VOLUME 1 NUMBER 1
1994

Delivering the Promise

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Concurrent engineering promises to deliver an increased competitive advantage to the company that not only hears its message, but sincerely applies the principles contained within its scope. So the question is, if a product development team avidly pursues concurrent engineering, can it truly expect these results? And will this concept of the 1980s and 1990s really provide the kind of breakthrough companies need to compete in the years ahead? One way to find out is to examine a case history of a product development team that avidly followed the tenets of the concurrent engineering concept.

The development of the Hewlett-Packard (HP) 34401A multimeter demonstrates the progress that can be realized when the necessary ingredients are in place and the people involved are given a chance to excel. The HP 34401A can be seen to represent a significant advance in price, performance, and value in the test and measurement market.

Project Objective

HP Loveland designs, manufactures and markets a variety of electronic products for use in the test and measurement market. This $5 billion market is presently characterized by slow growth and increased competition from both Europe and the Pacific Rim. The digital multimeter segment of the test and measurement market comprises about $300 million. Products in this mature market range in price from a few hundred dollars to several thousand dollars based on performance and capability. The 34401A development challenge was to deliver the performance of $3,000 to $5,000 instruments at a $1,000 price. Meeting this objective was a vital part of our overall business strategy. To do this and still provide growth through satisfactory profit, would require a comprehensive and fresh approach to the product development cycle.

Team Formation

The formation of the 34401A team was done in a number of phases rather than an immediate and deliberate attempt to define a huge simultaneous engineering team. The initial staffing consisted of a project manager, mechanical R&D engineer, two electrical R&D engineers, and a manufacturing engineer to review alternatives to the mechanical approach to the product. Four more R&D engineers and a marketing engineer were added shortly to complete phase one. The second phase involved the assignment of several manufacturing engineers and subsequently a manufacturing project manager. Phase three followed quickly when two events occurred. The first was the collocation of the entire development team, the second, when management expanded the boundaries so that the team could function as a “virtual Greenfield” effort. The team consisting of R&D, manufacturing, and marketing was now in the same location enabling easier communication and alignment of purpose.

As a part of the second event, the team was allowed by upper management to challenge the existing financial systems and processes that were in place. The R&D and manufacturing project managers worked together to develop a strategy concerning financial and accounting related issues. Traditional cost accounting would bear tough scrutiny on the 34401A project.

Learning to Work Together

Phase one and two had incorporated some design for assembly and design for manufacture focus. There was also extensive activity in the area of market research. But not until phase three, when the entire team was geographically together, did we realize that there was something lacking in our product development culture. That something was, quite simply, the skill of working together as a cross-functional team. The R&D portion of the team had worked together before on similarly challenging projects. However, most of the

World Class Design to Manufacture, Vol. 1 No. 1, 1994, pp. 33-38
MCB University Press, 1352-3074

manufacturing staff had not previously worked together and also had to catch up quickly with the team momentum. They were now thrust into a new daily interaction with each other and we quickly discovered that working together as a cross-functional team is a progressively learned skill. Unfortunately, the technical community is typically not trained in academia to function as team members. Engineers are especially vulnerable to individual competition in undergraduate and even graduate level education. As a result they can sometimes bring a maverick individualism into the workplace that disrupts commonsensical endeavours such as concurrent engineering. To overcome some of these challenges, the project team took some collective training in such areas as team development, conflict management, and personality type analysis. We needed to discover how to handle the inevitable conflicts that arise in product development constructively. Also, team development models and the Myers-Briggs personality type analysis were utilized. These analyses helped us learn how to benefit from diversity instead of working against it.

Tools

Aside from extensive market research, the HP 34401A project primarily used three key tools in the course of its development. Quality function deployment (QFD), activity-based costing (ABC), and design for manufacture and assembly (DFMA) were the primary team tools used to focus on the areas we felt were most important to the success of the product.

