BETTER, CHEAPER, FASTER PRODUCTS - BY DESIGN

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NEW CHALLENGES

Today, most manufacturing companies are being challenged to commit even greater investments in bringing new products to market. All this at a time when product life cycles are shortening through a customer need for greater product variety more often.

In many industries, even six months can now be packed with moves and counter-moves. Products are born and others are phased out. New technologies emerge and others fade. Customers will no longer tolerate lengthy delivery times. They see new capabilities emerge that better fit their needs, and they want it now. Not tomorrow, nor next month. But right now.

This challenge which is facing many companies today is not insignificant. To succeed, it means having to turn conventional wisdom upside down. It means having to discard old methods and working practices for newer 'right first time' alternatives. It means knowing what the leading performers are doing. Then through a process of continuous improvement, it means trying to beat the competition with 'better, cheaper, faster products to market'.

This article presents how Digital Equipment Corporation is responding to this challenge. It discusses how cross-functional product teams are playing a key role in breaking down traditional department barriers, whilst enabling many of the development activities to be carried out concurrently. It goes on to discuss how major attention has been placed on improving the development process whilst introducing 'right first time' techniques such as Quality Function Deployment (QFD), Design for Manufacturing and Assembly (DFMA), and Taguchi methods. Finally, key measures are discussed which have been used to provide feedback for continuous improvement of the development process.

Over the past 4-5 years of focusing on 'Better, Cheaper, Faster - by Design', some devastating results have been achieved in many corners of the company. A few specific instances include:

Better: 100% improvement in the reliability of a disk storage system.

Cheaper: $75m life cycle cost avoidance for a mid-range computer.

Faster: 75% less time to market for a graphics workstation product.

CHANGING THE FOCUS

Throughout the past decade, the volatile nature of our markets has necessitated that companies continuously re-tune their competitive strategies. In the early 1980s, for example, Digital Equipment introduced its new family of mid-range computers - the VAX 11/780. The technical merits of this product created immense market pull, to such an extent, that demand outstripped manufacturing capacity. Meeting customer delivery dates became the single most important challenge for the company and it responded by investing heavily in automation.

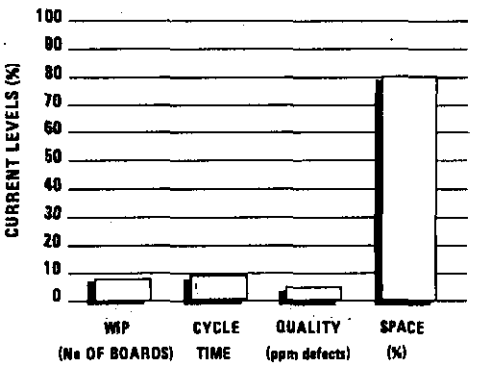
But by the mid-1980s, the competitive elements of the business had shifted. Customer satisfaction, total quality, and lower cost were rapidly becoming the new determinants of success. In response, MRPII and JIT/TQC programmes were launched within the manufacturing activities of the company and major business improvements followed through lower work-in-progress levels, less defects, less space, and shorter cycle times. (See Figure 1).

Over the last few years, however, the competitive determinant of our markets have shifted yet again. It is now highly customer driven, and is creating the following new challenges:

SHORTER TIME TO MARKET

These highly volatile markets are making it increasingly difficult to design products which will still meet the customer needs by the time they can be shipped. In the computer industry, for example, it is no longer acceptable to take 30 months, or even half that time, to introduce new workstation products. It is too big a risk on the projected revenues. Today, products have to be delivered in 6-9 months, and in even less time for follow-on products.

FIGURE 1
MANUFACTURING IMPROVEMENTS



MORE PRODUCT VARIETY AT LESS COST

Having previously done the good work in manufacturing to bring costs down, customers now want more options with their products. This demand can potentially spiral manufacturing costs back up again through less accurate forecasting, longer set-ups, more work-in-progress, etc.

MORE NEW PRODUCTS MORE OFTEN

Customers invariably want the next product that is probably still on the drawing board and they want it now. It is simply shrinking the potential selling window, making it more difficult to continue to generate respectable life cycle profits.

