The Importance of Communication Infrastructure in Concurrent Engineering

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Abstract

Concurrent engineering is an imperative concept in the world of product development. With the globalisation of industry, the market has been demanding higher quality products at lower costs, delivered at faster pace. With most companies today accepting the concurrent engineering approach as a formula for product development success, this approach is becoming ever more popular and dominating over the slower sequential product development method. Fast changes in technology, forced design cycle time reduction, emergence of new information technology and methodologies, as well as other aspects such as organisational and behavioural basis caused the sequential design process to progress into a concurrent engineering approach.

The basic concept behind the concurrent engineering approach is that all parts of the design, manufacture, production, management, finance, and marketing of the product are usually involved in the early stages of a product's design cycle, enabling faster product development through extensive use of simulation. Its key approach is to get the right data for the right person at the right time.

There are forces that govern changes in the product development, and these forces must be steered towards prompt response to competition and higher productivity in order for companies to exist and successfully expand in the global market place.

Concurrent engineering is made up of four key dimensions, one of them the communication infrastructure dimension, which is the focus of this study. This study defines the information infrastructure dimension, and some of the tools and technologies that support communication and collaboration. It then discusses how to employ

the concurrent engineering approach from a communication infrastructure dimension point of view, starting with assessing the current product development process and eventually envisioning the path to take to a successful concurrent engineering environment. Communication infrastructure technologies and tools can be seen as central to a company's implementation of concurrent engineering, as shown in the case studies covered in this work.

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Nomenclature

Acronyms

IDA	Institute for Defence Analyses
IT	Information Technology
PC	Personal Computer
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
3D	Three Dimensional
DFM	Design for Manufacturing
QFD	Quality Function Deployment
R & D	Research and Development
DARPA	Defence Advanced Research Agency
CE	Concurrent Engineering
CALS	Computer-Aided Acquisition and Logistics Support
NFS	Network File System
LAN	Local Area Network
EDM	Engineering Data Management
PCB	Printed Circuit Board
DEMI	Design Engineering to Manufacture Interface
PPCC	Product Planning Change Control
IADB	Issue and Archive Database
ENDB	Engineering Database
PLT	Product Launch Team
PDT	Product Development Team
PMT	Product Management Team
PTMs	Project Technical Meetings
PCMs	Project Control Meetings

1

Chapter 1

Introduction to Concurrent Engineering

1.1 Concurrent engineering

Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasizes the response to customer expectations. It embodies team values of co-operation, trust and sharing in such a manner that decision-making is by consensus, involving all perspectives in parallel, from the beginning of the product life cycle.[1]

This approach is not new. Many companies will argue that they have been practicing concurrent engineering for a long time, and to varying degrees, they are right.

1.2 Research Background on the History of Concurrent Engineering

In the 1980s, companies began to feel the effects of three major influences on their product development:

- New and innovative technologies
- Increasing product complexities
- Larger organizations

Companies were forced to look for new product development methods. One of the most significant events in the concurrent engineering time line took place in 1982, when the Defence Advanced Research Agency (DARPA) began a study to look for ways to improve concurrency in the design process. Five years later, when the results of the DARPA study were released, they proved to be an important foundation on which other groups would base further study.

In the summer of 1986, the Institute for Defence Analyses (IDA) report R-338 coined the term concurrent engineering to explain the systematic method of concurrently designing both the product and its downstream production and support processes. The IDA report provided the first definition of concurrent engineering:

“Concurrent engineering 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 developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, schedule, and user requirements.” [2]

The majority of companies today have agreed upon concurrent engineering as the recipe for instigating an outstanding practice that enables them to produce high quality, low cost products, at a faster rate to the market, and develop an edge on the competition. Concurrent engineering is a methodical and organised approach that brings together product design and process methods for the whole company.

1.2.1 The old, over-the-wall product development approach

In the past, product development was a slow and sequential process. Once one group completed its work, it ‘threw it over the wall’ to the next, as illustrated in Figure 1-1.

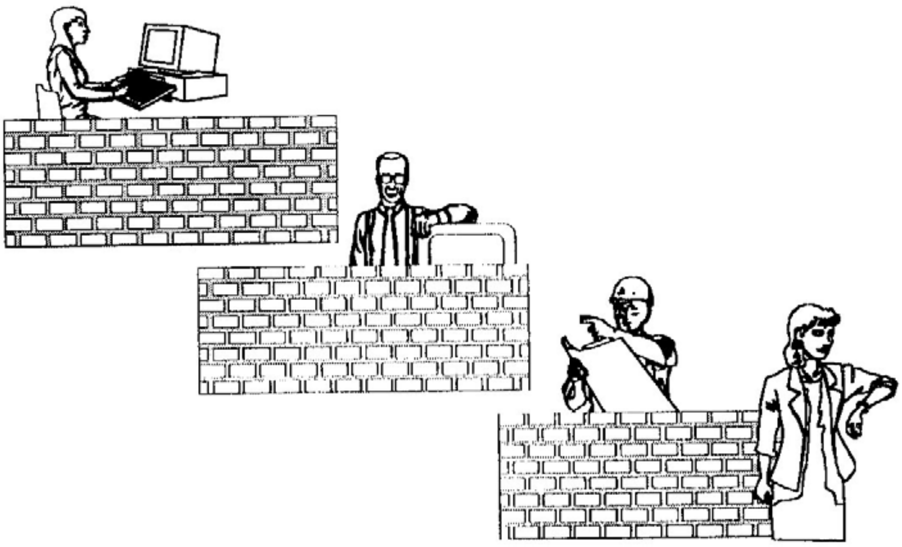

Figure 1-1: Over-the-wall product development process[3]

The old sequential product development process was no longer viable in today's competitive market place for many reasons. The key reasons that initiated the design process to progress into a concurrent engineering approach are:[4]

- Fast change in technology
- Forced design cycle time reduction
- New Information Technology (IT) and methodologies coming to light

Technologies are progressing at a very fast rate. Many companies took advantage of new emerging technologies and turned them into products securing market share. As for the other companies that were behind on their technology use, a lot of competitive pressure was put on them. Their design teams were driven by these pressures to develop products in a short time-to-market, and to offer a competitive edge to regain their position back in the global market. Some of these companies might have been able to pick up the pace again, but others faced an impossible challenge to draw near to the ever-progressing technology curve. The comfort of long product and development process cycles came to an end when the concept of short time-to-market – time taken from initial conception to shipping the product to customers – was introduced. It became a competitive scheme and a goal for many companies.

Because design engineering teams were put under pressure to develop products quickly, manufacturing and marketing contributions in the early design of products were pushed aside, considered as low priority, and sometimes did not happen since they were perceived to delay the design schedule or cause scope creep. Management determined requirements and specifications were the sole focus of the engineers, and product development was the only thing that they had time for. Production cost and manufacturability issues are owned by manufacturing engineers, while customers' needs and expectations are owned by marketing. Yet, only a small number of their proposals that did not have a setback influence on the general product development schedule were integrated into the design.

This all ended badly, as products did not meet the customer demands in the market. Manufacturing costs were high because of bad designs that were difficult to manufacture. Moreover, because of design inadequacies and defectiveness, multiple design iterations were necessary at the end of the development cycle, which in turn lead to major delays in delivering the completed designs on time. Hence, speeding up the design process was not the solution to reducing product development time.

The surfacing of workstations and Personal Computers (PCs) promoted the development of modern design technologies such as Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) to assist the product development process. As a result, use of these design technologies became extensive, more cost effective, and with enhanced capability. For example, CAD was no longer used just to execute what is an otherwise tedious task of precise drawings, but supported new capabilities like electronic assembly, multiple views, three dimensional solid object views (3D) and much more. CAE tools however, were being developed to assist in examining and analysing products from a more technically detailed approach – specifically simulation tools.

At the same time, the introduction of electronic communications helped speed up the development process through the use of electronic mail (email). Anything communicated is now electronically written and logged through email, which in turn holds individuals responsible for their contribution in terms of correctness and reliability. Furthermore, the time taken for individuals to respond to requests, and action items –

all of which are essential for project management – were easily traced through recording of email messages.

Understanding and predicting product functionality, cost to build, and meeting market demands is vital. Structured techniques introduced better approaches to understand these requirements. For example, Design for Manufacturing (DFM) reduces material and assembly costs. On the other hand, Quality Function Deployment (QFD) facilitates the evaluation of key product features and conformity of input from all functions involved – engineering, manufacturing, and marketing.

Therefore, we can say that design technologies and structured techniques together reformed the traditional product development process into a concurrent engineering one.

Other aspects such as organisational and behavioural basis – where a part of the issues related to the sequential product development process – influenced the establishment of concurrent engineering

As companies arranged their design functions in a divided manner, such that their organisations became self-directed, requiring very little or next to no contribution of input from the marketing and manufacturing functions on a daily basis. The divisions created organisational boundaries and restrictions that in turn negatively influenced the product development cycle. Once the design function think they have completed the designs, they pass them onto manufacturing, who then checked that the designs are producible without running over the cost budget because of unwarranted operations. Manufacturing then passes them back to engineering in an attempt to improve manufacturability and cost effectiveness. This process lead to a phenomenon that is referred to as the ‘over-the-wall’ syndrome, where each function passes the designs back and forth until they have reached functional success.[5] This technique formed a difficult barrier to the implementation of concurrent engineering. Figure 1-2 shows the functional focused development approach, which can go on for months frustrating both marketing and engineering.

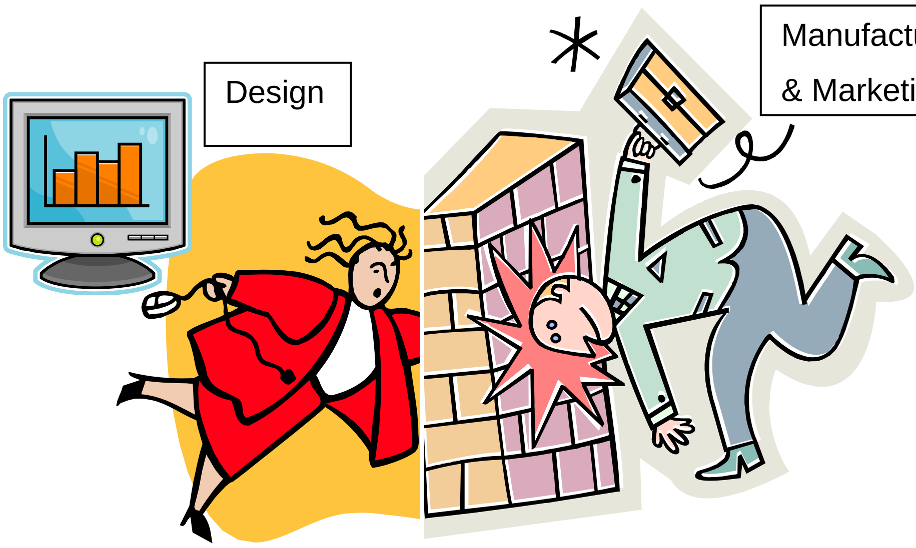

Figure 1-2: Over the wall functional focused development

Because the traditional sequential development cycle was forced to reduce its design cycle time, the engineers working in that environment did not have time to give to their functional role, or understanding the market needs and the newest movements in the world of manufacturing. Therefore, they replaced established manufacturing capabilities studies and formal manufacturing procedures with ideas from the manufacturing team, and information from sales leaflets, catalogues, and trade journals. They had little contact and discussions with their clients to set their market needs and expectations. Instead, they assumed their own engineering outlook over the marketing function's view.

On top of that, when engineering consulted with the marketing and manufacturing functions they allowed very little time for them to come back with thorough and well-supported responses. And so, the responses provided were experience-based, rather than by evidence and facts supported explicitly by modelling methodologies and market research. The lack of inputs into the design phase led the design engineers to believe that their vision was the only one that they could rely on. This attitude often ignored some excellent and concrete marketing and manufacturing information inputs.

This behaviour caused products to be designed in multiple iterations – usually a minimum of three. Iterations start with the conceptual phase of the design where marketing plans and inputs are required for management approval. A second iteration occurs during the development phase, where engineers performed what they thought was necessary – often missing considerable core features and marketing requirements from the previous phase. The third iteration begins as soon as the product commences manufacturing, by purging detail design slip-ups, and improving on the costs of manufacturability.

Since the product goes through so many iterations and alterations towards achieving functional success, the expectations and requirements of the marketing and manufacturing functions were rarely fulfilled. Design engineers made product compromising decisions, without taking into consideration the impact they made on marketing and manufacturing, resulting in trust issues in the design function. For example, the product ends up reaching the market with core features missing as mentioned previously, or the product itself is non-competitive and manufacturing is not capable of producing the product in keeping with the budget and engineering and marketing expectations. Over time, the functions of engineering, manufacturing and marketing lost faith in the ability of one another, and saw each other as the obligatory evil to complete their tasks.

Time reduction of the design cycle instigated the existing issues of functionally divided organisations to transform into business dilemmas, long design cycles, overspending in manufacturing, non-competitive products, and losing out on market prospects, as well as lack of trust across the different functions in the organisation.

1.2.2 The concurrent engineering concept

The basic concept behind the concurrent engineering approach is that all parts of the design, manufacture, production, management, finance, and marketing of the product are usually involved in the early stages of a product's design cycle, enabling faster product development through extensive use of simulation. Substantial design savings can be accomplished through incorporating all of the design cycles and utilising a computer workstation environment. This provides access to a commonly shared database where any alteration to a product design is updated and disseminated for all members of the design and support teams, however only key personnel have the necessary privileges to alter this data.

1.2.3 The concurrent engineering approach

The goal of concurrent engineering is that the preceding design activities should all be occurring at the same time, or concurrently, to significantly increase productivity, product quality, reducing cycle-times, manufacturing, re-work and quality costs – allowing errors and re-designs to be discovered early in the design process when the project is still in the concept stage.

In concurrent engineering is important to get the correct data to the intended person or tool at the right time, and in the precise format.

The large variety of software integrated into the electronic design environment has allowed multi-disciplinary teams to work in their own environment. Simultaneously, the electronic design environment contains commonly shared information that is utilised to simulate the entire system. Incorporating the expertise of the specialists into this facilitating environment where concurrent engineering can be carried out, results in enhancing the efficiency of the design process.

Concurrent engineering can be considered as a systematic approach that brings product development and processes together for the entire company.[6]

1.3 The Forces of Change Influencing Product Development

There are five fundamental forces that shape the product development processes. They are shown in Figure 1-3 below:

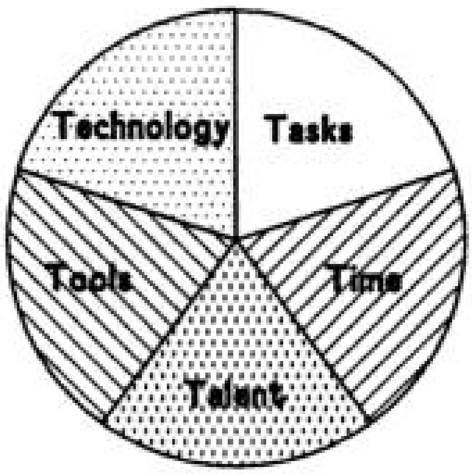

Figure 1-3: The five forces of change[7]

These forces are:

- Technology
- Tasks
- Tools
- Time
- Talent

The forces above exist in parallel (side by side) with product development, as well as being fully and uniformly incorporated in the product development environment. They can balance out or undermine a company's product development environment. The elements affected within the product development environment involve people and ideas – all of which are essential for product design, manufacture, and marketing.

In order for companies to subsist and successfully expand in the global market place, management must steer these forces towards prompt response to competition and higher productivity. Some facets of the five forces of change can be managed by means of organisation and strategies contained by the product development environment. Others are managed by a company's interaction with the resources outside this environment.

1.3.1 Examining the influence of the five forces of change

A set of questions was formulated by Donald E. Carter of how a company should view and work with the five forces of change.[8] These are:

Technology. How successfully does your company take advantage of those technologies that are currently available? Are you a technology leader in your market place? Are the product interfaces built on industry standards? Do you have a long-range vision for your product that will guide the technology you use and develop? Are you developing technologies that will provide product leadership?

Tasks. How are tasks defined, then divided up, and managed effectively – especially as they increase in complexity? Is the task process continually improved upon to achieve increasing levels of quality and productivity? Would the automation of tasks increase your efficiency?

Tools. What are the best tools to use? What level of automation is required? What level of compatibility and integration is required? How well is your company managing the impact of new tools on your employees and their tasks? Are you actively working with other industry leaders and associations to standardise tool interfaces? What data is required by the tools and how will that data be managed?

Time. How does your company shorten product time-to-market? How do you quickly introduce product improvements? What are the metrics for improving the product development cycle time?

Talent. How does your company get talented employees to work effectively, and of greater concern, how do you ensure a long term supply of talent? Do you provide interesting and challenging jobs with continuing training and education? Do managers help to keep employees satisfied and empower them by relinquishing authority? Do managers understand and communicate company’s vision?

The way a company works with one of these forces influences what they have to do with another. For example, deciding on technologies influences the choice of tools. The tools used could condense time-to-market. Another example is, the way tasks are structured can impact how well workforce talents are used, the quality of their Research and Development (R & D), and the time necessary to perform these tasks.

In order for a company to successfully compete in the global market, they must realise and accept that these forces are part of the living corporate fabric that is being continuously woven and re-patterned. These forces can be turned into valuable resources with the help of innovative and efficient management.

1.4 The Scope of the Thesis

This thesis discusses the concept of and philosophy behind concurrent engineering, starting with where the product development process was, and how it evolved into concurrent engineering. In addition, it provides an insight into exercising concurrent engineering. This thesis researches strategies and implementation paths for the development of proficient, efficient, project focused, cost effective and on-time product development teams.

Concurrent engineering techniques are driven by information technology that influences the communication infrastructure supporting product development. Many companies support the concept of 'virtual teams' where engineering teams are made of individuals from different disciplines, and possibly outsourced specialised skills contractors. These teams initiate new standards in the communication infrastructure dimension that improve product quality and time to market.

The communication infrastructure dimension has been the lynch pin of concurrent engineering. In the past, there have been a number of studies that looked into exploiting concurrent engineering and its key dimensions (which include the communication infrastructure dimension). [5, 8, 9] In those studies a number of technology areas and tools related to communication were researched. For instance, Thomas A. Salomone [5] discusses a selection of tools and technologies that have been a major factor in the emergence of concurrent engineering. Other studies like Backhouse and Brookes [2] illustrate the application of computerised tools and technologies as central to a company's implementation of concurrent engineering. However, no one study has directly focused on the communication infrastructure dimension in concurrent engineering in detail, but rather was covered in general with the rest of the dimensions that make up the concurrent engineering approach. Therefore, this thesis will explain the communication infrastructure dimension concept, some of the technologies for communication and collaboration, and their significance to the concurrent engineering process. The idea is not to focus on any one company's tools, or one tool versus another, but rather to give a general overview of how the tools and technologies are utilised to influence the overall concurrent engineering process. It goes over employing the concurrent engineering approach from a communication infrastructure point of view using a tool to aid in assessing the current development process and envisioning a concurrent engineering environment that would help the product flourish. Finally, it will illustrate through examples of case studies how companies have implemented concurrent engineering by choosing to focus on the communication infrastructure. This study will demonstrate the importance of the role that the communication infrastructure plays in the successful implementation of concurrent engineering.

The chapters of this thesis are arranged as follows:

In Chapter 2 the four dimensions – organisation, communication infrastructure, requirements, and product development – that make up concurrent engineering are briefly explained, and hints that the communication infrastructure dimension is philosophically based.

In Chapter 3, the concept of the communication infrastructure is introduced in more detail, as well as some tools and technologies that support communication and collaboration.

Chapter 4 introduces and talks about the four concurrent engineering approaches – task, project, program, enterprise – and how each one of these approaches corresponds to a certain type of team effort that a company must carry out in order to implement a successful concurrent engineering environment. It then describes an assessment tool that aids in employing the right concurrent engineering approach, and its four parts, focusing on the communication infrastructure key dimension.

Chapter 5 illustrates through case studies of three different companies the application of concurrent engineering – IBM, Instron, and D2D – and how they invested heavily in information technology support tools. It shows that all three companies have developed sophisticated electronic communication capabilities that facilitate rapid evaluation of product designs by development team members at geographically dispersed sites. It then establishes that the application of these tools is seen as essential to implementing concurrent engineering.

Chapter 6 concludes the thesis with a summary, and suggestions for future directions for additional study.

