merged into GBCS in 1992 to better serve their combined markets.
- Second, this new business unit began a transformation based on concurrency, from idea generation through product offering to the customer.
- Third, advancements in information technology are being harnessed to begin to support this much broader venue for CE.

What looked like a radical scope in 1988, redefining the relationship between design and manufacturing, is now being dwarfed by the scope of a BU transforming all of its processes to one of concurrency and empowered teams. What remains unchanged is the need for following a rigorous set of steps, such as the ones outlined in this paper, so that both technology and people's creativity can be tapped for success.

Competitive pressures make constant improvement a matter of survival and excellence. AT&T, NCR, Paradyne, and other new members of the AT&T family, have already enjoyed some success after making the necessary investment to use concurrent engineering. This paper has presented an overview of CE concepts, how a CE effort can be started for a project, and how it enhances competitiveness. We have found that CE works, but making CE a reality requires careful planning, discipline, and hard work.

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David A. Gatenby *is technical manager of the Concurrent Engineering and Robust Design group in the New Product/Service Introduction Organization in the Quality, Engineering, Software, and Technologies (QUEST) Area of AT&T Bell Labs. He is responsible for managing the development and deployment of robust design and concurrent engineering methodologies in partnership with new product introduction teams in AT&T Business Units. He joined AT&T in 1981. Mr. Gatenby earned a B.S. degree in electrical engineering from Trinity College in Hartford, Connecticut, and an M.S. degree in computer engineering from Carnegie Mellon University in Pittsburgh, Pennsylvania.*

Paul M. Lee *is a member of technical staff in the New Product/Service Introduction Organization in the Quality, Engineering, Software, and Technologies (QUEST) Area of AT&T Bell Labs in Holmdel, New Jersey. He provides concurrent engineering implementation support for product and service introduction to organizations throughout AT&T. Mr. Lee received a B.S. degree in industrial engineering from the Pennsylvania State University in State College, Pennsylvania, and an M.S. degree in operations research from Stanford University in Palo Alto, California. He joined AT&T in 1991.*

Randall E. Howard*, formerly the technical manager of Concurrent Systems and Processes in Global Business Communications Systems (GBCS), is now on leave at Colorado State University to study artificial intelligence as applied to design. His former group develops, deploys, and manages information systems, and design processes that shorten hardware-design cycles in support of GBCS products. Mr. Howard earned his B.S. degree in mechanical engineering from the University of Maryland, College Park, and his M.S. degree in mechanical engineering from Virginia Tech in Blacksburg, Virginia. He joined AT&T in 1985.*

Kaveh Hushyar *is a technical manager of the Network Operations Planning Group in the Operations Technology Center of Network Services Division of AT&T. He joined AT&T in 1984. His group is responsible for developing operations solutions for the evolution of the AT&T communication network. Mr. Hushyar has B.S. and M.S. degrees in industrial engineering from, respectively, Arya-Mehr University in Iran, and from Stanford University in Pala Alto, California.*

Rich Layendecker *is technical manager of the Design for X (DFX) Group, responsible for fostering the DFX approach to product design within AT&T. The DFX Group adapts or creates DFX methodologies to meet the needs of AT&T's product development organizations. Mr. Layendecker has a B.S. degree in mechanical engineering from the Newark College of Engineering in Newark, New Jersey, and an M.S. degree in mechanical engineering from the New Jersey Institute of Technology in Newark. He joined the company in 1977.*

John Wesner *is a technical manager with AT&T Bell Laboratories, managing process integration for the Global Business Communications Systems (GBCS) R&D organization. Mr. Wesner has a B.S. degree from Carnegie Tech, an M.S. degree from Caltech, and a Ph.D. from Carnegie Mellon, all in mechanical engineering. He joined the company in 1968.*