AT THE CROSS-ROADS

Although manufacturing improvements have been commendable within Digital Equipment over recent years, it has been difficult to see where further similar increments of competitivess can be found. Quite simply, it needs some dramatic change in company strategy in order to significantly influence quality, cost and responsiveness.

This was illustrated about 4 years ago with a workstation product. The company targeted to take a large share of this rapidly growing market. It certainly had the technology leadership, the right skills, and the 'World Class' manufacturing operation to build them. Yet the best it could achieve was a mediocre commercial performance.

In hindsight, it was clear that the company relied too long on its manufacturing strengths and didn't adjust quickly enough to the emerging competitive determinants of the market. It was assumed that:

- you could simply go on competing with high technology products
- product life cycles were longer than they really were
- product options were a direct trade-off against lower product costs.

These products are now history. But they continue to provide a constant reminder that 'the best products don't count if they don't show up on time'.

CHANGING THE RULES

Today, Digital Equipment has made a major investment in refining its development process. They have brought in new methods to support a 'right first time' approach, changed traditional attitudes and have experienced that meaningful measures on the product teams can help to continuously improve competitiveness.

Three years on from those painful experiences, the company is now seeing substantial benefits from its investment in design. For example, compared to previous similar workstations, today's products are:

- hitting the market in less than half the time
- supported by four-fold more options, whilst product costs have been halved
- capturing twice the market share, at a time when product life cycles have halved.

But the most significant factor of all is that life cycle profits are now several times greater. This competitive revival has come about through critical attention and improvement to all aspects of the design/engineering cycle. The main ingredients which have provided the foundation for this success are discussed below.

INTRODUCING CROSS-FUNCTIONAL TEAMS

A key factor in reducing development time is the implementation of cross-functional teams whereby the necessary skills are brought together to work the product through to the market place. For the first time, manufacturing and design people are sitting down together and resolving issues at the earliest opportunity. Marketing is sharing the same specifications with other team members. They all work to the same common cause and in doing so, it has unfreezed many of the problems that occurred at the department boundaries such as formal hand-overs and resource scheduling.

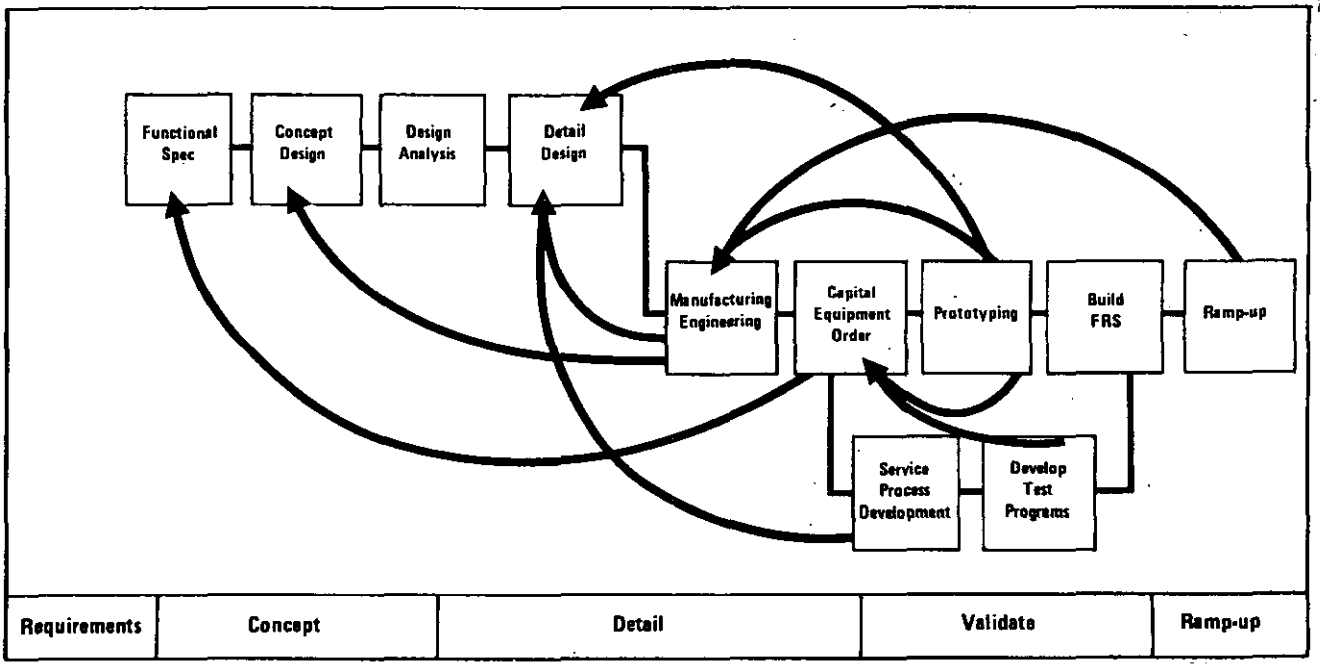
Today these teams operate through closeness, trust and common goals. But their introduction did not come easily. (See Figure 2). Many changes in organisational structure and working practice had to be made. Teams were empowered to make decisions where they could be most effective. And in doing so, managers had to stand back and let the team get on with it, whilst resisting the temptation to continuously interfere with the flow of work. B[illegible] instead, they were expected to concentrate their energies coaching and enabling the team to give them the environment to succeed. Team members also had to get used to staying with the product from concept to market. In many cases, this would involve collocation to provide close interaction and mutual understanding. Problems would be shared, and new solutions would percolate to the surface through the collective efforts and skills of the team. When the rewards are dished out, they will all win or fail together depending upon the extent of their achievements.