Quality Function Deployment

As mentioned before, extensive market research had been conducted prior to team co-location. This effort continued with phone surveys, key customer visits, focus groups, mail surveys, and interviews with internal users of multimeters. The information gleaned from this research was compiled by the team and was analysed using quality function deployment (QFD). This tool proved valuable to the team in a number of ways. First, it allowed us to focus on real customer needs. The all important “voice of the customer” was a concept that helped us navigate through times of disagreement. Second, QFD allowed the four requirements asked for by the “voice of the customer” to be translated into measurable manufacturing requirements. For example, one of the clear considerations of future customers was the availability of the instrument. A specific objective of 24-hour turnaround from order receipt to the shipment of the multimeter, drove manufacturing to develop new processes that could deliver at that throughput level. Third, QFD became a common thread allowing marketing, manufacturing, and R&D functions to actually optimize the overall business objectives. It provided the necessary alignment of goals and objectives for the whole product team. The benefits of using the QFD process can be summed up by the following list.

It was used to:

- Focus on delivering “just enough” functionality to meet customer needs.
- Identify customer “excitement features”.
- Document decisions, considerations, and rationale.
- Make trade-offs between alternate scenarios.
- Communicate expectations and rationale.
- Disseminate information between team members.
- Do front-end decision making.

Its output was a document that:

- Did not presume a solution.
- Captured financial goals and boundary conditions.
- Captured factory performance metrics in addition to cost.
- Embodied the product development vision.
- Provided a common communication medium with others.

Activity-based Costing

In the past, products had been developed using a “bottoms up” approach. That is, they were first designed with rough customer goals in mind, then costed, and then priced. The HP 34401A reversed that approach. With our market research in hand, and the QFD done, we knew exactly what the price needed to be. Now it was a matter of costing the product. The design would have to fit these hard-cost goals.

Much has been written about the virtues of activity-based costing (ABC) in recent years. HP’s form of ABC had been in place about four years at the time of the 34401A project. At that time there were in excess of 15 manufacturing process cost drivers in place. However, our ABC system just wasn’t sensitive enough to the changes we proposed. It captured the status quo very well, but it became obvious that it would not represent the true costs of the processes and improvements being considered. Its limiting factor was that it assumed the use of existing processes and allocations. For example, there were still some non-process related costs that were being allocated across complete product lines. This was being done without regard for such things as the difference in engineering support requirements or differences in field warranty rate. Therefore we needed an enhanced financial model to characterize this specific product as if it were the only product in a start-up type of business. Such a model was developed by the team responsible for breakthrough costing, including the finance department partners. The objectives of this financial model were to:

- lay the foundation for modelling the 34401A profitability;
- evaluate different manufacturing options, processes and volume sensitive scenarios;
- document assumptions;
- provide feedback in less than two hours.

Basically we wanted to be able to make quick, accurate decisions based on the product's stand alone true costs while shedding old traditional cost burdens. Design trade-offs could be quickly evaluated based on the off-line models. For example we closely examined areas such as material stock and pull. New methods were developed to have suppliers deliver directly to the line in a "weekly" JIT process. We also improved the reliability of the unit to avoid costs for trouble shooting and technician allocations. This was done by making the design more robust and then verified with exhaustive reliability testing. We also concentrated on selecting higher quality materials and components.

Design for Manufacture and Assembly

Prior to the 34401A project, HP Loveland already had experience with design for assembly and design for manufacture (DFMA). In the mid-1980s initial DFMA efforts centred around redesigns of existing products to enhance their manufacturability. There was a reserved opinion about the credibility of any "new" approach such as DFMA to have a favourable impact on new product development. Most managers saw it as a threat to meeting their schedules. Because of these conditions, the redesign route was chosen to "test" the power DFMA could have. The conclusion was that even on existing products with far more constraints to design than on a new project, DFMA efforts are not only worth it, but they provide excellent competitive results. Production cost savings on these redesign projects ranged anywhere between a low of 5 per cent to a high of 18 per cent.[1]

From that point, HP Loveland embarked on several other DFA efforts in new product development and achieved significant success in the reduction of parts, assembly time, number of operations and types of fasteners used in their products (see Figure 1).