2

Chapter 2

Rejuvenation and Success

2.1 Introduction

Successful companies today will learn to manage the changes needed to ensure continued productivity in the global marketplace – getting the highest quality, lowest cost product to market in the least time. To manage the forces of change, a company (or division in a corporation) must have a product development environment that uses concurrent engineering to produce its basic product – whether it is as complex as a space shuttle or as simple as a pressure gauge. Simply stated, the often sequential and fragmented product development environment of the 1980s and early 1990s must transform itself into a concurrent engineering environment for today. The concurrent engineering environment is a co-operative and collaborative one, as illustrated in Figure 2-1 which shows how knocking down the old walls opens up opportunities for greater input into the earlier stages of the development cycle.

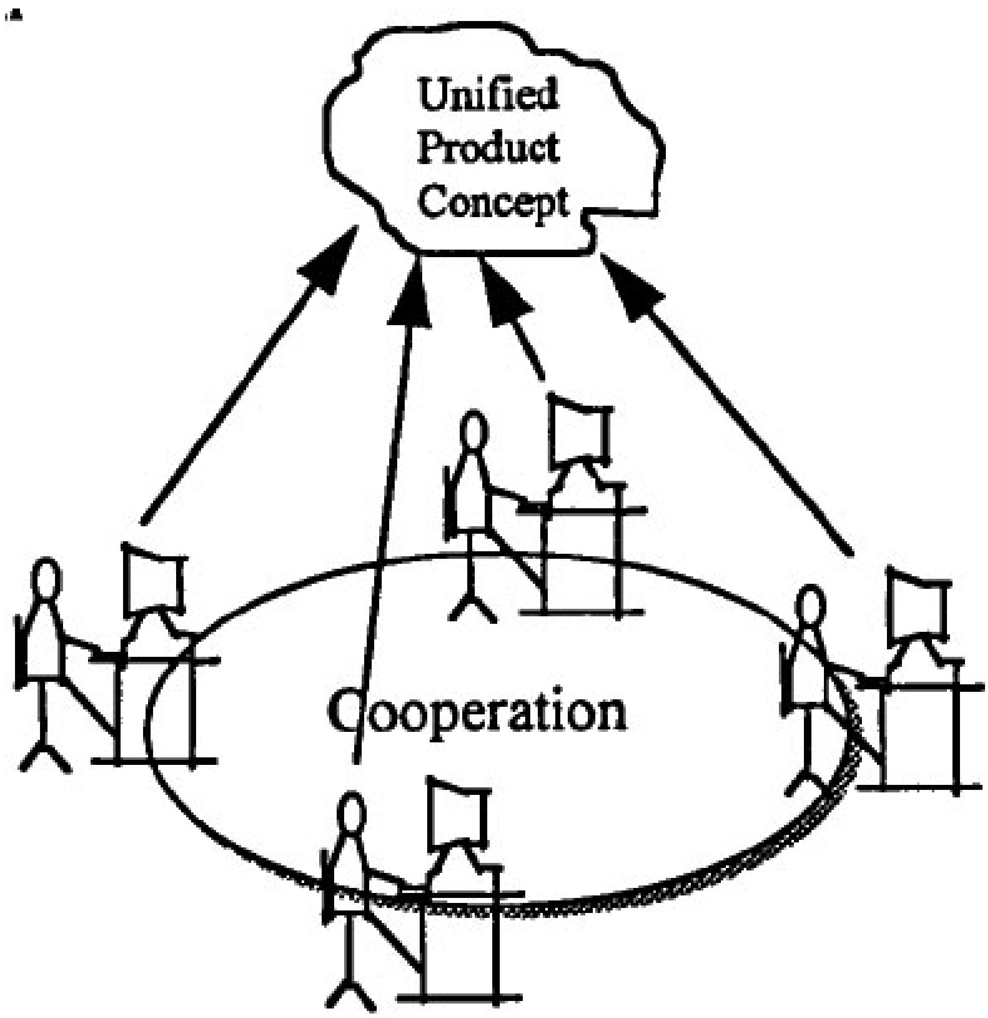

Figure 2-1: Collaborating – knocking down the old walls [10]

When a company decides to initiate the transition to a concurrent engineering environment for development of its product, it makes a commitment to harness and control the five forces of change that keep sweeping through the product development environment: technology, tools, tasks, talent, and time.

The way to nurture and keep control of these forces – reshaping them into resources for change – is to create a dynamic environment whose foundation is not cast in concrete, but rather in four interconnected dimensions: the organization of managers and employees, their means of communicating, their unwavering focus on what the customer wants, and the development process by which the product evolves, adapts, and continues to sell.

2.2 The Four Key Dimensions of Concurrent Engineering

The five forces of change are managed in a Concurrent Engineering environment. This environment always has at least four key dimensions as illustrated in Figure 2-2. The shape of these dimensions and their relative balance continually shift, depending on the specific product and the current market forces. The following is a summarised view of each dimension:[11-15]

Organization: Managers and the product development teams are the two key parts that form this dimension. Managers must create, empower and support product development teams whose number of individuals and included disciplines are based on the complexity of a product. Development teams must assume authority and responsibility for their design decisions, and individual members must commit themselves to team decisions.

Communication infrastructure: Linking people, ideas, specifications, processes and feedback are characteristics of a good and sound communication infrastructure. Related information from the other three dimensions should easily infuse into this dimension and be available as team members require it.

Requirements: This dimension has a given form at a particular instant in time: the sum of customer, company, and industry requirements for a product. This dimension focuses on customer requirements, and most requirements are viewed, to some degree, in terms of factors that influence customer acceptance. Companies need to determine what their customers want, make certain that they are getting it, and make certain that the product meets formal company standards as well as industry standards. Two vital company standards are to exercise the following:

- Planning strategies
- Planning standpoints

These standards help drive and energise the other dimensions.

Product development: For each individual company and its product(s), this dimension has a stable outline because of its integrated vision of the total product development process – from design conception to manufacturing and support. This method develops libraries of components, takes into account downstream processes early in the design, and endeavours to continually improve the product development process.

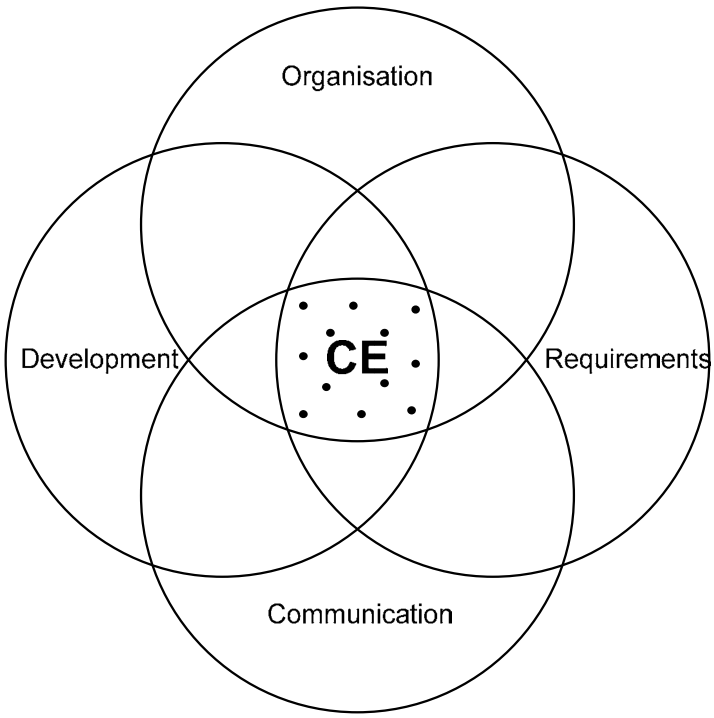

Figure 2-2: The four Dimensions of Concurrent Engineering[7]

2.3 The Perfect Equilibrium in a Concurrent Engineering Environment

If each dimension was in relative harmony with the other three, the result would be a balanced concurrent engineering requirement. This environment can be found in an organisation of one – an individual who has no business with other employees and developing a simple product or service.

This individual is both the product development team and the manager. There is one communication path for all information. As well as the responsibility for meeting customer requirements, this individual must keep in mind the total product development process. In this perfect environment, the manager is the only individual with with one purpose and one set of priorities. The technology for a communication infrastructure may be a computer, a cell phone, and a few other tools; the end product or service is expected to satisfy customer requirements, because only one individual needed to understand the requirements and keep track of their implementation. All processes, from design to manufacturing, marketing and sales, are in the hands and intellect of the one person, and are almost concurrently applied to all aspects of the product or service development.

This idealism of concurrent engineering rarely exists beyond a single employee company.

Larger companies have to continuously examine the dimensions of concurrent engineering and adjust each one to bring it into balance with the others. Each of these dimensions has its own internal factors that can be reinforced in a way to positively influence the environment.

Fixing issues in one dimension does not necessarily mean that it will also solve problems in another. For Example, changing customer requirements does not solve issues in the communication infrastructure.

All four dimensions in a concurrent engineering environment are separate, but they interact with each other. Hence, the focus can be on fine-tuning that environment for success. Understanding these four dimensions makes the company's move to a concurrent engineering environment both possible and manageable. Assessing the degree to which these dimensions are already in place, can help companies work more effectively.

3

Chapter 3

The Communication Infrastructure Dimension

3.1 Introduction

This chapter focuses on the communication aspect of concurrent engineering – one of the four dimensions mentioned during earlier discussion in chapter 2. Detailed discussions of the remaining three dimensions are outside the scope of this work.

3.2 Communication Infrastructure

The dimension of communication infrastructure has a philosophical aspect. Its creation is usually based on some manager(s) decision as to what are the most effective means of communication. Therefore, reflecting someone's belief about what works for a company producing a specific product or service of certain complexity.

3.2.1 What is communication infrastructure?

Any system, equipment, or software that facilitates the meaningful movement of information.[16] Naturally, in concurrent engineering one or more teams work together and share information in an integrated product development environment; hence, effective communication is crucial for success.

Regardless of how simple or complex a product can be, communication problems can arise and impede or even stop team activities. Even when teams are clear about the purpose of their work, their priorities, have plentiful employees, adequate time, abundant materials, and adequate technology, the overall purpose of the team effort covering a project, task, program, or enterprise, does not always succeed. The more complex a product becomes, the more likely that its development will fail before reaching its technological limitations if the existing communication infrastructure does not properly support the necessary types and volume of information. The communication infrastructure must expedite important information to the right people.

It is vital to understand that the concurrent engineering environment does not focus on numbers of people in determining the shape and contents of the communication infrastructure dimension, though undoubtedly it is a factor. The greater the number of people involved in a project, the higher the chances of poor communication to occur. For example, a project involving 1,000 individuals with 99% of communication paths eliminated, still leaves approximately 5000 paths.[8] Figure 3-1 illustrates the communication paths formula.

However, thousands of paths of communications between thousands of individuals can be achieved simply through email. The fact that it is simple for these individual-to-individual communication paths to be in place results in the focus of this dimension quickly shifting to collaboration, and the infrastructure determines the degree to which information or data from different disciplines can be meaningfully organised and accessed by development team members in order to create a shared understanding of the product or service and the processes involved in developing it.

The complexity of a product or service can determine the number of disciplines involved, and both of these determine the type of infrastructure needed to share information or data. Increased components and disciplines results in component data being more varied and un-integrated, which in turn requires more complex infrastructure that can integrate the data and keep everyone informed about activity in the concurrent engineering environment and each individual's respective role.

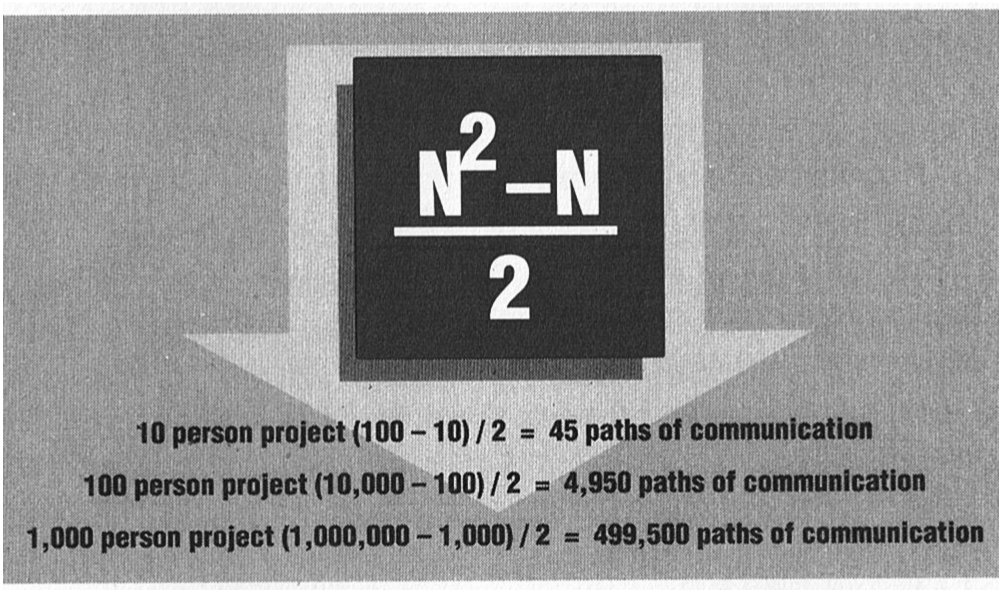

Figure 3-1: Formula for potential communication paths in a project [8]

When communication infrastructure is in balance with the other dimensions, it can nurture and support them.[8] Nevertheless, when not in balance, the process of collaboration breaks down, and the development teams lose the fundamental, desired behaviour of the product. This can result in:

- The product losing its functionality
- Delays in manufacturing
- Problems in testability
- Loss of customers

These are the reasons why no one company should neglect the technological requirements of the communication infrastructure dimension.

3.2.2 Different technologies that support communication and collaboration

Communication infrastructures provide the backbone technologies that support the communication and collaboration necessary for the product development life cycle. These technologies help in realizing and defining what should be built, how to build it, and is the final product or service doing what it is supposed to do as per original design goals. When viewed from this angle, these communication technologies are likely to be just as vital for the product's success as the technologies used in the actual development of the product.

Examples of technologies that must be in place to support product realization and definition can be electronic mail systems, databases holding customer requirements, product related data such as warrantee information and field defects, closed-loop corrective action systems such as problem reporting and defect tracking systems, and lastly monitoring and evaluation systems.[17, 18] These technology examples also enhance communication of published findings, and garner requirements and definitions from ongoing development activities.

As the level of effort and complexity in a concurrent engineering environment gets higher, the level of the technological support should correspond to it accordingly. The concurrent engineering environment for a complex product envelopes all the more basic communication technologies required for simpler products as well as those required for the more complex infrastructure. Figure 3-2 shows the much needed changes in the communication infrastructure in order to move from a traditional sequential product development to a concurrent engineering one.

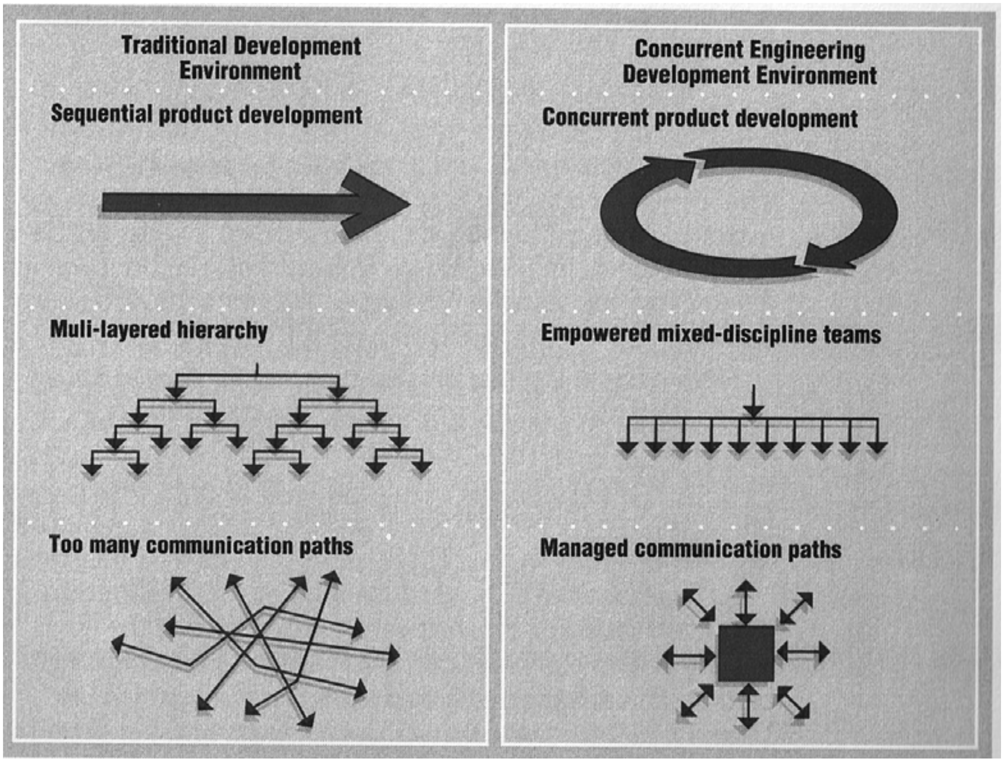

Figure 3-2: Changes required in the communication infrastructure [8]

3.2.2.1 Different supporting technologies

3.2.2.1.1 Design database

Communication technologies support realization and definition all through the product development life cycle in a variety of methods.

Product development teams consisting of only a few disciplines usually entail that the team is small and that the development process, present customer requirements, and product are quite simple, so a simple solution such as an electronic mail system suffices as means for linking information about the design to ongoing activities. In this case, individuals may hold important information in their memory, their computers, or file cabinets, and thus to get that information requires asking the right individual.

However, with more disciplines involved, the use of a design database with query and reporting capability becomes critical. This database can be accessed by the development team members and design tools to compile information about the design into various usable forms, such as legacy of design problems and lists of possible replacement parts.

As the level of product complexity increases, the need for an interactive browsing capability arises. An interactive browser should be accessible to both the development team members and design tools, to assist in rapid interactive access to a design database that may actually be composed of the design-related data contained in several databases from several disciplines. A single database for design data may not exist. An example of this is that a design engineer easily checks all the information about a specific design feature (manufacture problems and customer acceptance criteria) by browsing through all the databases in the concurrent engineering environment.

3.2.2.1.2 Design knowledge databases

When development is composed of programs that include projects with multiple defined tasks, managing this development requires automating as much of the process of discovery and definition as possible.[19] One way of doing this is by using a design decision database to organize the project design requirements, design decisions, and data for a discipline-specific design. This database serves as the design knowledge database and may include interactive and automatic decision support for the ongoing product development life cycle.

3.2.2.1.3 Interactive reporting and monitoring systems

In order to utilize the design knowledge database, it is necessary to have a system in place that can evaluate, organize and retrieve information in usable ways, along with managing and reporting systems to expand the knowledge database. Management and reporting systems must:

- Track the decision process
- Monitor and evaluate the progress and quality of decisions
- Track problems associated with product development process activities
- Maintain links to outside sources of information

High complexity products require that management and reporting systems are interactive with all phases of the development life cycle. An example of this can be, as an engineer is designing a product the reporting system informs the engineer of cost issues such as a component cost going over the projected budget, as well as manufacturing issues like atypical manufacturing procedures.

3.2.2.1.4 Recording and making the most of the decision path

Documenting the thought process behind a product's design and development involves that the design knowledge database must be interactive with a managing and reporting system that can capture the decision path.

Team members communicate the discovery and change of definitions of what is going to be built, however, the knowledge database must be kept up to date through recording the evolving design requirements and decisions, so that afterwards anyone can trace the decision paths – which design change came from what requirements and decisions.

At the start of the design process, the managing and reporting system must be active as it captures and traces the conceptual requirements that lead to the behaviour of the design, and over time, captures and traces the detailed design decisions. All interactions among team members, customers, and industry standard committees that lead to design decisions are ideally encapsulated in the record of this decision path. Thoroughness and discrimination are essential in the managing and reporting system that tracks and documents the decision paths and stores the related data in the knowledge database, so that the reasons behind these decisions are clear.

As time goes by, the product matures and new features are added, therefore a monitoring and evaluation system can use the knowledge database to assist team members in making decisions that result in the clean maturation of the product's design and implementation. This method increases the product reliability and extends its life.