For Digital Equipment, the introduction of product teams has provided a major contribution to reducing time to market, whilst ensuring that designs can be manufactured, serviced and sold at market acceptable prices within timescales that suit the customer.

FIGURE 2
NEW WAYS OF WORKING

	Old Style	New Style
Focus	Internal	External
Rewarding	Individual	Team
Management Style	Supervision	Coaching, enabling
Decisions	Directed	Empowered
Goals	Department	Product life cycle
Commitment	Task completion	Concept to market
Resolve Conflicts	By the Manager	By the Team
Location	Functional Dept.	Co-location

FIGURE 3
SERIAL DESIGN PROCESS



GET THE PROCESS RIGHT

'A superior product will provide an advantage over the life of a product. But a superior development process will provide a constant stream of advantages'.

The truth of the statement is all too apparent as the development process contains the heart beat of competitiveness. If it is well structured, then it will tie together the concurrent activities, the phase review/release activities and the energies of the cross-functional team in such a way that a highly disciplined and competitive operation results. Since many development tasks do not change substantially from one release of product to another, then the learnings and improvements from each project can be carried forward as a source of continuous process improvement. Repeated mistakes and non-value adding tasks can be gradually eliminated and activities re-sequenced within the process. All of which will help to establish a leaner and more responsive development process.

But for many companies, this is far from the case. Their current development processes have typically accumulated over many years and contain all the rough edges, the loop backs and the hand-offs which disturbed the normal flow of work. Conseqently designs would iterate backwards/forwards until a stable manufacturable product definition resulted, or as usually happened, time would run out. (See Figure 3).

Today, this development process must stay highly tuned through continuous improvement. A small change here, and another there, each of which contributes to a steady stream of small improvements which result in 'better, cheaper, faster products to market'.

'RIGHT FIRST TIME' METHODS

Within this highly tuned development process, the company has introduced several process methods to encourage a 'right first time' approach. These methods ensure that the team's efforts are being directed towards value adding work, rather than 'fire fighting' the build up of engineering changes which traditionally increases as the product design gets closer to being manufactured. Some of the principal methods which are currently being employed are briefly discussed below.

CAPTURING THE VOICE OF THE CUSTOMER

For many years, design teams believed they knew what their customers wanted. They would design, detail and prototype, only to find out that they had not got it quite right. The net result was a flood of late engineering changes which simply poured good money down the drain.