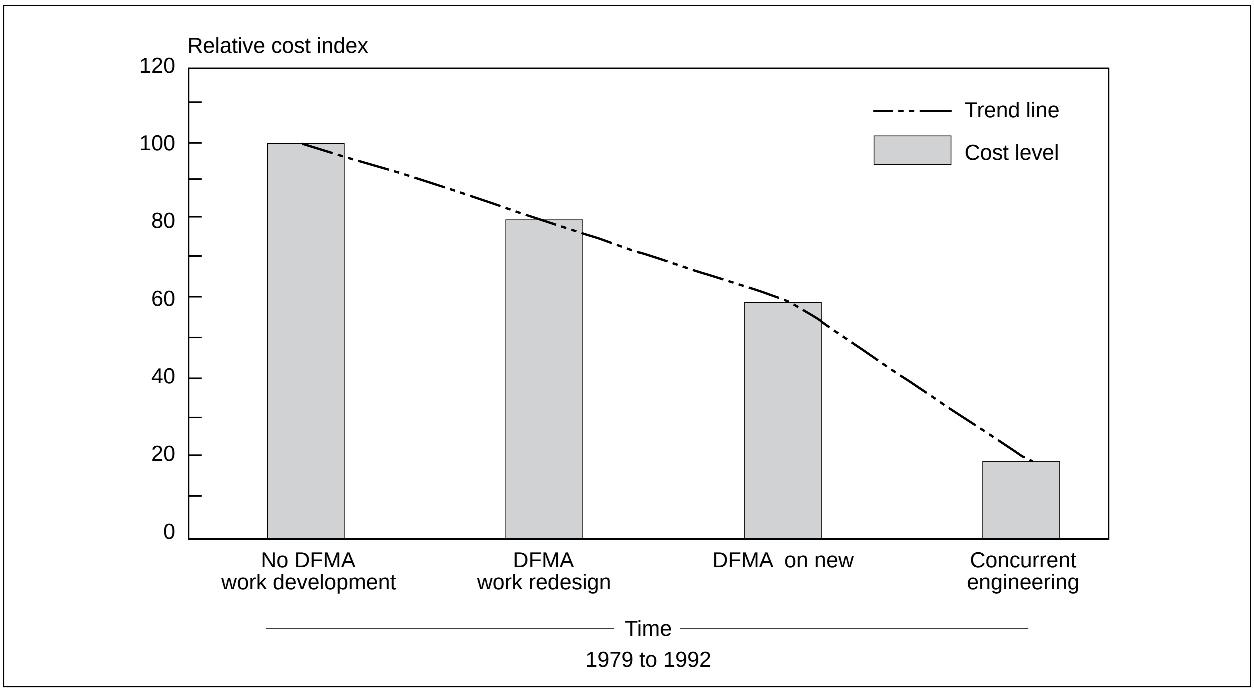

Figure 1.
Relative Improvement Using DFMA and Moving towards Concurrent Engineering

Product development during this time took the form of one-to-three manufacturing engineers interacting frequently with members of the R&D team. The assembly improvements were primarily due to a heightened awareness of DFA by the designers. One retrospective lesson learned from these early successes was that the cost-cutting power of good design through DFMA was enough to create excess assemblers on released product lines. We did not adequately attend to the long-range labour planning affected by these improvements. We were eventually faced with the resizing or redeployment issues of the people that used to put these products together, and thereby lost some of the cost improvements while doing so.