Experiences captured in the design decision path associated with prior projects can be of assistance and benefit to new projects. A design knowledge database can help bring new people on a project up to speed rapidly by understanding and appreciating why decisions were made. In addition to design data, the knowledge database reflects the organization of a project, including what processes were utilized and what tools were needed. An example of this can be a vast number of design decisions made with each product add-on or enhancement. Most of these decisions are forgotten or lost, often because the key people who were involved in those decisions are no longer available. When decisions are stored as part of the design knowledge database, engineers working on the next release would greatly benefit from it by understanding the decision path to previous decisions.

3.2.2.1.5 Problem tracking systems

The notion of problem tracking systems that assist in the test and support phases of a project can be extended to a similar system that supports the entire product development process. Information such as problems associated with the design and the development process can be contained within the knowledge database. As designs become more complex in nature and more design dependencies are created, the managing and reporting system helps resolve present problems and prevent new problems by generating new action items, prompting people for pending action items, and reporting on the status of existing action items.

3.2.2.1.6 Connecting to a library of knowledge

The design knowledge database comprises a wealth of easily accessible reference material such as programming manuals, interface documents, internal procedure manuals, industry standards, and component libraries. Actual designs of related internal projects are also considered reference material. In addition, published research from other countries and companies may influence design and manufacturing.

A further type of interactive managing and reporting system gathers and sorts this reference material consistent with what is happening in the concurrent engineering environment. As team members utilize this information, the managing and reporting system documents its use and provides for comment systems, such as a hypertext product that automatically links documents together, so that an individual can document their thoughts about a particular subject and link comments to the appropriate material in the knowledge database. An example of this is a programmer reviewing functional requirements using the Wikipedia and leaving their comments about their thoughts on the subject material page.

The principle for the previous examples about using communication technologies is not to suggest specific systems, equipment, or software, but rather the processes and functions that need to be performed by whatever communication technologies a company uses. As per prior suggestion, the choice of which feature-specific technologies should compose the communication infrastructure is purely “philosophical”. It is the duty of one or more individuals – the management – who know the company’s vision and understand what the different teams, employees, and their tools require for efficient communication and continued success.

4

Chapter 4

Employing the Concurrent Engineering Approach

4.1 Introduction

The concurrent engineering environment is today's necessity for companies who want to prosper and succeed. Customer's purchase decisions are influenced by various factors: [4, 9]

- Is it of better quality?
- Is it cheaper?
- Is it faster?

These factors demand changes in the four dimensions: product development, organization, communication infrastructure, and requirements. In order to satisfy customer demand a company must ask which concurrent engineering approach does it require, rather than asking, does it require concurrent engineering?

4.2 Determining the Scope of the Concurrent Engineering Environment

Usually it is the product, including its parts and processes required to develop it, which determine the scope of the concurrent engineering environment.

4.2.1 Simple products

Simple products generally allow a simple approach. For example, a product can be an electric fence energiser, and so the concurrent engineering approach possibly will be simple, as well as the number and type of methods to implement it, because overall the tasks and purpose of individuals are ultimately the same (to build and produce the electric fence energiser).

4.2.2 Complex products

In complex products such as a jumbo jet – including many parts, add-on features, and complicated development process – individual tasks only contribute to the development process. Bridging must be applied over the gap between the company's overall purpose and the individual tasks. Therefore, the product necessitates the need for a more extensive concurrent environment. For this example, the most successful concurrent engineering approach is the one that would populate the four dimensions with many suitable tools, tasks, technologies and talents – these are the means for change that fuel the product development in a timely manner. This concurrent engineering environment employs any technique required to utilize these means productively.

Regardless of the type of product a company might have, these means for change must be provided by utilizing techniques that bring into balance the four dimensions of concurrent engineering. Ordinarily, the techniques can be grouped into four concurrent engineering approaches. These approaches are task, program, project, and enterprise. Individual approaches each correspond to a specific type of team effort that the company should make to have a concurrent engineering environment that functions.

A brief synopsis of each approach is described below.[8, 20-22] These descriptions are broad-spectrum so they apply to most products.

Task:
A task effort is required when the product under development has only one main unit and only requires a few individuals to develop it.

Project:
The product under development has multiple similar units, thus requiring a group of individuals in the same engineering discipline, forming a single-discipline team that represents a project effort (covering task efforts).

Program:
The product has different units, thus requiring different engineering disciplines. Individual units may have their own team, called a project team. Representatives from each project team can create a mixed-discipline program team, which manages the overall development process and encourages communication across different disciplines. The product uses a program effort, which includes task and project efforts.

Enterprise:

This indicates that a company's broad team effort is an enterprise effort that includes task, project, and program. Usually, the product is very complicated and requires the presence of many mixed-discipline teams – program teams – that could incorporate third-party vendors, and a level of communication that necessitates an enterprise team.

Generally, the descriptions above outline which overall concurrent engineering approach a company needs to take. However, the real merit is in knowing which techniques can implement each approach.

As seen in the descriptions above, the approaches are incremental. For example, in order to implement the program approach, the task approach must be implemented, followed by the project approach. Companies may already have some of the resources for the changes that a concurrent engineering environment needs. These resources must be used effectively to keep the four concurrent engineering dimensions in equilibrium. Bringing these dimensions into equilibrium creates a highly productive and efficient development process that is critical to success and securing customers and markets.

The question now is, what are the techniques that implement each approach in a way that brings the four dimensions of concurrent engineering into equilibrium?

The answer would be: A company must assess where it is right now, and where it needs to be. Using this assessment provides an overall vision of a concurrent engineering environment, one that enables further investigation of the changes required to continue to stay on top.

4.3 Assessing the Current Product Development Environment

The assessment tool used in this chapter is a concurrent engineering assessment. It blends elements from other assessment tools such as the Mentor Graphics Corporation Process Maturity Assessment Questionnaire, Carnegie Mellon University Software Engineering Institute Assessment Questionnaire, and the Department of Defence CALS/CE Task Group for Electronic Systems Self Assessment.[8, 23-25] The focus of this tool is to assess and improve the concurrent engineering aspect of communication infrastructure. It is only a starting point, to help provide a general view of the current product development process, and concurrent engineering environment.

This tool facilitates:

- Looking at a company's current product development environment
- Proposing a vision for a concurrent engineering environment that would help a company's product grow
- Demonstrating what a company needs to do to bring the four dimensions of concurrent engineering into equilibrium
- Designing a roadmap to convert a company's product development environment into a concurrent engineering environment.

The tool introduced here comprises four parts:

1. Company assessment questionnaire:
   Assists a company in establishing the current state of its product development environment relative to the four dimensions of

concurrent engineering and to main areas within each individual dimension.

2. Methods Matrix:
   Assists in establishing the general concurrent engineering methods that a company requires in order to develop its product successfully. It does this by analysing dimension by dimension, and approach by approach. It produces the concurrent engineering vision that a company ought to have.

3. Dimensions map:
   Demonstrates the variances in each concurrent engineering dimension between where the company is at, and where it should be. It provides recommendations to facilitate implementing the vision in such a way so that the dimensions are in equilibrium.

4. Priority roadmap:
   Helps establish priorities for starting to bring the dimensions into equilibrium. These priorities implement the concurrent engineering vision for the company.

This is not be used as a scientific measure to stipulate exactly what a company needs to do, but rather to demonstrate a general idea of the type of change that is necessary for a company to create a concurrent engineering environment. This tool is merely a starting point for a vision in the near future. Another use for it is to discover where attention should be focused and perhaps increasing resources.

4.4 Finding Out Where the Company Currently Stands with its Communication Infrastructure

In order to find out where a company currently stands it is vital to personify the present development environment in which a company develops its product. Thus, a company assessment questionnaire is required. In bigger companies, diverse products can exist and as a result, the focus should be on the development environment for one product that the company promotes. To utilise the company assessment questionnaire successfully, the questions must be answered in relation to the company's current development environment rather than future plans to change it.

These questions are categorised relative to the four dimensions of concurrent engineering, and further clustered into key areas within each dimension. The focus will be on the communication infrastructure section of the questionnaire as part of this work.

Concurrent engineering engages all disciplines into the design of the product. Consequently, utilising effective communication paths and tools to manage tasks, employees, product information, and changes to the product grows to be crucial for success. In order for teams and individuals to understand the product development process at any time, the decision rationale, decision consequences, operational product data and lessons learned must be tracked. Communication between all workstation tools and between individuals is critical; it establishes how data is obtained and distributed within each of the concurrent engineering approaches – task, project, program, and enterprise.

The communication infrastructure questionnaire investigates where the company currently stands in terms of key factors that personify this dimension in a concurrent engineering environment.

The key factors or areas are:

Feedback:

The feedback factor keeps the product development process on course and allows teams and individuals to manage divergence from the functional specifications, customer expectations, industry and law standards, as well as other requirements. Feedback coming from reviews such as walk throughs, technical reviews and inspections produces action items plus suggestions for improvements to the product.

Product data:

Product data must always be absolute and precise, so that teams and individuals can access, use, and modify the data as fitting.

Product management:

Successful communication paths are fundamental to product management in order for teams and individuals to understand their designated roles and goals, facilitate setting up the development process, check that roles and goals are achieved, and enhance the process as required.

4.4.1 Sample questionnaire

These are sample questions only, and supplied for the purpose of illustration rather than an exhaustive list. They can be added to or modified to suit specific product development environments.

The answers are either agree or disagree. Answering with 'agree' must only be used if the company sufficiently and unswervingly executes the action implied by the question.

Feedback:

1. Are issues investigated and traced to their root cause, then rectified? Agree/Disagree

2. Are issues logged, given a severity, priority, scheduled for rectification or dismissal, and followed through until they are resolved? Agree/Disagree

3. Are action items, improvement suggestions, and reported issues stored in a decision database, and used as a guide for customer satisfaction? Agree/Disagree

4. Are trends that emerge from action items, improvement suggestions, reported issues, as well as other business decisions evaluated to constantly enhance the development process? Agree/Disagree

Product data:

5. Is the product development data managed by each person? Agree/Disagree

6. Do individuals in a single-discipline team have full access to the entire product development data related to their discipline? Agree/Disagree

7. Do individuals have electronic access to product development data related to the diverse disciplines involved in developing the product? Agree/Disagree

8. Do teams as well as individuals have electronic access to cross-company product development data (including customer data and supplier data)? Agree/Disagree

9. Are the product development functional specifications and designs documented and used in a determined manner during the product development process? Agree/Disagree

10. Is product development data stored, managed, modified, and version controlled in a shared computer database? Agree/Disagree

11. Is product development data in the database interoperable with the different design automation tools? Agree/Disagree

12. Are the product functional specifications, requirements, and development data under automatic change control and version control? Agree/Disagree

Product Management:

13. Does each individual have access to electronic mail resources? Agree/Disagree

14. Does each individual have access to online reporting and query facilities? Agree/Disagree

15. Does each individual have access to interactive product data browsers? Agree/Disagree

16. Can each individual obtain decision support? Agree/Disagree

17. Are technical reviews and inspections carried out after achieving each objective? Agree/Disagree

18. Do project efforts undergo constant and disciplined product management? Agree/Disagree

19. Does a communication path exist between the system requirements and all facets of project management? Agree/Disagree

20. Is information about issues and their status instinctively and concurrently broadcasted to managers and co-dependent project teams? Agree/Disagree

4.5 Establishing Where Communication Infrastructure Should Be

A company must select a product that is either current or future targeted before considering which concurrent engineering method would boost its success in developing it. The methods matrix (shown in Table 4-1) assists in establishing the approaches a company can utilise in its product development environment in order to make the most of concurrent engineering.

Key Factors	Approach			
	Task	Project	Program	Enterprise
Feedback	Issues are investigated and traced to their root cause, then rectified.	Issues are logged, given a severity, priority, scheduled for rectification or dismissal, and followed through until they are resolved.	Action items, improvement suggestions, and reported issues are stored in a decision database, and used as a guide for customer satisfaction.	Trends that emerge from action items, improvement suggestions, reported issues, as well as other business decisions are evaluated to constantly enhance the development process.
Product data	The product development functional specifications and designs are documented and used in a pre-determined manner during	The product development data is stored, managed, modified, and version controlled in a shared computer database.	Multi-discipline product development data in the database is interoperable with the different design automation	The product functional specifications, requirements, and development data are under automatic change control and version

	the product development process.		tools.	control. Live data is obtainable throughout the enterprise.
Product management	Each individual has access to electronic mail resources. Technical reviews and inspections are carried out after achieving each objective.	Project efforts undergo constant and disciplined product management. Each individual has access to online reporting and query facilities.	Product and system designs are interrelated. Each individual has access to interactive product data browsers.	Information about issues and their status is instinctively and concurrently broadcasted. Each individual obtains decision support.

Table 4-1: Communications infrastructure methods matrix

To utilise the decision matrix, the descriptions across from each key factor must be selected in a way that reflects the approach(s) necessary for successful development of the selected product. None, several, or all four of the descriptions may be selected, depending on what is essential to a company for instigating that key factor and the overall process it suggests (as shown in Table 4-2). A rule of the thumb is that the more complicated the selected product is, the more likely it is that more descriptions are selected per key factor.

4.5.1 Establishing which concurrent engineering approach is best to employ

Key Factors	Approach			
	Task	Project	Program	Enterprise
Feedback	Issues are investigated	Issues are logged, given a	Action items, improvement	Trends that emerge from

	and traced to their root cause, then rectified.	severity, priority, scheduled for rectification or dismissal, and followed through until they are resolved.	suggestions, and reported issues are stored in a decision database, and used as a guide for customer satisfaction.	action items, improvement suggestions, reported issues, as well as other business decisions are evaluated to constantly enhance the development process.
Product data	The product development functional specifications and designs are documented and used in a pre-determined manner during the product development process.	The product development data is stored, managed, modified, and version controlled in a shared computer database.	Multi-discipline product development data in the database is interoperable with the different design automation tools.	The product functional specifications, requirements, and development data are under automatic change control and version control. Live data is obtainable throughout the enterprise.
Product management	Each individual has access to electronic mail resources. Technical reviews and inspections are carried out after achieving each objective.	Project efforts undergo constant and disciplined product management. Each individual has access to online reporting and query facilities.	Product and system designs are interrelated. Each individual has access to interactive product data browsers.	Information about issues and their status is instinctively and concurrently broadcasted. Each individual obtains decision support.

Table 4-2: Part filled methods matrix

After selecting or highlighting descriptions in the methods matrix, the next step is to find out which concurrent engineering approach, whether it is task, project, program or enterprise, is best suited for realising a concurrent engineering environment for the selected product.

Selections for key factors are usually made from left to right and without a gap between them. The most recurrent number of descriptions selected for all the factors concludes which of the four concurrent engineering approaches is most suitable for the product chosen. In the example above, the chosen product visibly requires a project approach, and also incorporates the methods selected under the task approach.

4.5.2 Checking discrepancies

It is vital to investigate the discrepancies in the methods matrix and recognise how all the methods for each of the key factors function best as part of a single consistent approach. These discrepancies come about when a description for a simpler approach is not selected (for example Task Approach and Feedback in Table 4-2), or a description for a more complicated approach is selected (for example, selecting Program Approach and Product Management). When the simpler description is not selected under the general approach, which the selected product requires, it is recommended to review the methods for that key factor. Not employing the methods of the simpler approach may cause issues to roll through the development process, since the methods that sum up the approach the product requires are all correlated.

On the other hand, selecting a description for a more complicated approach than what the product requires causes the efficient use of resources to deviate.

If these two sorts of discrepancies in approach are not eliminated, they can destabilize the four dimensions equilibrium. In addition, these discrepancies can also direct focus to which factors in the communication infrastructure dimension demand further attention and investigation.

Establishing which concurrent engineering approach the product selected for assessment requires, provides a concurrent engineering vision for that product. The methods matrix presents a good overall picture of the processes and methods required to define and have the four dimensions in equilibrium, in order to successfully develop the selected product.

4.6 Turning the Vision into a Reality

In order to generate a roadmap to set up a successful concurrent engineering environment, initially the assessment data from both the company questionnaire and the methods matrix must be compiled, and then the results examined. From the results, actions can be defined. These actions are what the company is required to adopt to achieve a concurrent engineering environment that is in keeping with the vision realised through the methods matrix.

4.6.1 Mapping out the results using the dimensions map

To visualise where the company is at and where it should be, the dimensions map – third part of the concurrent engineering assessment tool – is used to graphically map the assessment data from the company questionnaire and the methods matrix as illustrated in Table 4-3 below).

Communication Infrastructure					
	Feedback	Product Data		Product Management	
Enterprise	4	8	12	16	20
Program	3	7	11	15	19
Project	2	6	10	14	18
Task	1	5	9	13	17

Table 4-3: The dimensions map

The map is divided into 3 columns according to the key factors, and four rows corresponding to the concurrent engineering approaches. The numbers represent the questions from the company assessment questionnaire, and they are distributed according to the key factors and approaches to which they correspond.

Answers with ‘Agree’ from the company assessment questionnaire are marked on the map next to the corresponding question number and the ‘Disagree’ answers are not marked. Then, the outermost marks are connected as in Table 4-4 below.

Communication Infrastructure					
	Feedback	Product Data		Product Management	
Enterprise	4	8	12	16	20
Program	3 •	7	11	15	19
Project	2 •	6 •	10 •	14	18 •
Task	1 •	5 •	9 •	13 •	17 •

Table 4-4: Assessment questionnaire data applied

Previously, the concurrent engineering approach necessary to develop the selected product was determined through using the methods matrix. That result relates to one of the rows in the dimensions map. A red line is drawn along the row that relates to the approach the selected product requires. See Table 4-5 below.

Communication Infrastructure					
	Feedback	Product Data		Product Management	
Enterprise	4	8	12	16	20
Program	3 •	7	11	15	19
Project	2	6	10	14	18
Task	1 •	5 •	9 •	13 •	17 •

Table 4-5: Methods matrix data applied

4.6.2 Investigating the outcomes

Finding out the differences between where the company's current product development environment is at and where it should be in a fully functional concurrent engineering environment can be done by contrasting the company assessment questionnaire data against what appears to be the suitable concurrent engineering approach that the selected product requires. The black line connecting the outmost marks represents the concurrent engineering methods the company uses as part of its current product development environment, whereas the red line points at the concurrent engineering approach that the company requires to develop its selected product. The variation between the two lines demonstrates where the company is required to take action.

4.6.2.1 The current communication infrastructure balance

Table 4-5 above demonstrates how in balance or out of balance the current product development environment is, relative to the concurrent engineering environment that is necessary for the development of the selected product. As seen, the techniques required to implement a concurrent engineering environment are in the project approach, which also includes the task approach. This is shown where the red line runs though the project approach row; the key factors – feedback, product data, product management – have the essential procedures and resources for the communication infrastructure dimension. However, the uneven or zigzagged line joining the marked dots exhibits where the current product development environment lacks the procedures and resources in some key factors (in this case product management) as well as where it might be going over the top to what is required (feedback key factor).

To remedy this imbalance, attention must be drawn towards this dimension because of its deficiency in applied procedures and resources. Highlighting these areas in a company's concurrent engineer dimensions map assists in moving towards a transparent overview of their objectives.

4.6.2.2 Creating a plan to balance the communication infrastructure dimension

Using the same example from section 4.6.1, in the case of surplus procedures and resources to implement a key factor, one way to manage this is by redistribution to areas that lack or are deficient, otherwise, by maintaining these resources in place they can be ready for future a product that require a more complicated concurrent engineering approach. Having extra resources does not necessarily mean that key factor(s) are successfully covered.

A company must organise the information regarding what it is required to do in order to achieve its concurrent engineering environment. This in turn helps the company understand the results. By looking at the dimensions map and studying the unmarked question numbers that are at the same level as or below the approach that the selected product requires (red line and below), these questions would have been answered with an 'Agree' if the current product development environment had the necessary procedures and resources to implement the concurrent engineering environment. It is vital for the company to go over these questions again and consider them to support where they require taking action.

The next step is to employ the priority roadmap with these questions in order to organize and prioritize the list of action points. This is done by listing each of the key factors and their related questions that preferably should have been answered with an 'Agree'. Then, using the substance of each question and the information derived in the methods matrix (which relates to the location of the question on the dimensions map) to generate an action point. A priority number is assigned to the action point and a team member in charge of it. An example of the priority road map can be seen below.

Communication infrastructure dimension

Product Management:

Priority $\boxed{1}$ Completed $\boxed{}$

14. Provide access to online reporting and query facilities

The steps a company requires to instigate its vision of a concurrent engineering environment are finally established. This vision must be spread out across the company for all employees to partake in making it happen.