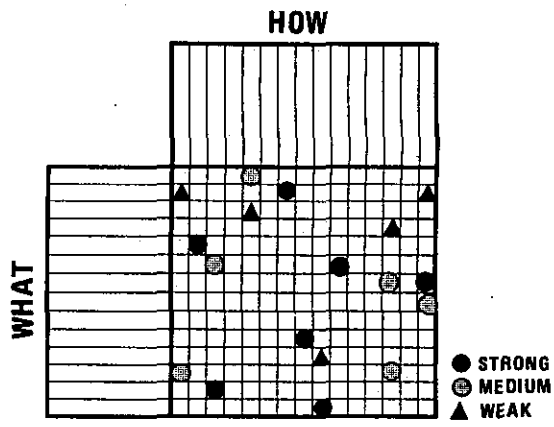
About 4 years ago, QFD was introduced into the company. Its purpose was to provide a channel into the customer base so that their opinions could be captured. Then through the structured methodology of QFD, this 'voice of the customer' could be used to drive out the design requirements, part characteristics, process control characteristics, and operating instructions. (See Figure 4).

QFD has clearly succeeded in re-adjusting the team's approach to design. For example, it has:

- forced the traditionalists to get out there for the first time in their lives and listen to the customer
- killed off many misconceptions and reduced unproductive debate within the team
- focused the minds of the team on design target values rather than on acceptable limits.

Using the target analogy of Figure 5, QFD has helped Digital Equipment to become much more 'outwardly looking' throughout the development process. In doing so, it has enabled the requirements to be closely focused on customer needs rather than the scattered views from within the company. More than 100 QFD studies have now been completed for both products and services and has lead to some staggering results. The recent VT1000

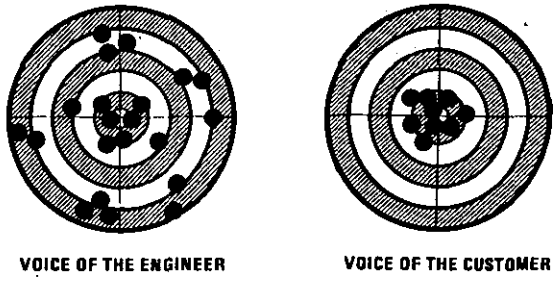
FIGURE 4
QFD PLANNING MATRIX



terminal when compared with a previous similar product, resulted in:

- 75% reduction in the concept phase time
- 40% reduction in the total engineering changes needed to get the product to market
- 25% reduction in product features (mainly through designing what the customer wanted, rather than over-designing what the team believed the customer would want).

FIGURE 5
CUSTOMER DRIVEN DESIGNS

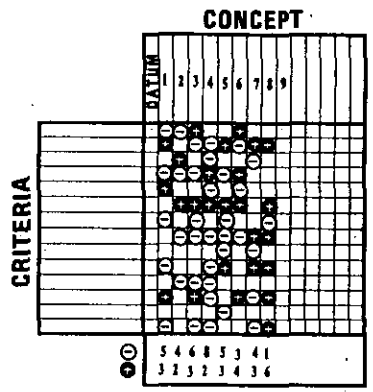


CONVERGING ON THE BEST CONCEPT (CONCEPT SELECTION)

After producing several concept proposals, designers would use their best judgement to determine which one to take forward. Their judgement would invariably be based on providing the best functional product and not necessarily the best for manufacturability, servicing, and other considerations. Only at a later date in the development cycle would these weaknesses become clear. By then it would be too late to revisit another potentially 'better' concept and work it through.

Today, the chart method, as shown in Figure 6, is used to direct the team through a disciplined procedure for evaluating and converging towards the best overall product concept. After capturing the 'voice of the customer' through QFD, some 10 to 20 product concept proposals may be developed. The technique then required the team to rate each concept for a given set of life cycle criteria. As trends in strengths and weaknesses start to emerge, the team will be stimulated into creating further concepts. The net result is a far superior concept which blends many of the individual strengths of previously evaluated concepts.

FIGURE 6
CONCEPT SELECTION



MANUFACTURABLE DESIGN FROM THE START (DFMA)

Within the design concept phase, the team considers how best to reduce manufacturing costs and time. Working to a set of DFMA objectives, they have made substantial competitive savings in the 70% of costs which are normally committed during design. The key objectives include:

- design for minimum number of parts
- develop modular designs
- minimise part variation
- design parts to be multi-functional
- avoid separate fasteners
- minimise assembly directions

  design for ease of assembly
- minimise handling
- eliminate or simplify adjustments
- avoid flexible components.