On the HP 34401A, every piece of the product was analysed using the DFMA™ methodology and software from Boothroyd-Dewhurst Inc. As a result, there are many DFMA-related features on the 34401A, but probably the most innovative of those is the input connection scheme. Previous multimeters from both HP and its competitors utilized point-to-point wiring from the terminal receptors to the printed circuit board. Because analogue measurement requires high impedance, Teflon wire was hand soldered between these two points. That meant a total of ten wires, each with two hand-soldering operations at final assembly. A clever design consisting of formed copper tubing of the required diameter for a "banana jack", coupled with a high-temperature plastic housing, allowed these terminations to be made at the wave solder machine rather than having to hand solder at final assembly. Also of particular note is the fact that the entire front panel assembles with no screws.

Many of the ideas for these features and sub-assemblies were conceived well before the bulk of the team had arrived. But it should be emphasized here that it took a cross-functional team effort to identify producible designs, materials, and the correct suppliers to make the ideas work. The key deliverable of any DFMA effort is a significantly reduced part count. Lower part count allowed us the freedom to try some new manufacturing processes.

Visible Success

One of the most efficient ways to discover the relative success of a concurrent engineering effort is to take a look at the product's final assembly area. A visit to the 34401A's final assembly cell is visual proof of long-term thinking, thorough planning and reliable design. To begin, we see a multimeter that can be assembled manually by one person in just over six minutes compared with 20 minutes for a unit that it replaces. The product is then placed in a test system directly behind the main assembly area. After the unit is temperature stabilized, zero calibration is accomplished followed by full-scale calibration and performance verification.

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Demand variations can be responded to easily

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We also observe that a week's worth of parts resides in a space of less than 300 square feet and that the production line is designed so that most part suppliers can bring parts directly onto the production floor, stock them, and remove empty totes and boxes from last week's build. Industrial dollies are rolled from the supplier's wagons directly into the final assembly cell. The environmental problems and time-related costs of dealing with corrugated boxes, packing material, and the whole issue of detrashing has virtually been eliminated by these recyclable totes and durable dollies. Visitors also see production and assembly personnel ordering next week's required material via "fax kanban", without the need for a material buyer on a regular basis. Open purchase orders with key suppliers have been negotiated long ago by a buyer. The production personnel give regular quality feedback to the suppliers via phone or once a week when deliveries are made directly to the line. With only 18 parts to keep track of, demand variations can be responded to easily by increasing or decreasing next week's orders. Inventory levels are immediately visible and are monitored once per week and compared to orders to calculate future required part quantities. Inventory turns are greatly enhanced and material has a much higher throughput than previous designs. Typical instruments for example have the equivalent of 60 to 75 days of inventory at any given time. The 34401A averages the equivalent of 2 to 4 days of inventory. Production engineers have limited involvement since turn on rates are so high and field warranty rates are lower than previous instruments.

The key point is that part count drives virtually all of the downstream processes in manufacturing. Without development tools, particularly DFMA, these competitive advantages could not be realized. Without the concurrent product development team working together early on, cost benefits such as these could not have been captured.

Extended Teamworking

Additional cross-functional efforts tackled by the team involved characterization of new printed circuit board assembly techniques, concurrent custom-integrated circuit parts and process development, and design and process characterization for process capability.

First, the technical product definition which evolved in phase one, and then later as QFD was rigorously applied, made one thing obvious. We would be forced into a serious consideration of using at least some degree of surface mount technology (SMT). To the casual observer this probably would not be so impressive, given the broad acceptance of SMT. However, one must consider that a system multimeter capable of measuring one millionth of a volt, requires exceptional cleanliness in the PCB and PCA processes. We had never done a precision analogue measurement board using mixed through-hole and surface mount technology before now. The evaluation of variables such as solder mask type, platings, trace widths, laminate type, solder paste cleanliness, post-reflow cleaning techniques, and other mechanical part innovations, made for a project within a project. A manufacturing process engineer on the team was assigned with the task of investigating many technical alternatives and then pulling together the peripheral resources necessary for implementation. At the same time this person interfaced with the surface mount factory team particularly to convey reliability goals of the product.