4.6.3 Improving and communicating the vision of a concurrent engineering environment

The priority road map is not the end the track that a company must take. Its message must be communicated to others in the company so that a collective vision grows.

The assessment tool discussed in this chapter can be utilised as a communication tool to get others in the company thinking about concurrent engineering approaches and techniques. It is strongly recommended that both development teams and management should complete all parts of the assessment tool. Their attitudes would be undeniably different and would assist in building the foundations for more discussions in creating a shared company vision. Their group effort will result in reaching a consensus on common objectives and priorities. This way they can agree on the best way to apply concurrent engineering techniques to change the current product development environment to a concurrent engineering environment. And, the most important outcome of all this is a priority road map that all employees of the company embrace with their best endeavours.

4.6.4 Introducing the concurrent engineering approach

A pilot project is the best way to introduce and measure usefulness of the selected concurrent engineering approach. It has several advantages, some of which are listed below:

- Individuals involved in the pilot project train in the actual operations of the new procedures and organization, and later serve as experts for proliferating the new procedures and methods to the rest of the company.
- Verifying the new concurrent engineering approach put in place.
- Illustrate the expected improvements.
- Finds unanticipated problems with new approaches before they affect ongoing products, programs, or projects.

4.6.4.1 Evaluating the pilot project

It is crucial to assess how costs, implications, and changes of using a pilot will impinge on the functions of a company as a whole before being able to correctly evaluate the pilot and the concurrent engineering approach used to develop the pilot product. The pilot product should be cautiously selected, therefore starting with a small pilot is recommended so that the current product development environment is not dangerously disrupted.

A pilot product should:

- Be a real product – characterizes the levels of product development and the expected difficulties at the company.
- Have schedule flexibility for discrete milestones – so that the newly applied concurrent engineering approach would have a degree of experimentation and fine-tuning as the pilot project proceeds.

A pilot product can electively be:

- A new product
- A unit that is part of a lager product
- A specific product version

4.6.5 Conclusions

Implementing with a pilot product does not necessarily validate the new concurrent engineering approach, but rather it is merely a way for pointing a company in the right direction towards a sensible plan in the course of implementing a concurrent engineering environment.

Market forces are always changing and consequently the requirements for a company's product. Hence, reassessing is important and should be done by using teams and managers from different disciplines, and at different times. The communication infrastructure dimension can then be adjusted as needed. The tool presented in this chapter is one of many available and it is not the only means of assessing the product development environment, but has been showcased as an example of the procedure necessary to obtain the suitable concurrent engineering approach.

Continuous assessment and evaluation offers guidance for continuous improvement in the process creating the product, and the product itself.

5

Chapter 5

Case Studies

5.1 Introduction

The case studies explained in this chapter will demonstrate that there are several different ways to implementing concurrent engineering. This chapter will focus on the experience of three companies who have made vast investments in information technology support tools.

They are:

1. Design to Distribution Ltd (D2D)
2. IBM UK, Havant
3. Instron Ltd

To assist rapid assessment of product designs by the development team members who are typically spread out at different geographic locations, the above companies have developed advanced electronic communication capabilities – the concept of concurrent engineering consists primarily of an IT infrastructure that comprises rapid communication and management of engineering data between the dispersed sites.

Virtual teams of engineers who work together, but rarely if at all physically meet, are established to proceed with highly complex product development assignments. The physical location of each individual is not as important as having the ability to access shared databases and product development software.

All three companies work under the influence of different pressures. However, naturally all three companies are experiencing the same pressure to be more *efficient* which governs today's market environment – driving them to develop their new or selected products in a shorter time, and at lower cost than before while increasing or perhaps maintaining a high standard of quality. For the different case studies this pressure may be combined with the pressure of *proficiency* – where the company has to prove to customers its capability to develop new products – and usually these companies are engaged in acquiring substantial contracts such as providing manufacturing services or capital goods design and manufacture. Thus presenting the ability to perform to their clients is necessary. In other cases, the pressure to be efficient is joined with *incremental change* pressure, which is exerted by the global market for activities to occur more quickly and often – where companies frequently update their product range, but essentially build new products based on legacy knowledge. The pressure to be efficient can also be combined with both incremental change and proficiency all at the same time, as will be seen in the case studies following.

5.2 Electronics Manufacturing Services: The Information Technology Infrastructure[2]

Design to Distribution Ltd (D2D)

Summary

D2D provides electronics manufacturing services to clients. As such, it provides that vital concurrent engineering element: up-front input of manufacturing information into the product development process. To achieve its present and successful position in a highly competitive market D2D has invested heavily in its information technology infrastructure. It has developed a comprehensive IT capability allowing for design information to be considered by all team members, however geographically dispersed they may be. Supported by corporate component databases and automated design validation packages, the company can ensure that designs move rapidly from concept to manufacture with very high levels of confidence through its application of Engineering Data Management (EDM). The company's product development infrastructure is now so developed that the organization is constructed around virtual teams, with physical co-location being relatively unimportant.

Introduction

Design to Distribution Ltd (D2D) is a wholly owned subsidiary of ICL. It was created on 1 January 1994 when the original Manufacture and Supply Division of ICL was established as an independent company. Its employees are distributed over five sites within the UK. D2D's business is primarily in manufacturing electronics products, but as its full name suggests it provides services which range across the spectrum from the design of products to their distribution to customers. In fact, it extends beyond this range to encompass disposal and recycling.

Although it only obtained true independent status in 1994, the company had been operating as such for some years previously. This is reflected in the gradual change in the proportion of its activities related to ICL business. In 1990 all of its business was involved in the manufacture of ICL products. In 1995, just under 50 percent of its business was with ICL, for which it competed in the same manner as all other potential service suppliers. The range of technical services it provides to clients is illustrated in Figure 5-1 where it can be seen that D2D has the skills and tools to support activities at every stage in the development of a new electronics product. As such, D2D supplies services in the areas of product design and manufacture; printed circuit board (PCB) fabrication; PCB assembly; system assembly and test; supply, software and documentation services; repair, refurbishment and recycling. These services which follow the various stages in a new product realization can either be carried out directly by D2D or can be provided as general support for client companies to carry out these activities themselves. In practice, there is usually a mix of these two approaches depending on where the precise capabilities of the client company reside.

The company is a major player in the European market and has the ambition to become the largest provider of electronics manufacturing services in this geographic area. Its mission statement is very precise on this issue:

To become Europe's leading electronics manufacturing services company, in our chosen markets, by providing products and services world-wide that exceed our customers' expectations.

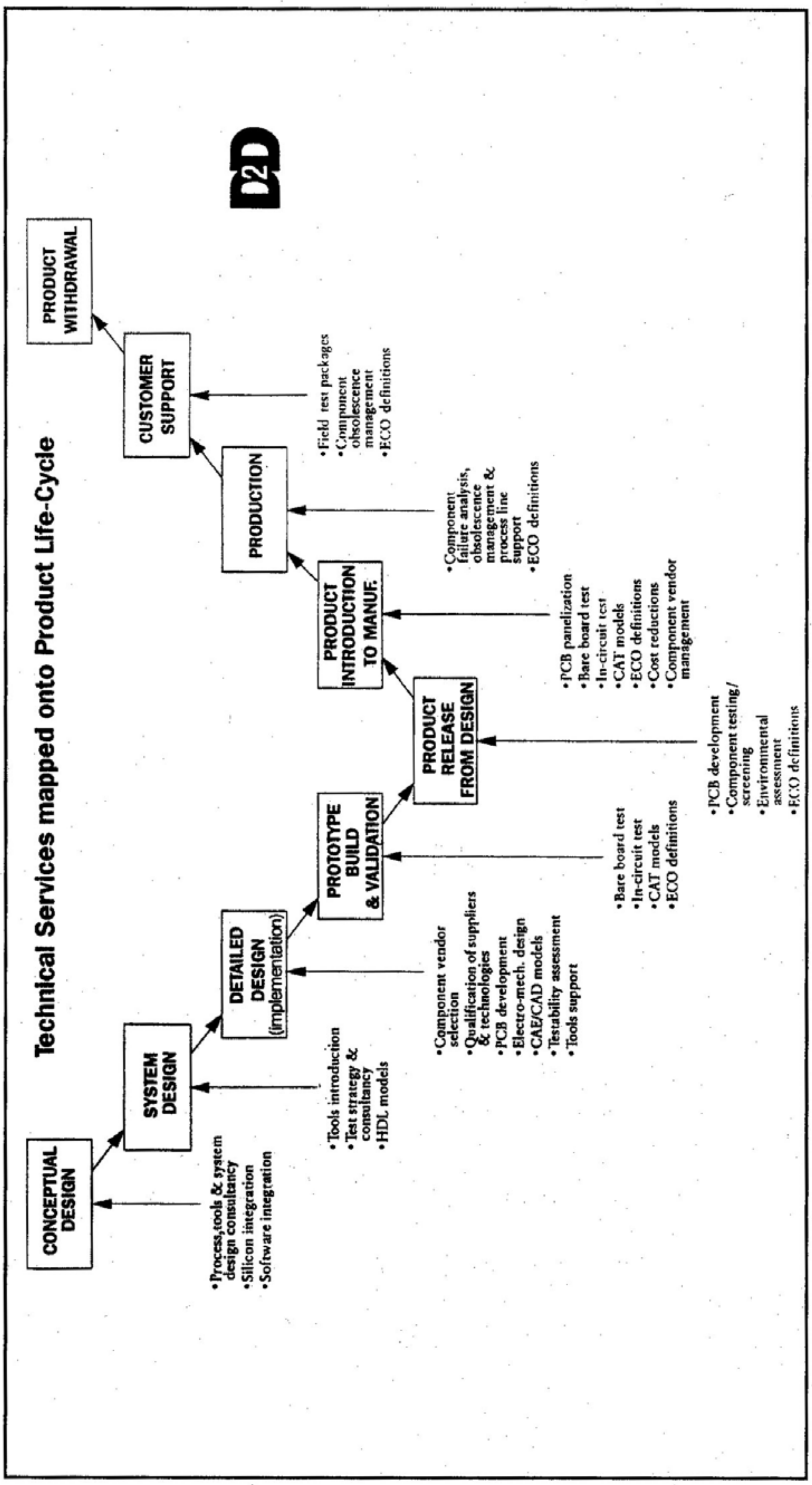

Figure 5-1: Technical services provided by D2D

D2D's origins were in the manufacture of personal computers, workstations, client server systems, mainframe computers and other networked computer systems. The company retains a strong lead in this area of electronics manufacture. However, as more of its business has been derived from non-ICL clients it has become involved in the development of a much wider range of products, including mobile phones, mass spectrometers, cash dispensing machines, supermarket checkout machines, head-up displays and similar products.

Competitive criteria

The major market pressures influencing the activities of D2D concern those typical of the electronics industry: a requirement to shorten time to market whilst simultaneously reducing cost and ensuring defect-free products. Typical time to market requirements for mainframe computers have been seen to reduce from five years to two years in the period since 1980, whilst capabilities and complexity have increased enormously. The reduction for personal computers is even more dramatic, with times to market for these products currently standing at three or four months, a situation highlighted in Figure 5-2. In addition to these market pressures, there also exists the need for increased flexibility of batch sizes and a requirement to meet environmental standards associated with safety, electromagnetic compatibility and recycling of components.

In parallel to the changing market conditions experienced by D2D, the product technology is advancing equally rapidly. As is found throughout the electronics industry there is a continuous move towards further miniaturization. This is driven by the requirement for increased functionality for a given component size resulting in an increasing number of connecting pins on the main printed circuit board components. In consequence, there has been a continuous reduction in the pin pitch to a stage where there are now approximately 6 pins per millimetre in standard components. This compares with 2 pins per millimetre in previous years and 4 pins per centimetre over twenty years ago. In manufacturing terms this has led to the requirement for continuing developments in the area of interconnectivity between the various components. With pins being so small the challenge is to ensure that manufacturing processes are capable of reliably populating printed circuit boards with such miniaturized components in order to produce a fault-free board.

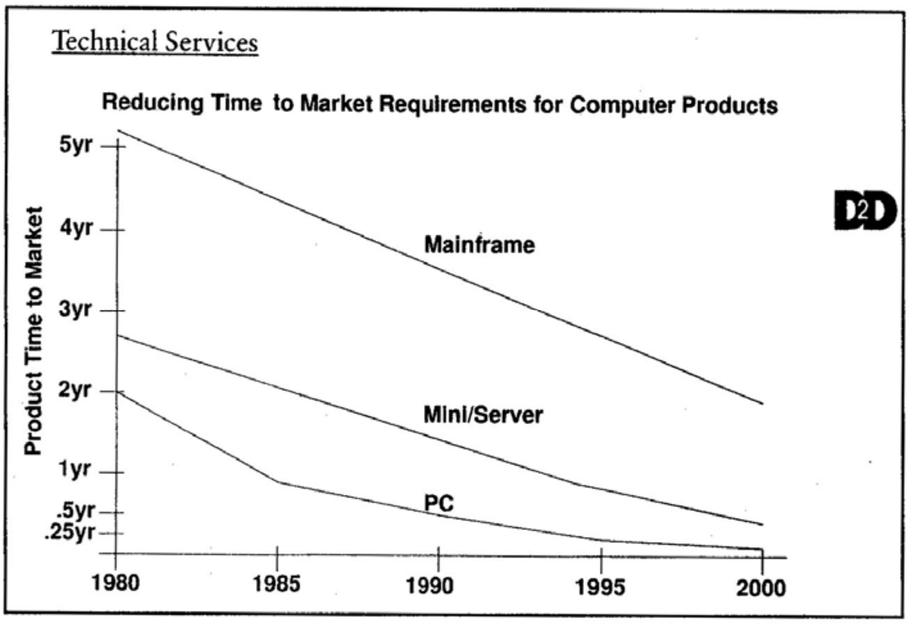

Figure 5-2: The reduction in time to market of computer products

D2D emphasizes its capabilities in the areas of the design process, computer-based design tools, component knowledge and strong links to component manufacturers. It is capable of supplying a front-end design service for many product domains and can provide project teams which will take the initial concept through to manufacture, including a sophisticated prototyping capability. It has wide expertise in the areas of conformance criteria, electromagnetic compatibility, shock and vibration testing and legislation regarding product standards. Finally, it provides logistics expertise and facilities to ensure that the product can be rapidly and efficiently distributed to the final customer. This distribution capability additionally differentiates D2D from its service supplier competitors in that it will organize suitable packing, storage and transportation to, and within, any country in the world.

One of the strategic responses of D2D to changes in the market conditions and the product technology has been to apply a regime of continuous improvement to all the company processes. This has been realized, in part, by the investment in computer-based tools to aid in the product development and in information management by maximizing communication both within D2D and with its customers and through automating many of the engineering processes. There has been a steady growth in the utilization and sophistication of the information technology infrastructure to ensure cooperative working through the rapid dissemination of information. Thus, the approach to implementing concurrent engineering within D2D can be seen to have been realized through technological developments in the use and coordination of knowledge and information – emphasis on the communication infrastructure dimension.

The client server project

An example of concurrent engineering as practiced by D2D was illustrated by the design and manufacture services provided to one customer who was developing a new range of products. The product, a UNIX file server, is a computer system in which software is located and available to be downloaded on request to networked PC workstations in a client server architecture. There is a rapidly growing world market for client server products as more users realize the benefits available from convenient availability of software across networks, often geographically dispersed.

The market for client servers is highly competitive, with product life-cycles being in the order of approximately one year. With electronics capabilities increasing so quickly the product rapidly loses competitiveness, often requiring a completely new design, rather than a simple upgrade, to compete successfully. Therefore, a necessary capability that D2D had to demonstrate before being awarded the contract to provide manufacturing services was that it could support a significant reduction in time to market relative to previous projects. The target in this instance was for the first client servers to be available just six months after commencement of the project, whereas previous best times had been twelve months. In addition, the range of products would be larger than previously attempted, and component miniaturization would be further advanced.

These requirements implied that D2D would have to liaise very closely with the customers from the very earliest stages. Due to the complexity of the product and the design resource required to complete the whole range, several customer sites were involved, not only within the UK. Two of the client servers were to be designed in Sweden and the other four were to be split between two UK design sites. In addition, the chip sets differed across the range of client servers, with SPARC being used for the higher performance UNIX units and Intel for lower performance UNIX servers and PC workstations. To ensure commonality of approach in the design process it was necessary for there to be constant interaction between design sites and for the manufacturing service supplier to be equally well integrated into the design process. The manufacturer of the client server would have to be able to liaise with several design sites, provide the necessary input to ensure manufacturability of the product and plan the final manufacture and distribution.

Financial considerations

Since D2D supplies a full range of services to cover activities throughout the development process, the project can be scoped early and refined as it progresses. Whilst there would normally be several stages in a project where financial negotiations take place, the early scoping significantly reduces the likelihood of unforeseen cost implications. Once the design has been assessed in terms of both functionality and manufacturability then the actual cost of manufacturing can be specified.

D2D operates an 'open book' policy whereby client companies can fully identify all D2D costs within any quotation. Contracts and quotation teams are in regular contact with customers throughout the progression of the project. It is possible for projects to be halted by the customer at any stage in the process if the financial viability of the product is called into question. This is, however, highly unusual and if it does occur is caused by changing market requirements being imposed after the start of the project. Additionally, the option is always available for customers to contract out certain activities to other service suppliers. Whilst this may provide apparent short-term benefits, in practice it proves to be a very dubious way of reducing costs. The need to establish new relationships and audit capabilities inevitably results in delays and unexpected increases in costs if service suppliers are switched in mid-project. Undoubtedly the most mutually beneficial arrangement is based on long-term relationships which include understanding and trust between customer and service provider.

Order-winning criteria

D2D was awarded the contract based on its ability to match the above set of requirements. It demonstrated that the combination of its capacity to merge into the project via its various information technology communication channels and its competence in terms of design and manufacturing capabilities would provide its customers with the expertise in order to reduce time to market. It had a proven ability to contribute during the early stages of a concept design and demonstrated the beneficial effects that this could have on manufacturing the product. In that respect, it provided the crucial aspect of concurrent engineering to the project - ensuring timely consideration of all downstream activities.

It is important to note that compatible and efficient communication networks between customer and service supplier are 'qualifiers' which need to be available before the service supplier is considered as a serious contender for a contract. Competitor service providers are now capable of rapidly establishing communication links to support design and it remains the quality of service that determines whether a contract is awarded. D2D was awarded the contract by initially demonstrating its information technology capabilities, but it crucially demonstrated its capabilities and experience in terms of providing the vital design embodiment and manufacturing engineering knowledge.

Project progression

It was the customer's responsibility to progress the basic functional design of the client servers. The customer employed several design sites who themselves were communicating on a very regular basis to coordinate different elements of the product design. In this situation, D2D had to provide coordinated support to several of the customer sites. All support was provided from remote sites so communications had to be confirmed at the earliest stages in the project. Following that, it was necessary for D2D to employ compatible design tools in order to ensure no ambiguity in the generated data between customer and service supplier.

The support that D2D provided to the project is shown graphically in Figure 5-3. The involvement of D2D engineering services commenced at the initial conceptual design phase where Computer Aided Engineering (CAE) tools were utilized to help the client develop the most suitable design whilst taking into account all aspects of manufacturability. It is well accepted in D2D that this early stage of design is where the majority of manufacturing cost is committed and considerable activity was exercised at this stage. High speed data communication links ensured that concepts could be remotely viewed on screen by all contributing designers, with designs being developed concurrently in terms of both functionality and manufacturability. A complex design developed on one customer site could be viewed by D2D personnel within a matter of minutes to ensure that no excessive manufacturing costs were being unnecessarily designed in.

Once the concepts were firmed up then D2D moved on to supply services in the area of simulation, PCB development, mechanical design, and packaging design. Validation of the product design was ensured through D2D's engineering database which carries a complete description of all products previously designed, and all components that D2D have validated as being suitable for inclusion in products. On completion of validation, the client server designs were formally released from design and a firm quote developed for the cost of manufacture. At this stage D2D manufacturing and assembly teams took over from engineering services to complete final manufacture.