In many instances, these DFMA objectives have encouraged the team to design products that open up greater manufacturing improvements in quality, cost and cycle time. For example, with traditional thinking, screws are considered as a quick and easy design method for holding two parts together. However for the production department, driving these screws into tens of thousands of products is far less productive than say plastic snap-fitting the assembly together. A quick calculation has shown that each screw that is designed out of a workstation assembly has saved the company around £20,000 per year in cost avoidance.

At the Colorado Springs Plant, Digital Equipment chose to assemble the critical parts of its head-drive assembly for its RA90 disk drive system in an automated clean-room environment. This automation was considered necessary to reduce scrap and rework from damage through manual assembly and to enhance manufacturing yields by avoiding human contamination during the assembly process. But getting the robots to assemble such a complex and delicate piece of equipment was not an easy task. Assembly clearly had to be made easier. Parts needed to be assembled with one hand, in one direction - from top to bottom, to make effective use of the robot. The only reasonable way of ensuring that the best results were achieved was to carry out product and process design in parallel.

Integrating product and manufacturing process design decisions at an early stage of the development cycle is now common practice within the company. Many benefits have resulted through lower part counts, simpler product bill of materials with less levels, shorter assembly times, simpler production control, less inventory, and less operations and material costs as shown on Figure 7.

BETTER QUALITY, LESS COST (TAGUCHI)

Designers are always being pushed to provide greater performance and capability from their designs. A key route to achieving this in the past has been to tighten up the specifications and tolerances. This approach may have met the functional goals for the designer, but frequently it resulted in more costly and highly sensitive designs which were easily degraded by variations in the manufacturing process or in the operating environment.

Today the emphasis has shifted to designing in robustness using the Taguchi methodology, Figure 8. This consists of analysing predefined combinations of parameter values to determine their effect on the overall product performance. After a limited number of analyses as determined by the Taguchi method, the optimum set of parameter values can be determined for maximum design robustness.

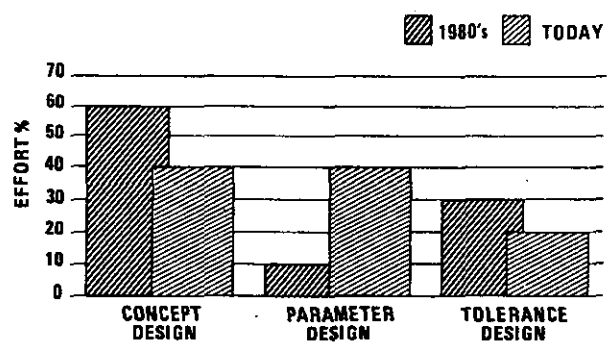
FIGURE 7
DESIGN FOR MANUFACTURING AND ASSEMBLY

	Workstation Mouse	Graphics Terminal (VT1000)	Magnetic Tape Unit	Mid-range Computer (VAX/6000)
Part Count Reduction	50%	43%	52%	20%
Assembly Time Reduction	65%	–	55%	42%
Reduced Assembly Operations	33%	–	–	–
Part Cost Savings	40%	72%	43%	–
Life Cycle Cost Avoidance	–	$21M	–	$75M
Design Cycle Time Reductions	–	73%	–	–

Where the necessary levels of robustness cannot be achieved through the Taguchi method, then the specifications and tolerances can be selectively tightened to meet the product objectives. This has required a major re-adjustment to the design culture, which 4 years ago, would have seen designers committing tolerances at the earliest opportunity.

Finally, prototyping is carried out with the optimum parameter values to prove that the product works. Many notable benefits have been achieved throughout the company as a direct result of improving quality through robust design:

FIGURE 8
APPROACH TO ROBUST DESIGN



- 60% reduction in re-work, and a 44% increase in machine utilisation for a surface mounted assembly process
- 25% cost of quality reduction for the head-drive assembly on the RA90 disk drives
- 50% increase in operational life for an input device.