The second area involving technology was the challenge of developing a custom integrated circuit for which there was no existing IC process. We had to work concurrently with our in-house IC facility and together, develop not only the device, but the process for manufacturing it. This was obviously a crucial leg in the product development cycle because it involved a great deal of the specifications required for higher performance. It was also vital in the quest to reduce the number of parts on the printed circuit board, which in turn helped reduce costs. The IC not only had to be developed, but had to meet aggressive producibility goals which were spelled out in the QFD effort. Process capabilities (Cp k) were set at 1.33 minimum.

The third area involving a new approach was the effort to ensure that all processes used and their parts could meet the 1.33 minimum process capability number. This kept members of the manufacturing portion of the team very busy. The same design care and exhaustive testing philosophy had to pervade every part and every supplier who made the part. The producibility of the total product is only as good as the multiplied producibility of each of its individual components.

Project Results

At this point the question to be asked is, "did concurrent engineering deliver its promises to the HP 34401A project?" Table I contains an abridged list of the promises of concurrent engineering along with the comparative data from previous HP products.

Summary

One of the early keys to the success of the 34401A was the high level of support received from the entire management chain. They gave us the freedom and ability to analyse the total system in order to find where true costs were originating, and they also gave us the necessary infrastructure to form a cross-functional collocated team. There was an overall project manager assigned up front. We were given a basic product development

Concurrent engineering metric	HP34401A	Percentage Previous generation	Previous
Material $	80	100	200
Non-material $	55	100	250
Assembly time	37	100	210
Average repair time	33	100	400
Number of mechanical parts	30	100	190
Number of fasteners	31	100	172
Number of fastener types	8	100	85
Connects/disconnects adjustments	36	100	120
Final assembly parts	40	100	153
Total parts	68	100	190
Total part numbers	77	100	150
Number of suppliers	70	100	N/avail
Inventory days	4	100	100
Throughput	1,000	100	100
First year engineering changes	0	100	58

Table I.
Concurrent Engineering Comparisons

charter, informed of general boundary conditions and then afforded the freedom to execute.

Also, the success is due in large part to three additional elements:

(1) Extensive use of market research.

(2) Tops down approach (start with cost and work down).

(3) Cross-functional, collocated team effort.

We found a great deal of satisfaction, knowing that we had not taken the easy road to product definition and development. The satisfaction comes when we see the product eagerly received in the marketplace, selling well ahead of projected marketing ramps. Satisfaction also comes when you see the team on the production floor enjoying what they do. They enjoy what they are doing because they contributed valuable inputs to the project in the early stages. They are not plagued by problems caused by lack of attention to details. Their involvement added the benefits of rapid response to changing order demands. We see the engineering support function able to devote their time to other value-added projects. This is possible because they are not fighting avoidable problems on the line or writing engineering change orders. Twenty-two months after production release we had not had a single design-related engineering change order written in order to keep the line shipping the product.

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We found concurrent engineering is just plain hard work

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Finally, we found that concurrent engineering, if genuinely done, is just plain hard work. As mentioned before, working together as a cross-functional team is a skill that eludes many Western firms. Our individualism had to be throttled to the extent where we could be a co-operative contributor to our team and yet still retain our individual creativity. Any way you analyse it, to make highly-trained, intelligent and competitive people to work together on a daily basis is a skill most companies wish they could just order by way of a decree. But it can be realized only when there is firm resolve, coupled with repeated trial and failure. Only then will the skill be developed. The intrinsic benefits of that developed skill are leverageable into the future and, if implemented properly, the concurrent engineering effort will again deliver on its promises.

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Reference

1. Corbett, J., Dooner, M., Meleka, J. and Pym, C., *Design for Manufacture – Strategies, Principles, and Techniques*, Addison-Wesley Publishers Ltd, Reading, MA, 1991, pp. 188-93.

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