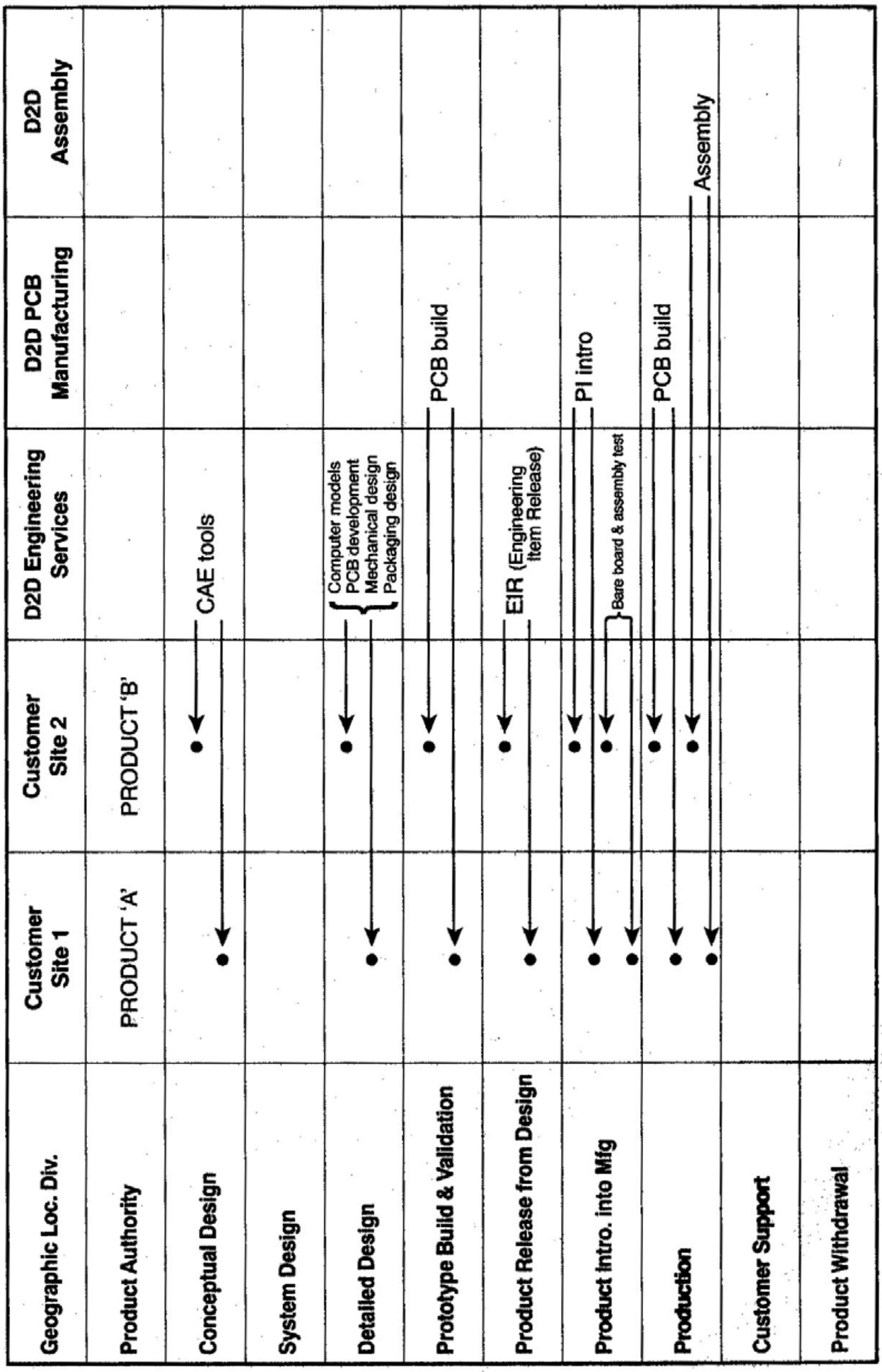

Figure 5-3: The activities of D2D on the client server project

D2D supplied design advice and design data from compatible software tools over the network to the customer design teams during several stages in the process. They provided primary input in terms of design for manufacture during the concept design phase, but they also provided customer sites with support in the most effective use of software design tools. It is policy to ensure that client design software is replicated within D2D to ensure full compatibility of data. D2D engineering services were heavily involved in conceptual design, component modelling and in the printed circuit board development. The matrix of activities and services supplied by D2D included engineering services providing compatible CAE data to various design sites, whilst PCB manufacturing provided services to validate the design, offer manufacturing support and commence order of components in order to schedule in the manufacturing processes.

IT support infrastructure

The rapid provision of expertise to its customers is one of D2D's major differentiators as a service supplier and was demonstrated in the client server project. In order to optimize this provision D2D has developed a very extensive support infrastructure based on information technology. At one level it has the capability for rapid communications between all its sites and with its client customers. Its basic method of communication is via its electronic mail system. This is an integrated office system providing at the local level word processing and spreadsheets etc., but at the wider level internal communications and a gateway into the Internet. Customers, suppliers, partners and academic institutions throughout the world are therefore all available over this network. It provides for standard text transmission and has now become one of the accepted methods for communication within D2D. In effect, colleagues and customers located in other UK sites, in Europe or in

America can interact on projects in much the same way as co-located employees.

Increasing use has also been made of videoconferencing. The significant advantage of this form of communication was given as the 'eyeball to eyeball' contact. Whilst the electronic mail system has been seen as a very significant step forward in terms of data exchange, it is recognized that the visual interaction available through videoconferencing has a significant role to play where complex issues require debate.

Virtual teams

The effect of this communications infrastructure is that when multidisciplinary teams are set up within D2D to coordinate new product introductions, they are not necessarily co-located and except for the key players are rarely full time on any one project. Some teams are made up of members dedicated to a single project but frequently individual engineers are, in fact, members of several different teams. The project team becomes a virtual team and rarely if ever will all its members come together physically. Only the project manager, who is involved on a full-time basis, will travel extensively to meet project team members at both the customer and D2D sites.

Project management

A networked project management package is used as the standard software tool for monitoring project progression. Team members have access at all times to identify their own individual set of actions and how these relate to the overall progress of the project. On some occasions, such as the client server project, the customer conducts the primary planning, monitoring and control of the project's progression, with D2D interfacing into the project management software. On other occasions D2D will have overall responsibility for planning and control once the client has defined key dates and stages.

In addition to the electronic mail system a high speed data link has been provided as a link between key D2D sites. However, whilst this ensures a higher transmission rate it is the fact that it is dedicated to D2D that is of primary importance. This is in direct contrast to electronic mail. With the Internet becoming so congested its response can no longer be relied on and at peak times it almost 'seizes up'. A dedicated high speed data link is not only fast but its speed is guaranteed at all times of day or night. With this facility it becomes possible to employ a team of design engineers, located on different sites, to optimize any given design. This ability enhances the potential for design engineers at the concept phase to consult with colleagues further downstream. Since turnaround time in providing input to concept designs is so short and the benefits so obvious, then this element of concurrent engineering becomes a natural part of the process.

Engineering data management

The approach within D2D has been to develop a fully integrated engineering data management (EDM) environment facilitating data interchange throughout the design to manufacture process. The relationship of the various components of this environment is illustrated in Figure 5-4**.** This automated approach to engineering data management was essential if D2D was to achieve its objective of enabling distributed individuals to form the virtual team environment. Once all of the data links had been established and verified then the physical location of any individual designer was irrelevant to the progress of the project.

In principle the structure of the system is straightforward. An engineering parts and structure database holds all information on past products. This information is directly available for manufacturing planning via the Design Engineering to Manufacture Interface (DEMI). For new products or for product changes this data is available through the change control interface, Product Planning Change Control (PPCC), and can be used to create necessary data within the Issue and Archive Database in manufacturing (IADB) for individual manufacturing cell control.

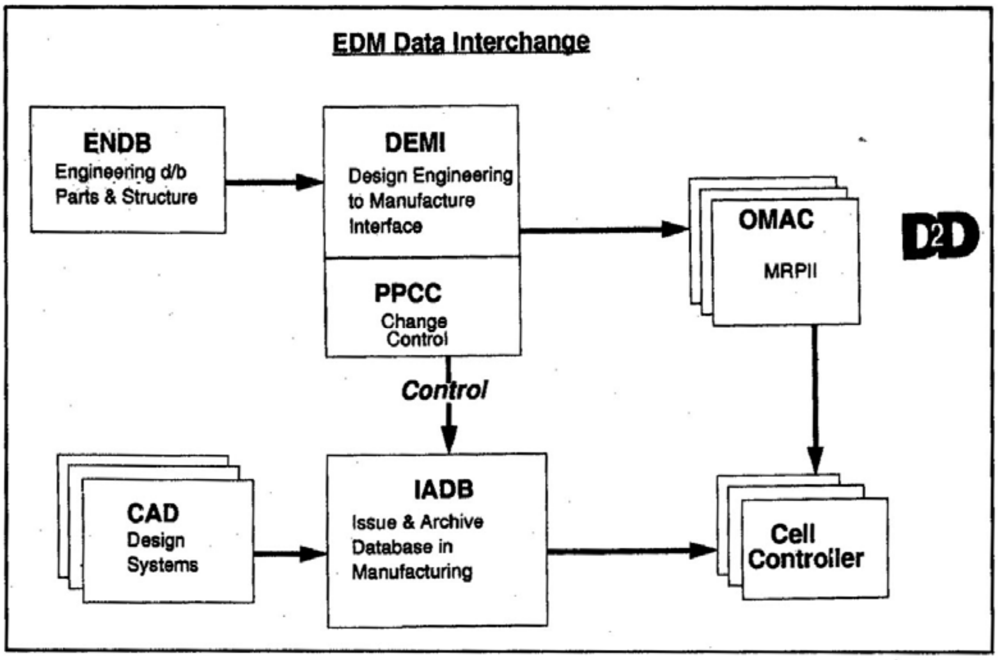

Figure 5-4: EDM data interchange

The reliable operation of this approach to data management is fundamentally dependent on the integrity and validity of the data held within the various databases. The data held within the Engineering Database (ENDB) is particularly prone to being changed and updated. Components are continuously being revised or withdrawn by manufacturers, with notifications of such changes being communicated to D2D at the rate of over 100 per month. Under these circumstances it is not surprising that D2D operates a significant procurement engineering group comprising approximately 20 to 30 engineers at any one time. New components must be evaluated before acceptance, the database updated, and project engineers informed if component changes are imminent for existing products or for products currently under development.

Computer aided engineering

In order to ensure compatibility with clients' in-house CAE software, D2D has available the three most popular standard suites of software for design through to manufacture of electronic products. Since each of the suites has its own strengths and weaknesses, it is unlikely that standardization will occur in this area for some time to come. Whilst data can be exchanged between the different CAE systems, the requirement for D2D to be completely integrated into a client's design process led to the strategy of operating three of the major systems.

These comprehensive design to manufacture tool sets are supported by more specific 'point tools'. They provide capabilities in a range of areas, including development of programmable logic devices, simulation of performance and timing characteristics, generation of PCB board panelization data and bare board test information. In addition, data conversion software is available to adapt data from those customers using CAE software which may no longer be fully supported and/or has a very small user base.

Engineering database

As far back as 1976 the engineering database (ENDB) was created to be the standard corporate component library. It has grown steadily over the years to match the increasing variety and complexity of the electronics products with which D2D is involved. The database holds hierarchical data in a typical bills of materials-type structure and can therefore be used to provide top-down information such as subassemblies to be reused in new designs. Alternatively it can be used bottom up, when it is necessary to identify all products which are affected by a component specification change. For whichever purpose the database is used, it is the integrity of the data which remains central to its effectiveness.

Design engineering and manufacture interface

The interface between manufacturing planning and the engineering database is straightforward for existing products, subassemblies and components. A direct link is established via the DEMI interface. However, where new designs are being developed or changes are required to existing products then there is a need for change control. This is achieved via the Product Planning Change Control package (PPCC) which provides a validation service used in all designs to ensure that data is complete and valid to the level of detail required. As each phase in the design process is reached then the design is checked by the PPCC to ensure that no data is missing. Once this has been satisfactorily achieved then the next stage of design detail will commence. On completion of the process, the data is utilized in the next stage of providing manufacturing information via the Issue and Archive Database (IADB).

Issue and archive database

In 1987 the IADB was introduced to act as a buffer between engineering and manufacturing. Design data which has been validated in terms of completeness and integrity by PPCC is transmitted to manufacturing via the IADB. When this database was initiated the concept had been that final validation of the data would be ensured through manufacturing trial runs. Any problems associated with manufacturability would become apparent at this stage and the design could be changed. Final validated data could then be approved by manufacturing in the IADB.

However, so rapidly has the world of electronics manufacturing changed that the validation process is now almost completely the reverse of that intended. With flexible production lines replacing fixed facilities, the correct arrangement of machines and processes requires physical validation. As more sophisticated software packages become available, the manufacturability of a product carries a higher level of confidence. The combination of these two factors has seen a significant shift away from trial runs being used to validate only the data towards the data being used to validate the complete production facilities.

Conclusions

D2D is a service provider in that it supplies extensive design and manufacturing support to client customers. All the products in which it is involved are initiated by original equipment manufacturers. This means that concurrent engineering has to take place across the divide between customer and supplier. Design and manufacturing will often be physically separated and any implementation of concurrent engineering has to take this factor into account. The extensive information technology infrastructure provided by D2D allows quick and easy communication between everyone involved in the development process and removes the usual concurrent engineering requirement for co-location of teams.

The extensive component database and the software validation programs ensure that each stage of the design process is complete before the next one is started. Efficient engineering data management provides D2D with the capability to develop new products and to optimize manufacturing processes such that they are constantly reducing time to market. The future understandably lies in the greater integration of D2D with customers through the application of IT to ensure an even more rapid delivery of services.

5.3 Tools and Techniques for Efficient Product Development[2]

IBM UK,Havant

Introduction

A concurrent engineering approach has been adopted in storage subsystems development at IBM UK, Havant, in order to maintain a competitive advantage. The company develops and manufactures disk drives and associated technology for IBM's RISC System/6000 workstation products. The products are industry leaders in performance, which is partly achieved by the use of serial link interface technology between the disk drives, array controller and computer adaptor.[26]

Open architecture environments, containing design automation and project management tools together with integrative databases, assist in the monitoring of product processes. They enhance the communication of innovations, requirements and definition for the product development cycle as a whole. Any failure to integrate and disseminate leads to conflict and a subsequent breakdown in both communication and direction.[27]

The availability of a common database infrastructure, accessible by all departments within the organization in the form they require, has been the aim for IBM.

Organization

The storage subsystems business unit is organized as shown in Figure 5-5. The three major functions of a product team are represented in one group, these being development, manufacturing and marketing. The structure of the development organization is a matrix of product and skill groups with clear boundaries of responsibility. This structure was established to address the increase in the number of projects and the need for reduced cycle time. Figure 5-6 shows the profile of cycle time and the number of products over the years.

The organization of project teams at IBM is a matrix style, as shown in Figure 5-7. A number of different skills combinations may be required for the various projects and so multidisciplinary development teams are formed. Projects are operated on and delivered using empowered and self-directed teamwork, with some team members being the champions of their skill area.

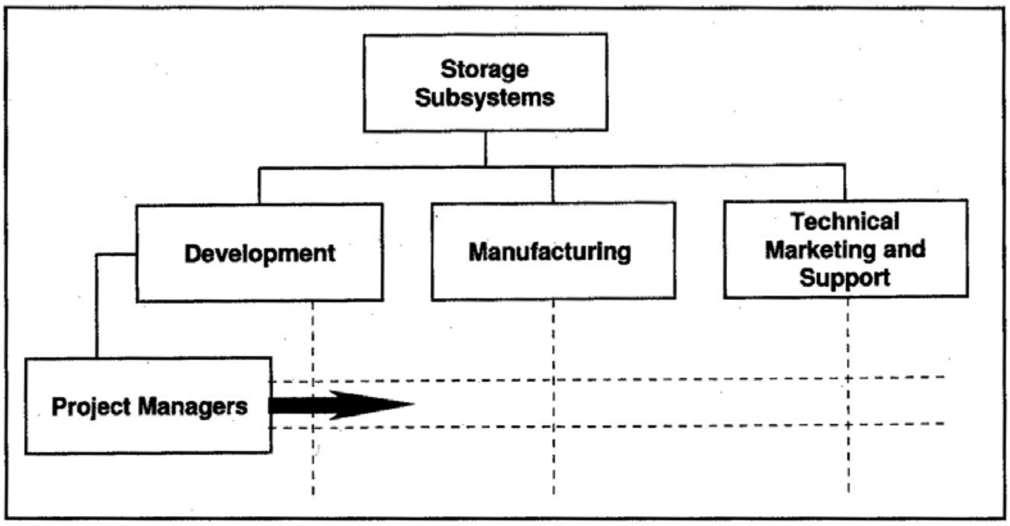

Figure 5-5: Storage subsystems organization

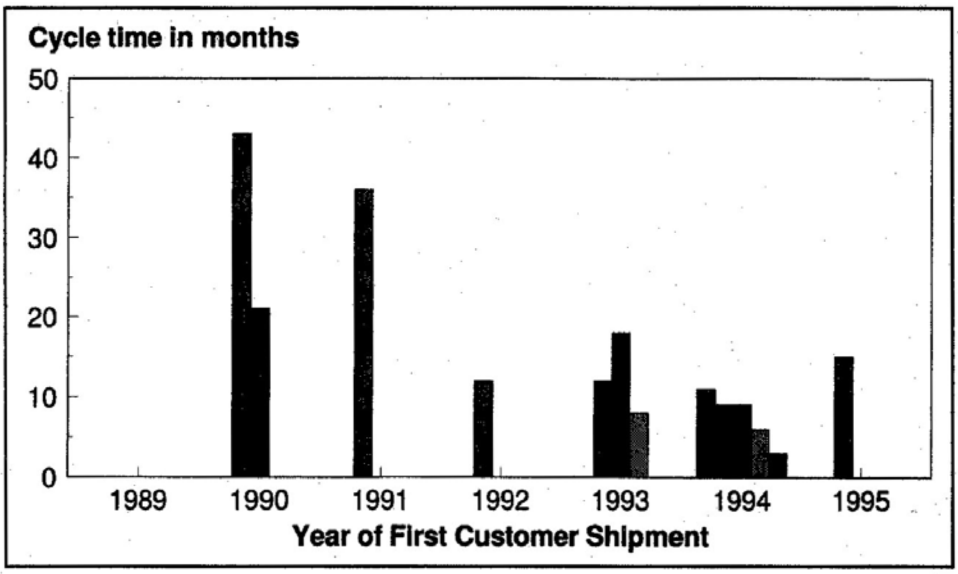

Figure 5-6: Development cycle time

The ability to work effectively as a member of a team is critical. Using multidisciplinary teams is not equivalent to forming committees where members often delay decision making. Instead, design teams get faster actions through early anticipation, identification and solutions to problems.[8]

Skill managers have the development team reporting directly to them and have the responsibility for developing the skills of their department. They also make commitments to the project managers to supply skills to support the product development schedules. Any resource conflicts are resolved by the development manager who can prioritize the work and authorize recruitment if necessary.