CHANGING TRADITIONAL ATTITUDES

Much of the design/engineering effort was previously expended at the back end of the process on those expensive engineering changes that occurred just before manufacture.

Today, the highly tuned design process and the 'right first time methods' have encouraged the product team to front load the effort around the concept/specification stage. (See Figure 9). This in turn has resulted in the total effort to deliver a product to market being cut by 50%.

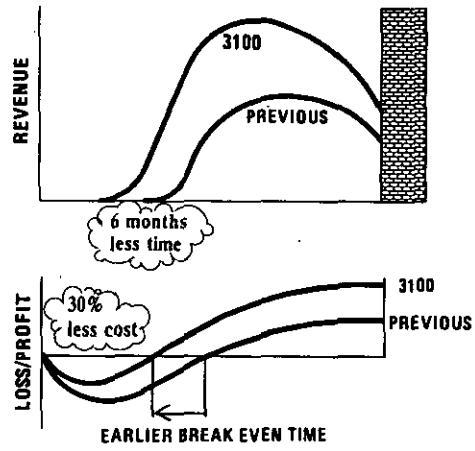
But this whole notion of front loading the effort presented a major barrier to management. Unlike putting more resource into a manufacturing operation and seeing more valuable work-in-progress coming out, in design, there is at best a few more drawings and charts. There is very little substance to suggest that things are going well. It has taken a great deal of commitment and confidence to believe that there will be major benefits down the line in superior time, cost and quality.

CLEAR TEAM GOALS

In order to understand clearly how well the delivery process and methods are working out, it is critical to measure the right things that create supportive attitudes and continuous improvement. In our business we have found that there are at least four key measures that help us to gauge whether we are making steady competitive progress. These key measures include:

- **Predictability** - It is necessary to determine the cost of the product at the earliest stage so that the best competitive concept is developed. These costs will be compared to the actual costs after launch.
- **Zero Engineering Changes** - The aim is to eliminate all engineering changes after prototyping and handing over to manufacturing. Today we are down to 10% of the levels experienced 3 years ago.
- **Zero Ramp-up Time** - Here we are measuring the time it takes to ramp-up to volume production levels. This has been driven down from months to weeks by going back and refining the process.