Product development structure

Responsibility for a product's profit and loss account resides with the product manager. As the product manager usually has a family of products to manage, he or she often delegates business responsibility for one product to a programme manager. The programme manager is chairperson of the product management team, which contains representatives from all areas of the company. Typically these would include representatives from:

- The development team
- Business planning
- Worldwide marketing
- Manufacturing
- Service

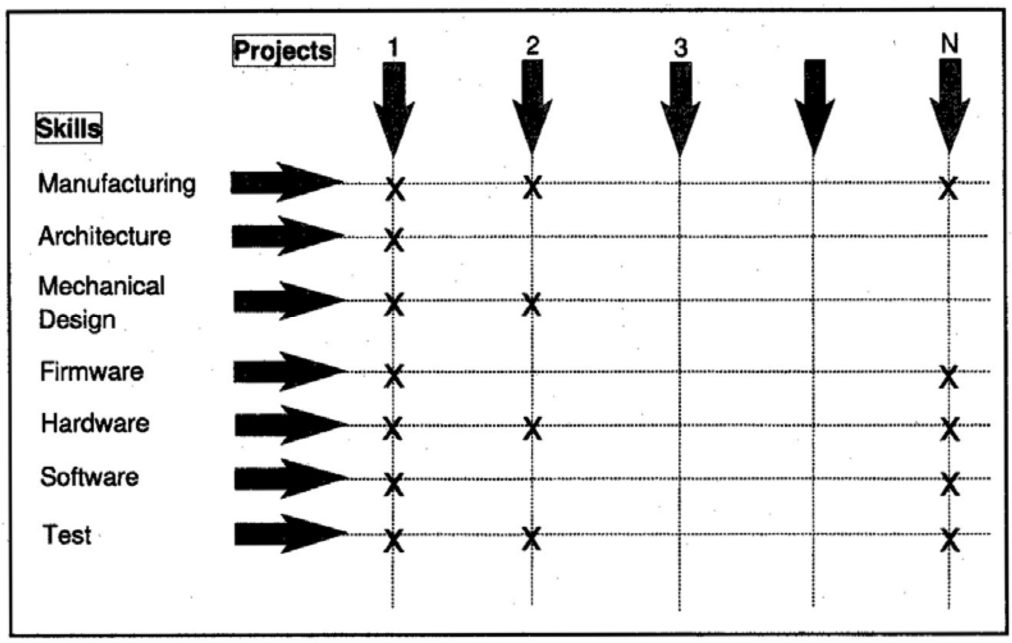

Figure 5-7: Matrix Structure for project teams

The typical project management structure is shown in Figure 5-8. The Product Launch Team (PLT) and the Product Development Team (PDT) both report to the Product Management Team (PMT). The PDT represents development activity and consists of representatives from American sites as well as Havant. Development, test, manufacturing, service and support status are addressed at meetings of the PDT. The PLT represents worldwide marketing, planning and finance. Pricing, product positioning, competitive analysis, education, customer fulfilment and technical support are addressed at meetings of the PLT. Meetings for the PMT, PDT and PLT usually occur in America in San Jose, Tucson and Austin.

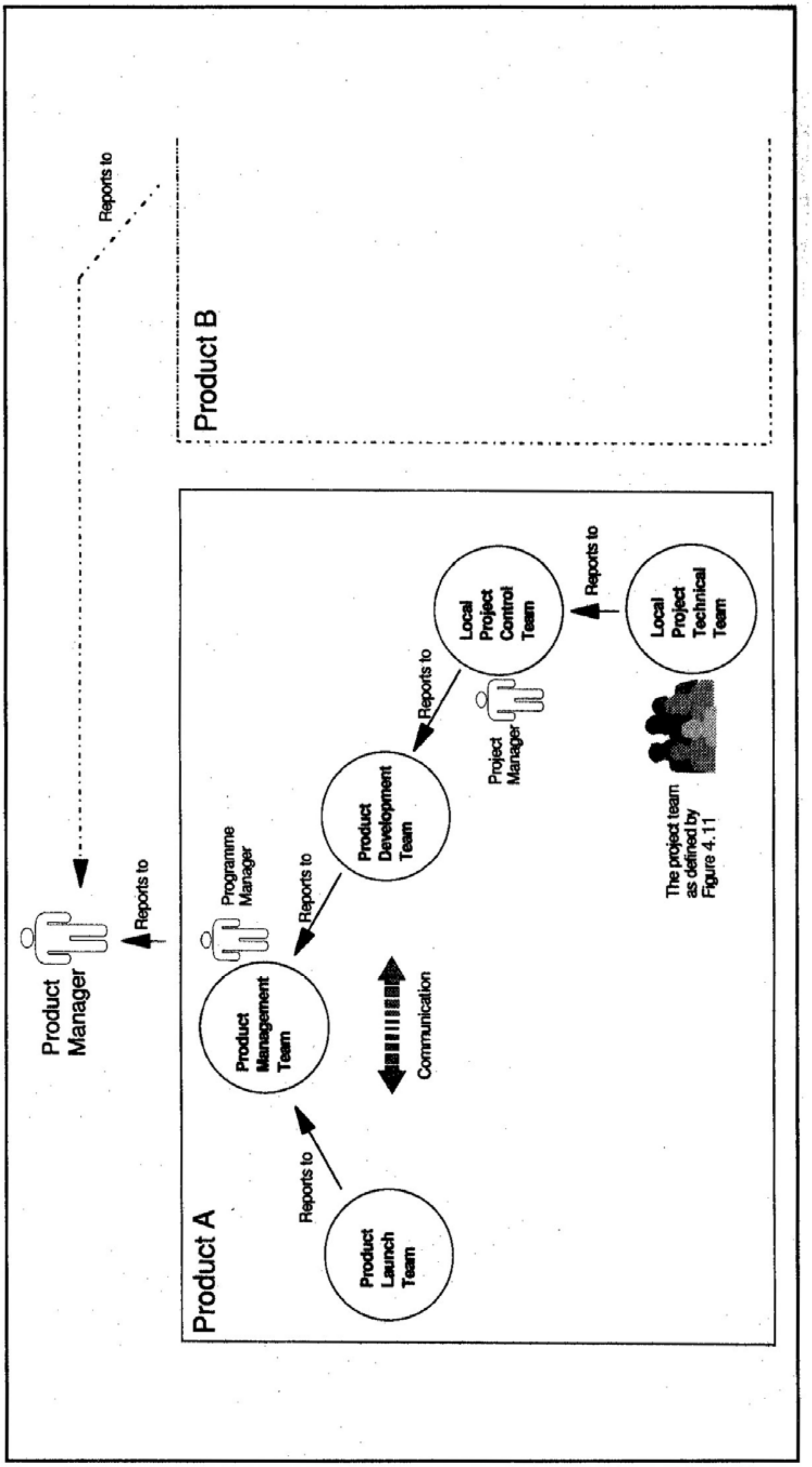

Figure 5-8: Typical project management structure

Local project control and technical teams exist in Havant and meetings occur in the form of Project Technical Meetings (PTMs) and Project Control Meetings (PCMs). PTMs are particularly useful in highlighting areas of critical development activity so that resources can be reallocated more usefully. PTMs report to PCMs where any important issues are highlighted. Whereas functional staff attend PTMs, functional management attends PCMs where development issues are raised and the project's status is evaluated. Typically, such a meeting will highlight issues that are preventing entry to the next development phase. In addition, PCM issues will be reported to the PDT.

The product management team meets at regular intervals throughout the development cycle. The programme manager is responsible for the business process, which has the following 'checkpoints':

- Initial business proposal
- Product announcement
- First customer shipment.

These checkpoints provide a progressive evaluation of the product business outlook as well as a thorough technical assessment as development proceeds. The development team is represented by the project manager whose task is to deliver the product into volume production on the agreed schedule. The project manager must create and execute implementation plans in order to assure that the completed product meets cost and expense commitments. He or she negotiates resource commitments with skill managers to develop and test the product, as well as coordinating all the business checkpoint tasks assigned by the programme manager.

Product development process

The increasing pressures of time, cost and quality demands have been a key driver for IBM to look at its business and the complete engineering development process. The factors contributing to these pressures include:

- Competition from companies that are fast to the market with new products
- Demands for better performance and 'value for money* from customers
- More international collaborative projects
- A need to replace aging systems
- A need to be more flexible and responsive to market opportunities.

A review of the characteristics of the development process revealed activities that consume major amounts of time and money. These offer the opportunity for improvements through the reduction of:

- Design lead-time
- Engineering changes
- Direct and indirect costs
- The amount of paperwork
- The transition time from design to manufacture
- Data management, searching and document handling times.

An overview of the typical product development process is shown in Figure 5-9. At IBM, product requirements are distilled into a set of product objectives by the project manager. These objectives form the basis of a resource-sizing activity and give the programme manager an understanding of the tasks involved. The project manager provides an outline schedule to the skill managers and requests a detailed resource- and expense-sizing from them. This is done for all projects and the technical planning manager consolidates the entire plan in order to assess the overall development expense budget for the organization. Work then starts on a high level design and functional specification which is a description of the product. It is reviewed to ascertain that it meets the requirements statement. It is also at about this time that the first cost estimate is done for consolidation into the initial business proposal. The marketing representatives provide sales volume estimates and a market price which is derived from competitive analysis. We now have the core ingredients for a business analysis:

Profit = Volume x (Price - Manufacturing Cost) – Expenses

Where *Expenses* are the sum of marketing, development, warranty and service expenses plus corporate allocations that fund research.

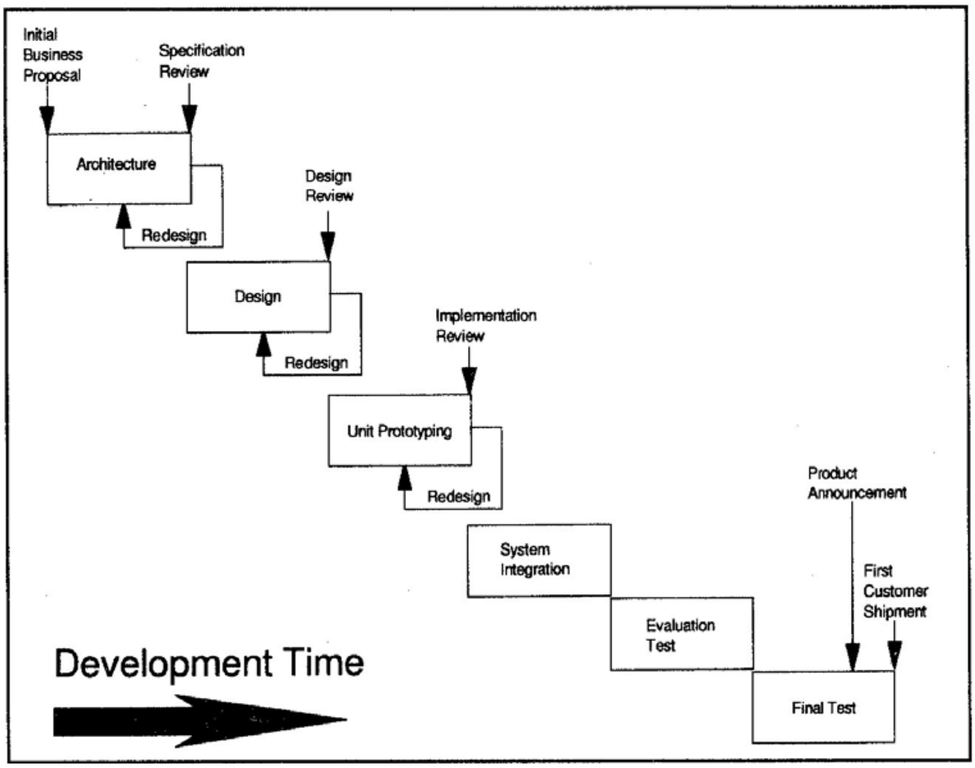

Figure 5-9: Typical product development process

Plans for marketing, test, technology, manufacturing and service are also formed at this early stage of the development cycle to make sure that it makes good business sense to proceed with the project.

The new product development team includes hardware and software engineers, who work in conjunction with test personnel at the earliest opportunity, in order to allow testing to be efficient and meaningful. This ensures the discovery of problems at the earliest possible stage of development, so that the final testing can be performed with the minimum of defects. Therefore much effort is put into reviews before hardware and software implementation begins.

A 'specification review' which looks at the high level design concepts and a 'design review' which looks at pre-implementation design specifications are both carried out before any work is implemented. These reviews are placed in the initial project schedule and act as evaluation checkpoints. Participants of the reviews include the following members:

- Author - the specifications writer;
- Moderator - ensures adequate preparation before the meeting, maintains discipline during the meeting and draws satisfactory conclusions at the meeting;
- Reader - any attendee, except the author, to read each section of the material;
- Reviewers (of which at least two are required) - query and probe the subject area.

Representatives with knowledge of the particular aspect of a project under review will attend these working meetings. An 'implementation review' will also occur after a design has been implemented.

The mechanical design team operates a 'fast path' approach where development, manufacturing and procurement engineers sit together to bring representative packaging models into test at the earliest opportunity. They operate two databases, one containing the description of models being built by manufacturing and another containing the latest ideas from development. A review process transfers the development parts to the manufacturing database subject to stability and availability of parts. Shortly before the product is in full production, the manufacturing database is transferred to the formal release process which enables products to be manufactured in any IBM plant. Reviews will occur for the mechanical design in a similar fashion to the hardware and software aspects of a project.

Simulation is performed at chip, card and system level. The micro code is also simulated during the design code and unit test process before being merged with models of the hardware in the card and system test. In general, fault isolation becomes more difficult the higher the level of test that is performed. System tests do, however, represent an environment that is closer to the final application. The system integration phase, where hardware and software are brought together for testing, will highlight any major compatibility problems.

The product planner drafts the formal announcement document which states the full ordering structure, price and availability date. Before product announcement, an 'announce readiness review' is carried out to check that all aspects of a new product introduction have been covered. For example, the order process is checked, a search against patents is made, a plan for educating service personnel is made and marketing prepares the launch material.

With many products, customer involvement starts at the design stage and prototype units are made available to enable early evaluation and feedback on their performance in real application environments.

Engineering data management

IBM's commitment to communication is based on its worldwide internal electronic mail system. Virtually all development data and documentation can be transmitted throughout the system. Communication is further enhanced via Local Area Network (LAN) applications that share common data. This enables schedules, engineering and financial data to be accessed by anyone with access to the LAN.

Problems of a more abstract nature that might relate to a general problem encountered in, for example, programming methods can be discussed in on-line forums. This ensures that a problem that might otherwise be ignored, or just discussed between a couple of people, becomes visible. Another person discovering a problem can search for any previous incidence of the problem and gain a much better insight into its cause and resolution.

With many projects running concurrently, there is a need for tight control of schedule, as any delay of a critical resource can have an impact on many projects. A PC LAN-based planning tool is used and the skill managers are responsible for tracking the progress of their deliverables into the main product schedule. The project manager maintains the overall schedule and holds frequent regular meetings with representatives from the whole team to review progress against the plan. There is also a weekly forum for all skill and project managers to discuss unresolved issues.

The project managers have formed a 'project office' where software tools for managing the information on progress can be developed. They make a risk assessment against their schedule milestones on a monthly basis. This is a prerequisite for the development report at the product management team meeting.

A company-wide software tool, known as configuration management version control or CMVC, is used during new product development at IBM. It is designed for use in a networked environment, where software located on a server controls all data throughout the development cycle. Workstations running 'client' software are used to access the information on the server, allowing relevant project data to be worked with by team members. Software and firmware files under development are maintained in a file system and are managed by a version control system. A relational database on the server maintains all other development data. The organization of projects within CMVC is hierarchical in nature and an example of this hierarchy is shown in Figure 5-10.

As can be seen from Figure 5-10, the top level component defines the project. A hierarchy is then developed to reflect each constituent of the product, in this case hardware, software, firmware and architecture. These components are expanded as appropriate, for example modules within firmware. The hierarchy formally defines the areas of product development and each component serves as a storage space to hold specific data. There are no inter-constituent connections.

The problem log is maintained on CMVC and is accessible to any employee with a user ID, to record details of problems found during development. All discourse about the problem is accessible to any user with the required authority. The problems are categorized according to their severity, age, target date, owner, component and originator. Severities are classified from one to four, with one being the most severe.

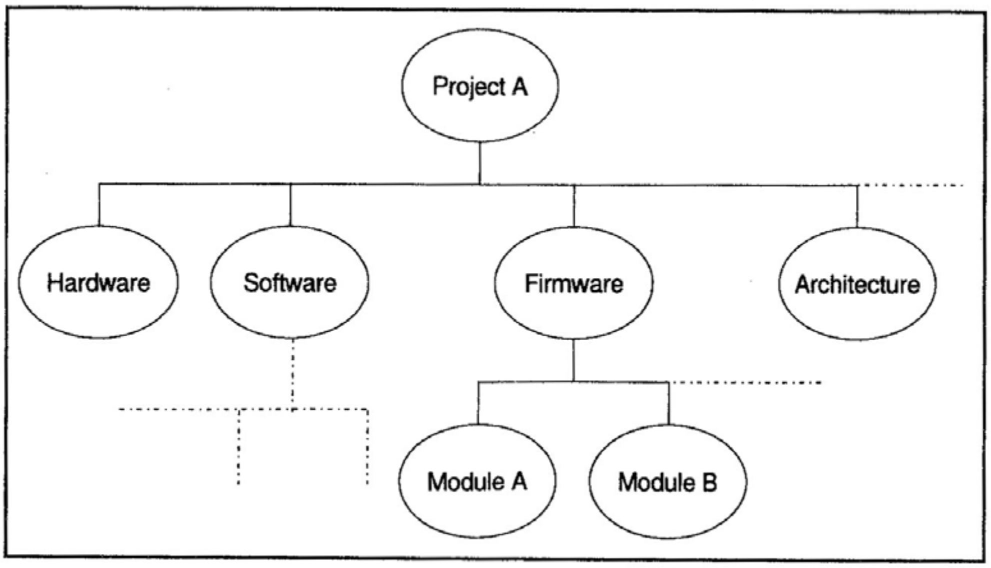

Figure 5-10: Configuration management version control – typical structure

Since all interested parties have access to this discourse, a very wide range of input is possible so that, for example, somebody generating documentation can be kept up to date about a design change that will affect him or her. The problem log becomes very powerful as a development tool during test phases. When a developer discovers a problem in a product during a test, it is raised on CMVC. The circumstances under which the problem was discovered and a code dump that will reveal the exact nature of the problem can be recorded. External suppliers also have access to the problem log so that problems that either affect them, or are affected by them, can be dealt with in a similar fashion.

The very significant documentation and clerical task workload associated with change and configuration management becomes a 'background task' automatically managed by the system. The system also provides full traceability by maintaining a complete history of all the changes. These actions undertaken by the project team as they create, use and modify the product data generate the required change history information.[28]

Defect analysis and prediction

Methods used previously for monitoring the product development process have in certain cases included the analysis and prediction of problems found. However, these methods do not take a holistic approach in terms of process analysis of new product development where many engineering disciplines can converge (e.g. computer systems). Moreover, they tend to concentrate on one aspect of the product, usually the software element. Much more emphasis is being placed on software within IBM's electronic systems, because software can be more easily and rapidly changed than hardware and can be used to fix either hardware or software problems.

When problems occur during new product development, they are documented and classified as defects. A large proportion of software programming expense can be attributed to the detection and removal of these defects, and the most cost-effective removal methods are those that eliminate the defects as early in the development cycle as possible. Various metrics have been proposed relating to software defects, to plan, control and evaluate the software development process, and this enables data to be collected and analysed in a meaningful way.[29, 30]

A model to predict the number of defects during development will help to provide a more efficient new product introduction and may provide an assessment of when to end testing of a product economically. This is useful because testing is expensive and needs to be optimized to provide a balance between test coverage and costs associated with the testing. When the rate of defect discovery starts to decrease, and providing that the project's progress is stable (e.g. there are no development problems that are bringing testing to a halt), then the test phase can be deemed close to completion. If the project schedule shows more testing resource than is necessary, then there may be scope for reductions in time allocated to testing. The outcome is a more efficient development process and improved product quality.

Reliability growth models have been used in the prediction of software defects.[31, 32] Such models require the use of data obtained relatively early in the software development life-cycle, to provide reasonable initial estimates of the quality of an evolving software system.

At IBM, a log is made of all defects found during new product development on CMVC to give accurate and comprehensive statistics for defect analysis and prediction. The most important processes monitored in the development cycle with regard to defect analysis are summarized below:

- Specification review (SR);
- Design review (DR);
- Implementation review (IR);
- Hardware and software integration;
- Evaluation test (ET) - a formal prototype evaluation. In addition to classical tests such as EMC, vibration etc., tests of functionality, compatibility, software, firmware, hardware and error recovery procedures are included;
- Final test (FT) - evaluation of the product against specification using parts manufactured by the proposed manufacturing processes (in low volume). Fixes to problems found in evaluation test will be retested in this stage;
- First customer shipment (FCS) - the point when the product is officially first available to customers.

From the defect data available, estimates of future defect numbers for the current project can be made, with initial focus being placed on the firmware, as this yields by far the highest number of defects raised. An IBM internally developed software tool for making these estimates is being used for the prediction. An example of the curve generated by the tool is shown in Figure 5-11. It shows the significant differences in timescale between previous and current projects, illustrating the reduced time to market of the concurrently developed new product.

The IBM structured approach to team make-up, in conjunction with the defect logging tool, makes data relatively easy to obtain for use in any predictive modelling. This is due to the projects being divided hierarchically and to good communications. Another aspect of concurrent engineering that helps in the production of predictions is the early involvement of downstream activities such as test in the development process. This allows defects to be found at the earliest possible stage and therefore defect data become readily available in the early project stages, to provide input to any model for predictions.

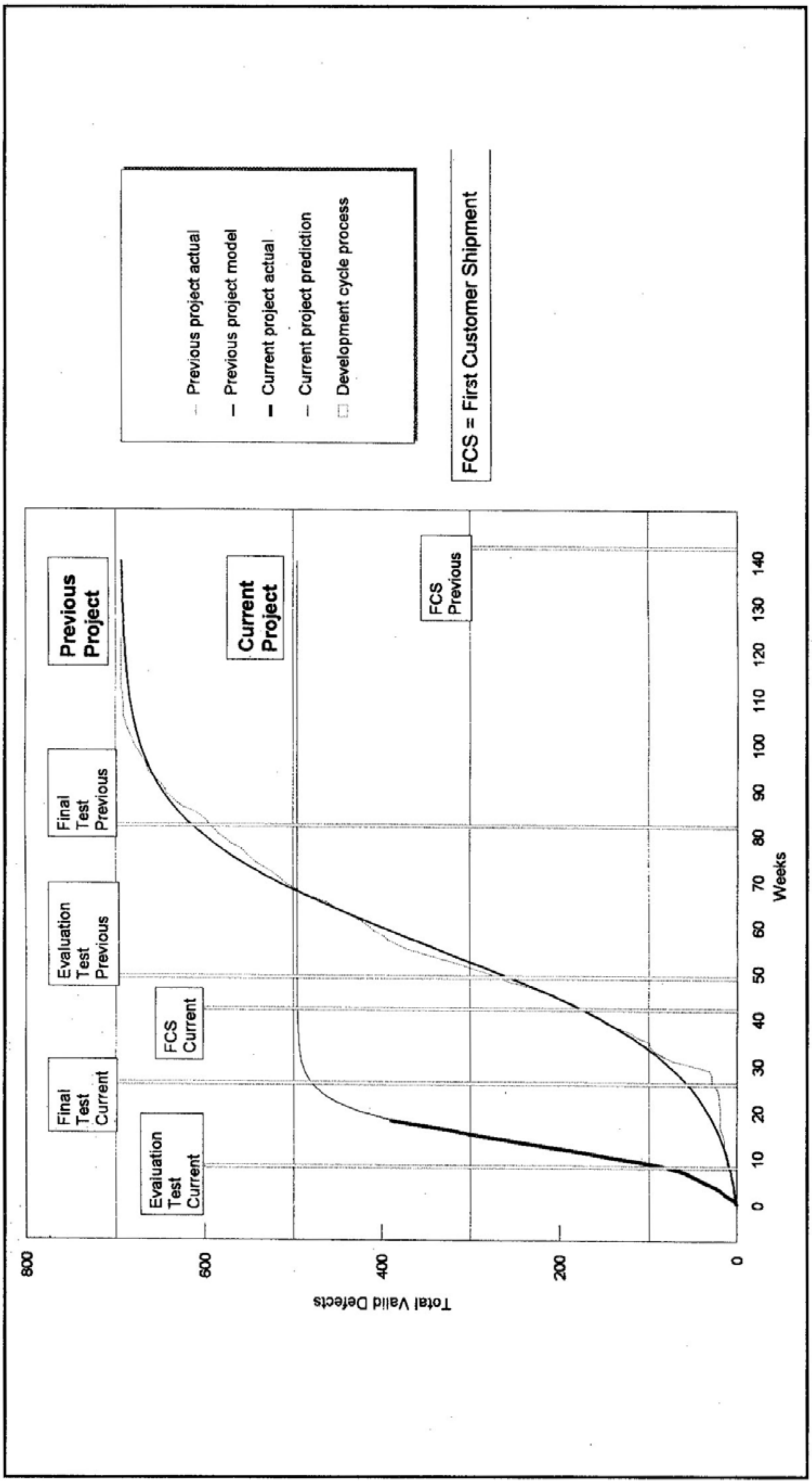

Figure 5-11: Firmware defects from the start of integration

Conclusions

A summary of concurrent engineering activities at IBM Havant includes the following:

- Team-building activities;
- High management visibility;
- The introduction of new team-working practices;
- The cooperation of manufacturing and procurement via physical as well as electronic media (quality engineering techniques such as quality function deployment were used where necessary);
- Hardware and software simulation;
- Shared problem log;
- Schedules available to all;
- Early test involvement;
- Communication enhancement workshop;
- Full project reviews and meetings.

These processes and activities represent a significant and comprehensive effort to implement concurrent engineering. Communication has been regarded as essential, and this is particularly evident during the test phases where developers and testers work on the same part of a product, but may be physically located apart from one another. IBM also benefits from an extremely effective communications system which allows employees to communicate with each other immediately and globally. It is common for staff to have more contact with their project team than with the person seated next to them.

High management visibility and communication mean that all staff are fully aware of the current status of the project and of their role within it. The importance of physical as well as electronic communications has been recognized, and activities that enhance communication have subsequently been implemented to entice functional staff away from their work and into conversation.

One of the most effective development tools is the problem log, maintained on CMVC. Functional as well as management staff are able to understand all outstanding project issues, by having access to a common database where information on problems found during development is stored.

The philosophy of concurrent engineering arose out of the need to develop products competitively. One way in which this is achieved is by engineering defects out at the earliest possible stage of development. Enhanced control over the development process will become apparent and so ambitious schedules are much more likely to be met. Hence product schedules become a reliable timetable of processes and milestones throughout the project.

The defect prediction technique is continuously refined at IBM, by looking at enhancements to the models and evaluating the use of other tools. The use of additional techniques found in the concurrent engineering arena, such as Quality Function Deployment (QFD), 'Taguchi' and producibility engineering, may also help in the task of producing accurate defect predictions during new product development.[33]

In a conventional development process, the discovery of defects at a late stage, possibly because there has been little concern towards designing for the complete life-cycle, dramatically increases the risk of a schedule being broken. The conventional process is very compartmentalized and does not include aspects such as design for test or design for manufacture at an early enough stage of a project. Finding defects in a late stage of a project may mean that a redesign is necessary. The impact of this will depend on the time that the defect was discovered and the work and resources required to fix it. In general, the later a defect is discovered, the worse the impact. With less control over the development process, the conventional development approach can be classed as unstable. Concurrent engineering leads to a more stable development process because of the enhanced control.[34]

Lessons learnt

There is relentless pressure from customers and competition to shorten development cycles, to produce lower cost products for less expense and to accelerate time to market. To respond to these market pressures, development, manufacturing, marketing and after-sales service have to work as a team focused on the common goal of reaching the market with a quality product. The diversity of products requires resources to be shared across these teams and this can only be achieved by having strict development controls and careful resource management. The engineers and programmers have to be flexible to respond to technical problems and changes in requirements. The use of common tools and predictive defect analysis is essential to manage the schedule exposures. As always, it is the quality and commitment of the team that will bring a successful product to the market.

5.4 An evolving Product Introduction Process[2]

Instron Ltd

Summary

The introduction of concurrent engineering within Instron Ltd is seen as a natural continuation of evolutionary change that has been progressing for many years. Modifications to the process of introducing new products have generally been the natural response to a changing set of market requirements. Reliance on a range of standard products has been modified to accommodate the market's need for customized materials testing systems. The company operates parallel teams, in the UK and America, for product development and has done so for many years. The coordination of the two teams is based on a combination of dedicated electronic communication links, the use of documented standard procedures which comprehensively define the process to follow in developing a product, and product module interface specifications. The company operates with a flexible matrix management structure while retaining functional lines of responsibility.

Background

Instron's origins date back to the early 1940s with the involvement of the two founders in testing material for parachute harnesses at the Massachusetts Institute of Technology (MIT). It was recognized that special equipment was required to provide constant straining rates despite increasing loads. No equipment with the necessary capabilities was commercially available at the time and a purpose-built machine was designed to conduct the experiments. Subsequently a company was created to design and manufacture test machines. From this early start, Instron Corporation developed a strong lead in the development of materials testing equipment, a lead which has remained with the company to this day.

Instron Corporation grew steadily in size as the materials testing market expanded, until by 1960 the number of employees exceeded 400. A decision was then taken to extend into the European market by establishing a marketing, design and manufacturing facility, Instron Ltd, in the UK. The size of the UK operation rose rapidly to match that of the American one by the end of the 1970s. A Japanese operation was initiated in 1965 and currently employs personnel involved in sales, service and customizing for the local market. In the 1990s a broadening of the corporation's mission saw the acquisition of companies in the fields of environmental and hardness testing. In total Instron now employs over 1200 dedicated, highly skilled employees in facilities located around the world.

For many years, until the late 1980s, there was a steady growth in the size of the market for standard test equipment. More recently, however, this market has reached maturity. The result has been that competition has become price dominated as the supply of test equipment has become global in nature. Customers, having once seen prices fall in real terms due to economic changes, are unwilling to accept subsequent price rises. As a consequence the company has expanded into other, related areas offering higher value-added potential.

Instron has extended its activities to offer complete laboratory test services. This has been achieved through a variety of initiatives. Acquisition of companies which manufacture related test equipment, such as hardness testing, has enabled Instron to satisfy customer needs for the complete range of equipment likely to be required in a single materials laboratory. The customer then benefits from a single source supplier who can provide maintenance support for the complete laboratory. In addition, Instron has moved into the customized product field where special test rigs and sophisticated data management of test results are required. This is a growing market as companies move along the road to meet the requirement for total life-cycle tests rather than simple strength tests. Finally, Instron has moved to update product designs constantly and introduce new standard products. Where this has focused on developing new controllers, it has had the additional benefit of providing the facility to retrofit onto its competitors' machines in addition to its own. This is especially relevant to a large proportion of potential customers who already own a test machine, where any new product must provide considerably enhanced functionality at a price that the customer is willing to pay. There are significant international competitors, based in America, Germany and Japan, but strong technologically driven local competition is always present.

Technology

Instron's competitive edge from the outset has been excellence in the fields of control and sensor technology allied to strengths in mechanical and electronic engineering and materials science. Controllers, which are key differentiating products for Instron, have always employed leading edge technology, progressing from thermionic valves in the 1940s, through discrete then integrated circuits, to microprocessors and digital signal processing today. The 8500 Plus controller was launched in 1994 and was the culmination of a product development process which encompassed parallel teams in the UK and America working on the design of both hardware and firmware.

Changes to the product introduction process

Until the early 1980s product development was carried on in a serial mode, with manufacturing often becoming closely involved in the process only when the engineering team had completed the design and documentation. This approach clearly could not continue as the market became more demanding and cost conscious. In response, Instron moved to ensure that all project teams were structured to include marketing and manufacturing input from their initial inception. This requirement to develop cross-functional teams at the very earliest stages of a product development programme was written into the formal company procedures, as can be seen in Figure 5-12. As soon as the initial feasibility study was initiated to develop a project budget, a cross-functional team would have to be considered.

The input of manufacturing personnel to the design process and the generally higher requirements being placed on them resulted in a change in the required educational profile. Instead of simply being involved in planning the manufacture of a new product from given designs, they were required to contribute actively to the design from the earliest stages. Required qualifications of manufacturing engineers were therefore raised to degree level, whereas previously the company would have been satisfied by an engineering diploma level of education. Manufacturing engineering personnel were relocated into the same office suite as that occupied by the design engineers, although, as is described later, they remained in their functional groupings.

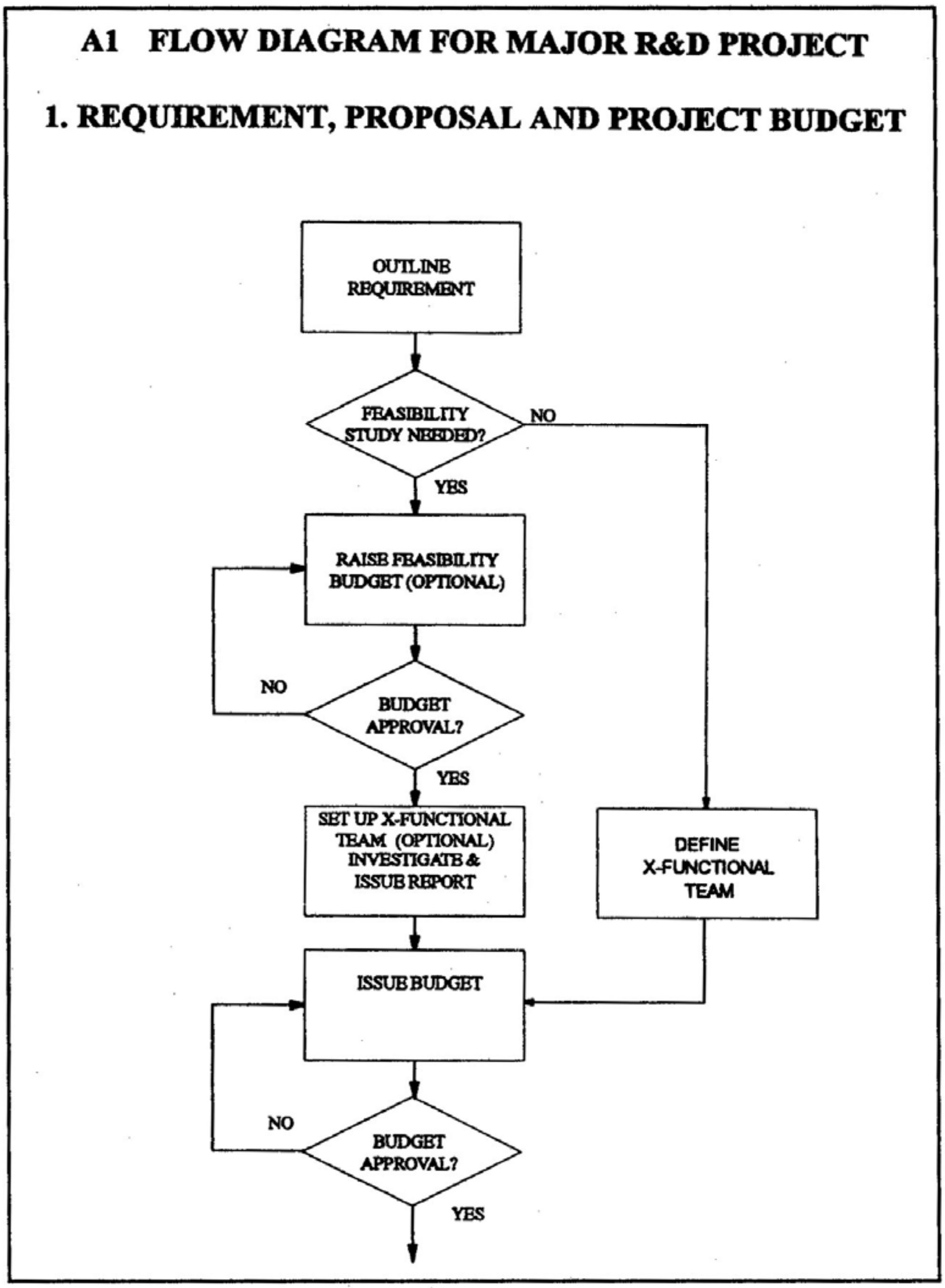

Figure 5-12: The documented procedure to develop a project budget

Whilst there were benefits in closer integration of design and manufacturing in terms of new product development there were, and remain, inevitable conflicts in priorities. In particular this relates to resource allocation of manufacturing personnel between the activities of new product development and those of producing existing products. In the early 1980s manufacturing activities had actually been divided to support operations and development as separate activities. However, this had led to a perception of two tiers of roles and crucially did not facilitate feedback of mistakes. The decision to split the activity has therefore been reversed, and the conflict of resource allocation has been accepted as the 'lesser of two evils' to be overcome through consensus management.

One of the major factors that facilitated the introduction of concurrent engineering techniques was a change in culture that the company had been experiencing over the years. As the market began to demand more customizing of products, then the roles of individuals started to blur. Informal teams set up to satisfy a particular contract slowly emerged as the standard way of progressing such projects. In practice, the changes that took place were so slow that it would be difficult to identify a particular time when they were initiated. When such change is imperceptible then there is not likely to be resistance, and unlike many companies moving over from a functional to a more project-oriented structure, Instron followed a smoother path of change. The term concurrent engineering is therefore seen simply as a suitable description for the approach to developing new products that Instron had naturally been adopting. The process of change has now been accepted by most as a way of organizational life within the company, as new project groups are formed and others disbanded to meet contract requirements.

Design tools

A key event in the adoption of concurrent engineering techniques within Instron was the introduction of CAD. The corporate decision to invest heavily in an advanced system common to both sites, motivated by efficiency gains, was crucial. 3D modelling, initially wire-frame, was embraced from the outset. 2D drawings became the output from the design process rather than the means by which it was conducted. For the first time sales, marketing and manufacturing could visualize the end product at the feasibility stage and know that they were all talking about the same product. Indeed, sales realized that the powerful tool which engineering had for design also provided them with a powerful tool for selling.

The move in 1991 to a CAE system offering analytical tools such as finite element stress analysis, modal analysis and kinematics within a true solid modelling environment served to unite analysis and designers. It was also a vital step in reducing project design and development time while increasing the ability to 'get it right first time'.

There has been a significant increase in the use of electronic communication tools within Instron. Full use is now made of electronic mail both within and between Instron in the UK and America. A direct high speed data link between the two sites was installed and now allows the rapid transfer of geometric and text data to facilitate rapid turnaround in design concepts. In addition, both sites are capable of accessing controlled databases of product modules which specify supplier information, change levels, bills of material etc. Other sources of information required by the designers have been automated and can be accessed across the network. Databases of project files, which are the repository of all of the design information for a project, standards and technical reports are available. The network also provides statistical feedback on service reports and holds warranty information against model type.

The information network aids with operating in a concurrent engineering mode, as it provides the background environment to facilitate this approach. High-speed data links, by which designs can be considered and modified very rapidly, ensure that co-location of all team members is not necessary. Working from common databases which contain controlled information ensures that all personnel are operating to the procedures and utilizing the same standard parts.

Company structure

The structure of both the UK and American sites are basically functional in form with additional matrix-type reporting lines. The overall structure of the UK site is shown in Figure 5-13. The managing director of the UK site reports to the American corporate headquarters. UK directors report to their managing director but also to corporate headquarters' functional directors. Beneath the UK site director level there exists a similar functional divide where personnel are located within traditional departments such as engineering, manufacturing and marketing.

The functional managers are responsible for controlling the reward system for all employees within their grouping and all the reporting system at this level follows the functional structure. In addition there are corporate employees who may be sited either in the UK or America. These include a corporate standards manager and corporate product planning (more of these later).