FIGURE 10
EARLIER BREAK EVEN TIME

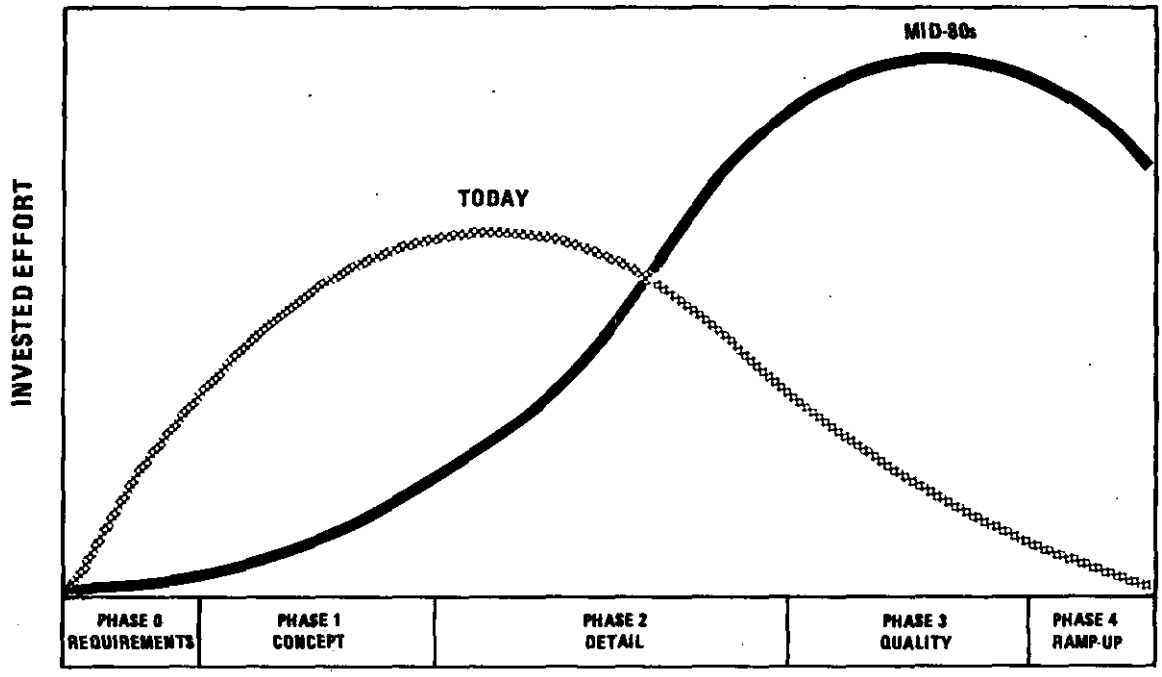


- **Zero Phase Reworks** - As each phase of the development process is progressively completed, lengthy rework loops can occur which severely disrupt and slow down the efforts of the team.

  An important source of feedback is the number of rework loops that cut back into previous development phases. With each development cycle, the objective is to eliminate them completely.
- **Break even time** - Is the time taken to balance the cumulative new product investment with the cumulative profit earned. It is the earliest commercial indicator for the team to assess the impact of time to market, customer satisfaction and product quality in a balanced way.

Figure 10 shows how the compounded effect of earlier-to-market and less cost-to-market for the MicroVAX 3100 can impact the break even time.

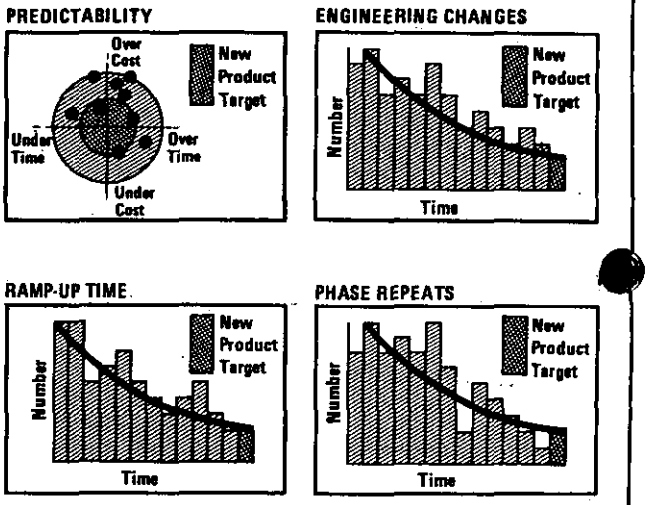
FIGURE 9
CHANGING TRADITIONAL ATTITUDES



CONTINUOUS IMPROVEMENT

With these measures in place, performance can be gauged in terms of meeting the key business drivers. At the end of each product life cycle, the process, the methods, the team activities, etc. will be reviewed and gradual improvements made to drive towards better results with the next product. Weaknesses will be brainstormed and incremental improvements recommended for inclusion into the process for following products. As the history of these performance measures are viewed, confidence can be gained in comparing the actual trends against target curves. (See Figure 11).

FIGURE 11
TARGET MEASURES



Through this process of continuous improvement, Digital Equipment has been able to halve the time to market, and halve both product and start-up costs. It is now planning a further halving of these within the next few years by improving on each process measure each time the product development cycle is performed.

In today's markets there is no alternative to getting it right first time. Profits are set in design and they provide the lifeblood of industry to re-invest in further success. None of this is an easy exercise. There will be many set-backs, changes, false starts, and disappointments along the way, but when it all starts to come good the rewards will almost certainly be devastating

About the Author

Keith Nichols joined EDS Limited in February 1992 as U.K. Manufacturing Consultancy Director.

Prior to joining EDS, Keith spent some 20 years in shipbuilding, defence, electronics and computer manufacturer organisations, and played a key role in getting products to market within cost, quality and delivery commitments.

He has worked and managed various product functions, including design, production engineering, support and marketing. He has first hand experience in moving organisations over to Product Teams and implementing a "right-first-time" approach.

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