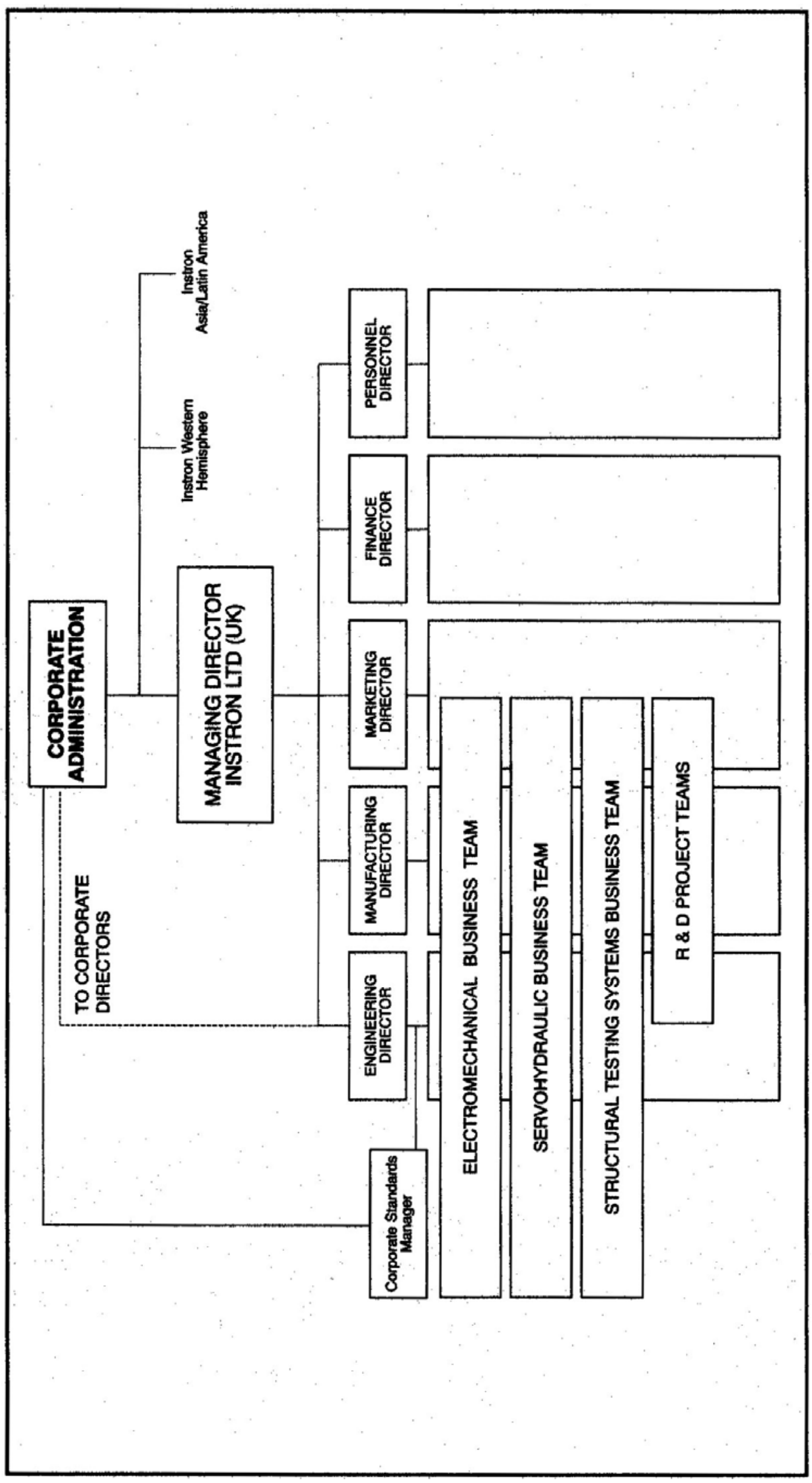

Figure 5-13: Project groups overlay the company's functional structure

Overlaying the functional structure is a flexible project-based structure. Interdepartmental business teams exist in the areas of electromechanical machines, servohydraulic machines and structural testing systems. Their role is primarily concerned with marketing and sales and with the design and development of custom products (not with standard products). The business units are created by co-locating project and design engineers, manufacturing engineers and marketing personnel.

An interesting aspect of the business team structure is that the individual members retain their normal departmental reporting lines. Since all members of the business team originate from defined functional groupings, their respective responsibilities are obvious and individuals take on actions as appropriate. A company director acts as 'mentor' to each business team but not in a directing capacity. The mentor provides advice and a direct communication link to top management. The mentor also acts as a facilitator on resourcing issues both internally and externally, e.g. strategic alliances.

R&D project teams are the groups of employees responsible for new standard product development. This may be an existing product which could be reduced in cost through redesign, or the development of a completely new product. The membership of the project teams comprises personnel from engineering, manufacturing, sales, service and occasionally finance, and is therefore somewhat similar to that of a business team. However, the significant difference is that all the project team members are not necessarily co-located. Whilst design and manufacturing engineers occupy the same office areas, they remain in their functional groupings. Other team members such as marketing and purchasing personnel are located at other points on the company site. In addition, where the UK and American sites are working on the same project, as was the case in developing the 8500 Plus series controller, then co-location is clearly not a feasible option.

Another argument against co-location is the considerable cross-activity between the team members. Individuals will often contribute to several project teams. Since projects range from single component redesigns to the development of completely new products, the degree of input required from each team member will vary considerably between projects. Whilst the major players in a given project team will interact on a daily basis within the functional groupings, they may also interact on a less regular basis with a team for which their input is less time consuming.

Leadership of the project teams is provided by product group managers who report directly to the engineering director. External monitoring of the project is achieved through formal review meetings corresponding to the project milestones as documented in company procedures. An example of this is shown in Figure 5-14 for the development activities up to the engineering prototype, followed by units for formal evaluation by marketing and manufacturing. It should, however, be remembered that both manufacturing and marketing personnel have had a significant input into the design in their role within the cross-functional teams. Design reviews are seen as formal acceptance milestones. Additionally, in order to ensure complete agreement and consideration of all detail a project review may be held twice, once on the UK site and once on the American one. Major project team members participate in both reviews.

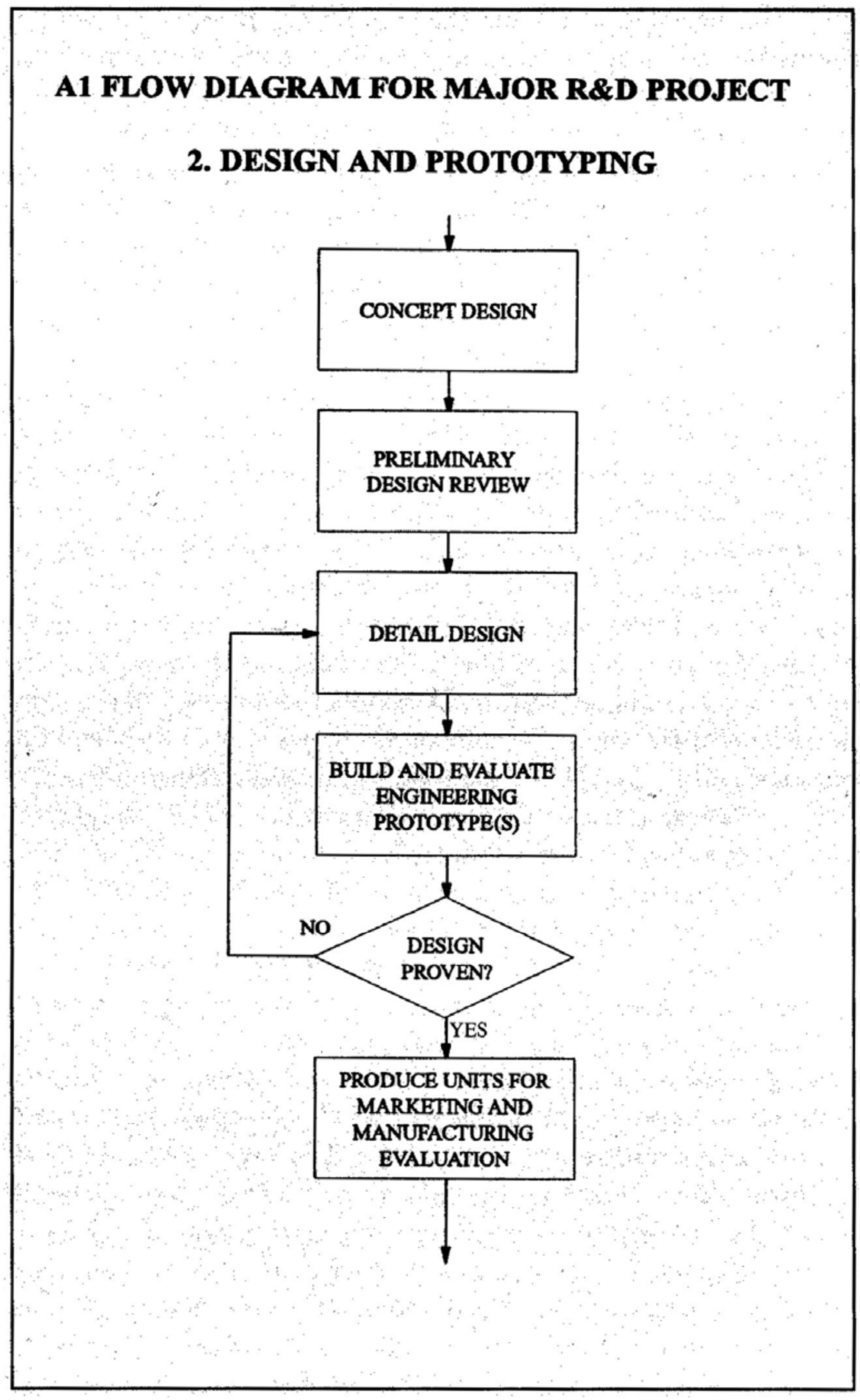

Figure 5-14: Formal procedures for developing initial prototype for evaluation

'Voice of the customer'

At the time when the initial concepts were being developed for the 8500 Plus series, a marketing initiative commenced from within corporate product planning. This section of Instron is responsible for identifying long-term product ideas and for convincing the business as a whole on future product strategies. Whilst it was felt that Instron was satisfying current customer requirements, there seemed to be an opportunity to identify other potential requirements, the benefits of which the customers themselves had not yet identified. To these ends a programme of activity under the banner of 'Voice of the customer' was initiated.

An important concept within the Voice of the customer' initiative was that employees from throughout the business, and not just from corporate product planning, conducted the visits. It was seen as fundamental to gaining a close understanding of customer requirements and to ensuring that ownership of the final results would be spread throughout Instron. The knowledge and understanding generated within the engineering functions was directly responsible for ensuring that common purpose was maintained in all subsequent development projects. The voice of the customer was therefore viewed as a fundamental requirement for the introduction of improved performance within the area of new product introduction and for concurrent engineering to operate successfully.

The voice of the customer consisted of personal visits to an array of existing users of test equipment. Two Instron employees, typically one from marketing and one from engineering, would visit a user to determine their views. Interviews were based on a structured questionnaire, although the individual questions were intentionally non-specific in nature. They asked questions which sought to identify what the user would like from test equipment rather than what the customer felt was lacking from current products. Through a large number of such interviews, a corporate document was created which detailed the likely long-term development requirements of new products in terms of customer requirements.

The first benefit from the study was the identification of a specific market area that Instron could immediately attack. One of the most intractable problems found to be experienced by customers concerned situations where they operated a range of machine controllers and application software having differing interfaces and requiring extensive training to master. Customers expressed a strong preference for consistent controller and software interfaces within their test laboratory, even if the test machine structures themselves came from different suppliers. Instron now have a significant market in retrofitting competitors' equipment with new digital controllers and application software.

The second benefit was the documented expression of a large number of customers' requirements. As with any technology-based company, many of Instron's employees had their own ideas about what constituted important product features. With the customer requirements better understood and documented, debate and uncertainty in this area was greatly reduced. This knowledge of customer requirements now drives new product development and is actively kept up to date.

Corporate standards

The responsibility of the corporate standards manager is to maintain and ensure the adoption of all company product standards. These standards define in comprehensive detail all of the interface requirements between components and subcomponents of mechanical equipment, controller hardware and software products. They define physical sizes, connection types, communication protocols, voltages etc. Thus, precise specifications of all possibly occurring interfaces are defined, such as those between actuators and load cells, between controllers and test machines and between transducers and control electronics. Unlike many companies where standards do exist these are followed precisely. No product is developed within the company unless it complies completely with the standards. In addition, the corporate standards manager ensures that the documentation specifying all bought-in components for all products is maintained and is up to date. Components cannot be purchased unless they exist on the corporate database which can be accessed from all Instron sites. Therefore, common parts will be employed in products irrespective of the site at which they are designed and manufactured.

Conclusions

Instron recognizes that the functional division of the company is not the conventional picture of a concurrent engineering implementation that many people would expect. However, the potential problems associated with functional divisions are well recognized and the procedures and methods of working that have been established within the company have been designed to minimize any such problems. In addition, the company remains a technology-oriented organization. Whilst the skills inherent in developing testing equipment and systems can be learnt, they are extremely difficult to master. The knowledge necessary to develop test equipment is built on over 50 years of experience. The primary core competence of Instron is therefore the ability of its personnel in marketing and in design and development. For this reason it was decided that Instron should protect and develop knowledge through a primarily functional-based structure.

In light of this decision to retain functional structures, the introduction of concurrent engineering can be seen to be procedural- and information technology-dominated. Fully documented procedures for developing new products ensure that each project follows precisely the same basic path. As part of this path the establishment of cross-functional teams is considered at the earliest stage. All subsequent activity is then carried out by the cross-functional team to ensure that significant marketing and manufacturing input occurs during the early stages. Project reviews occur at regular intervals to provide a project monitoring system.

In support of the documented procedures, product databases are maintained to ensure that all designs conform to standard company specifications for parts and for module interfaces. As a consequence, geographically distant project teams can work in parallel, being confident that their part of the design, conforming as it does to interface standards, will be compatible with other components being developed concurrently.

Nevertheless, crucially, the implementation of a comprehensive approach to information technology provides the linkage between people that is traditionally achieved through co-location. In particular, high-speed data links which make feasible the transmission of comprehensive design detail enable interaction to take place at a rate exceeding that obtained through traditional meeting schedules. Communication across the Atlantic Ocean is little different from that between various locations on the same site.

The future

Whilst the previous description of the product introduction process has demonstrated why a functional organization continues to work for Instron, it is not the whole story. Clearly, whilst the adherence to company standards provides a significant control mechanism to ensure right-first-time design, it also implies certain cost penalties. Specification of interface designs for all circumstances indicates redundancy and consequently extra cost. In the past the benefits of ensuring a smooth development programme have outweighed the extra cost of interface standards. One of the lessons to be learnt from other industry sectors is that it is unlikely that this situation will last forever. It is therefore assured that Instron will continue to evolve its organization, and the way it develops new products, for some considerable time to come.

5.5 Case Studies Discussion

In this chapter, D2D's case study showed a significant pressure to be more proficient. In order to win a contract they had to prove their capabilities and competence to customers, which in turn introduces a solid requirement that imposes demonstrating high levels of proficiency.

IBM Havant and Instron ought to respond to the pressure of proficiency too. This meant preserving and improving their skills and expertise to demonstrate capability and sustain competence in their product development. Nevertheless, both IBM Havant and Instron are experiencing the pressure for incremental change in their products, where they are mainly influenced to develop new products with a shorter time to market.

The companies are responding to long-term trends in product life cycles and capabilities. All the different products described in the three case studies are established around microelectronics technology. From that, it is easy to foresee new functionality for future products, the development time, and time before products require updates. The upcoming functionality of microprocessors is predicted using historical trends based on processor costs, operating speed, and time to develop. Hence, products that are developed based on microprocessors are high on the scales of intrinsic expectedness. Looking at it from this angle, the case studies described in this chapter cover companies that are following an evolutionary path to concurrent engineering since the pressure influencing them is for incremental change.

IBM Havant needed an IT Infrastructure predominantly in relation to their development and defect prediction of computer workstation subassemblies. They managed to significantly reduce the development time via statistically analysing test data, which in turn greatly reduced their time to market. On the other hand, D2D responded differently to pressure where they were required to demonstrate their capability and competence in development to impeding customers. For them to win a customer's contract and trust they had to demonstrate a certain level of proficiency regarding new product development.

5.5.1 The variance in the attention to IT areas between the three companies

Emphasis in terms of the areas of IT has been different for each of the companies. D2D stressed the importance of delivering an electronic manufacturing service to its customers that was reflected in its IT approach. As a requirement for engineering data management, IBM Havant has focused on developing a common database infrastructure accessible by all departments. In contrast, Instron responded to the necessity of communication between its geographically spread sites (UK and America) to ensure full collaboration for development projects running in parallel.

5.5.2 What they all shared in common

At the start of each case study, every one of the companies discussed in this chapter was noticeably out of date with their concurrent engineering implementation. They follow evolving paths that lead them to achieve their goals in a new product release. This conclusively mirrors the fact that they have had many substantial changes implemented in the past, and that they have now moved on to new priorities related to IT. Consequently, it has been shown that once an IT course has been espoused, organizational issues such as co-location of personnel are reduced, resulting in increased focus on electronic infrastructure development.

The concept of ‘virtual teams’ is concealed in all case studies, since it is not so much of an issue anymore and has been accepted as reality within each of the companies. This is especially illustrated in the case of IBM Havant, which depicts the matrix organizational structure. This structure was found to assist in developing new products. Hence, the case study affirms that it is common for staff to have more contact with their project team than with the person seated next to them.

The companies cohesively have a very clear view of the processes involved in developing a new product. They all have stipulated formal processes and procedures to follow during the development of new products. With D2D, processes and procedures are presented in a way to be fitted in with customers’ requirements. IBM Havant and Instron however are essentially developing their own products, so the processes and procedures are able to be refined into clear phases which every project can follow from conception to release.

The aim for all three companies is to organize their business in such a way that they can preserve strong centres of technical knowledge from which their teams are able obtain their required resource. This aim was achieved by creating multidisciplinary teams which entailed involving individuals from different skills areas. It is imperative to preserve these skill areas to guarantee long-term retention of skills. This objective was particularly stressed in the case of Insron where they have reversed previous attempts at reorganising to work entirely along project lines, so they could maintain their centres of technical knowledge.

5.5.3 The importance of communication infrastructure

Fast and reliable communication, whether between different team members or sites, cannot be stressed enough in this work. What has been highlighted in this chapter is electronic data management which covered the establishment of electronic links. These in turn provide for greater rate of contact by assisting and encouraging a team based approach to product development.

6

Chapter 6

Conclusion and Suggestions for Future Work

6.1 Conclusion

The traditional product development process is mostly serial. This is often due to the lack of a firm team organisational structure, absence of a real-time communication environment, no shared information model for product realisation, and also lack of a proper communication infrastructure and essential cooperating tools.[35] These issues result in different work functions such as design, manufacturing and marketing working in isolation, and having very little interaction or contact with each other to exchange ideas and inputs, as well as examining their impact. Tasks are often completed in the earlier stages of the product process, such as the design stage, with little or no feedback from manufacturing and marketing. Then they are passed on to the manufacturing and marketing stages, but by then there is very little time left to assess the design and suggest improvements, and so they are likely to be ignored. This approach to product development is susceptible to errors and can cause slip-ups in the release schedule. Problem areas in the early stages of development increase in severity, resulting in multiple design iterations. Concurrent engineering can be utilised to simplify resolving these problems.

Concurrent engineering is a systematic approach to product design and development that incorporates the integration of design, manufacturing, marketing and related functions. Concurrent engineering examines all aspects of the product development life cycle at the start. It centres on collaboration between team members from different functional groups to successfully complete product development. Multidisciplinary team members work together in a computer networked environment [35-37] on a shared basis, towards a common set of consistent goals.[35] With concurrent engineering, companies can improve their design by making it more efficient, and help them demonstrate high levels of proficiency in their operations to their clients in order to win contracts. Concurrent engineering helps in detecting defects early in the product development process, thus shortening the product development life cycle due to reduced number of iterations, hence achieving a faster time to market.

The communication infrastructure forms one of the four dimensions of concurrent engineering and is a lynch pin of concurrent engineering. A thriving concurrent engineering environment utilises smooth and structured communication means, and a system to make certain that team members and members of different disciplines collaborate in a diversified and geographically distributed environment.

Communication is a key element in collaboration, where individuals exchange ideas and access information, through trusted and reliable communication means that help realize the ‘virtual teams’ concept. Communication infrastructure is the foundation that provides a reliable and smooth communication environment that aids interaction between team members, and provides a shared common computer based model for accessing and sharing information as needed.

Today, the development of network technology has provided concurrent teams with many effective communication tools such as E-mail, Network File System (NFS), Lotus-Notes, Tele-conference, etc.[38]

The rise of the internet as a conventional tool utilised for collaboration in the work environment has brought together geographically separated sites from all over the world. Tools like this, made it possible for teams members to work together in a distributed environment.

Solid, reliable and smooth communication infrastructure ensures that the right information reaches the right person at the right time, warranting quality in the work tasks being carried out and improvement in efficiency of outputs and operations proficiency.[39] It also means that members can interact with anyone located anywhere around the world, and be able to exchange data, knowledge, inputs, and suggestions of process methods. A good communication infrastructure provides ways to transfer data and designs, and facilitate in making group decisions. It also enables communication to happen between the work functions, at different times or all at once regardless of the time zones of the individuals' geographic location. Finally, good and reliable infrastructures complement the other three dimensions of concurrent engineering and help bring them into balance.

6.2 Suggestions for Future Work

Looking closely at the dimensions of concurrent engineering, it is easy to see the relationship between the dimensions of organisation and communication infrastructure. They share a common philosophical aspect; therefore, their creation is influenced or dictated by individuals such as upper management, who make the decisions regarding structuring teams in the most effective way that they perceive, along with setting means of communication to best serve a particular company that makes a certain product(s) of a specific complexity. So in essence, these two dimensions reflect the individuals' experiences and beliefs.

Further investigation can be carried out into the two dimensions and how they interact with each other, for example, the organisation size and its team structure, and how this influences the implementation and complexity of the communication infrastructure. Perhaps, a closer examination of the various implementations of team structures in different companies and the resulting communication infrastructures they have adopted – what experience and beliefs were behind them? Lastly, how the two dimensions together benefit and affect the concurrent engineering environment.

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