# Reducing Cycle and Development Time at Ford Electronics

# Part I: Continuous Flow Manufacturing

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## 0. Prologue- Purpose and Method

The purpose of this study is to provide a dynamic framework in which to understand the key determinants of the success or failure of improvement efforts such as Total Quality Management (TQM) and Business Process Re-engineering (BPR). This case describes a particular initiative with emphasis on the descriptions provided by those who actually participated in the program.

The primary data collection method was interviews. Interviews were performed in a semi-structured fashion. Participants were presented with an outline that listed the topics to be covered. Participants were asked a number of standard questions. Each interview began with the participant describing his or her history with the company. Each person was then asked to give a more detailed description of her personal experience with the initiative. At this point only clarifying questions were asked. As the interview progressed, questions were asked that required progressively more speculation. Each interview culminated with the participant assessing the key successes and failures of the initiative. Given the preliminary nature of the research, participants were not forced to stay with the outline. If the interviewer felt that the participant was pursuing a profitable avenue, the participant could continue in that direction. All interviews were recorded, and all quotes were taken directly from the recordings. Participants have been allowed to check their statements for factual information, and to re-phrase sentences that did not translate well to the written format.

Quantitative data were obtained from the company. To protect confidentiality some data have been either normalized or disguised. In each case the transformation technique is described.

# Part I

## I. Introduction

Throughout its history the Ford Motor Company, like most large corporations, has undertaken a large number of ‘change’ initiatives. The number of these initiatives has increased substantially since the early 1980s when American industry realized it was losing market share to lower cost and higher quality Japanese products. Unfortunately, while some of these programs had a lasting impact, most did not. Many times they were quickly supplanted by a new program that offered the promise of improved results. The Electronics Division (ELD) within Ford has not been immune to such trials. It too tried numerous programs, many of which never took permanent hold. The purpose of this case is to document and analyze one initiative within ELD, Continuous Flow Manufacturing (CFM), which has had a sustained and dramatic impact on the division’s performance.

### The Site

The Electronics Division of the Ford Motor Company has primary responsibility for the design and manufacture of the electronic content of Ford cars and trucks. Among other products, ELD manufactures electronic engine control (EEC) modules, electronic steering and suspension systems, air bag diagnostic modules, driver information systems (instrument clusters, etc.), and audio products. Due primarily to the increasing electronic content of automobiles, ELD has grown significantly in the last decade. Currently, ELD has eight manufacturing facilities including locations in the United States, Canada, Mexico, Brazil, Spain, Portugal, and England. Two of these facilities have been added since 1988. The majority of the design and product engineering take place near the division’s headquarters in Dearborn, Michigan. In 1992, ELD had revenue over 2 billion dollars.

### The Customers

ELD’s primary customers are the car and truck production lines contained in Ford’s many body and assembly (B&A) facilities. B&A plants are very demanding. These facilities require substantial capital investment, and a premium is placed on keeping the production lines running at all times. Shutting down a production line for even one hour can result in the loss of as much as a half of a million dollars. A supplier’s ability to deliver parts on time and in the proper amount is critical. Even a few late shipments can result in lost business for ELD, as the customer looks to external suppliers for better shipment reliability. ELD customers are also focused on quality. Just as an ELD plant can be 'de-sourced' for poor shipment performance, it can lose business if it ships products that are defective.

### The Initiative

In early 1988 the manufacturing cycle time (MCT) (defined as the time required for a component to make its way through the shop floor and exit as a final product) for a typical product produced by the division was approximately 15 days. At that time the division carried approximately 200 million dollars worth of inventory. In 1988 the division planned to build a new manufacturing facility every year for the next four to five years. In January 1989, the division launched a plan to reduce inventory by 50% by 1994. In July of the following year the division management set an even more aggressive goal of reducing the average manufacturing cycle time of each plant to one day by the middle of 1995.

By the end of 1994 all these objectives had been achieved and, in some cases, surpassed. Inventory was valued at less than $100 million, the division's average cycle time had fallen to less than one day, and only two new plants were needed. Meanwhile the division's financial performance improved dramatically: revenue more than doubled, and profit increased over four fold, rising from less than 100 million dollars in 1988 to almost four hundred million dollars in 1994.

While the division introduced a number of change initiatives during this time, much of the improvement stemmed from an initiative focused on reducing the cycle time of ELD's manufacturing operations. This initiative, Continuous Flow Manufacturing (CFM), continues to play an important role in the operations of ELD. CFM also spawned a number of follow-on actions, including an effort to reduce the product development time, and another to propagate the success of CFM to Ford operations outside of ELD. The purpose of this paper is to document and analyze the success of the CFM initiative with a particular focus on identifying the factors that allowed CFM to succeed when similar initiatives failed.

### The Plants

This case will focus on the experience of two ELD manufacturing facilities, Alpha and Beta (pseudonyms).

*Alpha*

The Alpha facility, located in North America, was launched in 1984 to replace an outdated facility. It is approximately 300,000 square feet in size and produces air bag diagnostic modules, instrument clusters, and a range of other special purpose electronic modules. In 1992 Alpha employed over 1,00 hourly workers and approximately 200 salaried personnel. Within ELD Alpha has traditionally been an innovator in new manufacturing practices, and its managers pride themselves on their willingness to be innovative and to experiment. It has a highly skilled, diverse work-force; over thirty different languages are spoken in the plant.

*Beta*

The Beta facility was launched in 1990 to replace an older facility that was located in nearby. Electronic Engine Control (EEC) modules comprise over 50% of Beta's production. The previous facility was one of the oldest in ELD, and most of the work-force transferred to the new facility when it became operational.

## II. State of the Division before CFM

### Schedule Attainment and Equipment Utilization

Prior to the introduction of CFM in 1988, ELD's manufacturing facilities were operated in a manner similar to that of other companies whose business requires substantial capital investment and labor expense. There were two major operating goals: 1) satisfy the day's production requirements, and 2) keep each piece of equipment and each member of the work-force fully utilized. To support these goals, ELD used a traditional performance measurement and evaluation system that emphasized budgets and extensive analysis of the 'variances' between actual and budgeted performance. Direct labor performance, loosely defined as the number of units produced per person, was considered to be one of the most important measures of performance in each production area.

The measurement system bred an environment in which each line supervisor had two dominant thoughts each day: produce the daily production requirement and keep everybody busy. As an operations manager at Alpha said, "...supervisors would always hit their exact targets, if the goal was 200, they would pack [produce] 200, never 198, never 202." and another noted "...they would make sure everybody was busy all the time to make labor efficiency". The penalty for not doing these things was substantial: "... supervisors who missed their targets knew they were going to get 'beat up' by their managers."

## The Role of Inventory

The focus on hitting daily production targets and keeping machines and workers busy gave supervisors strong incentives to keep high levels of work in process inventory. The focus on utilization meant that every machine was kept running at all times regardless of whether the parts it produced were needed by a downstream operation or required by the production schedule. As a result inventory accumulated on the upstream side of every operation. A manager from Alpha explains:

> Supervisors at that time were evaluated on labor performance on a daily basis. It didn't take long for them to develop a buffer in front of their line so that if the schedule called for 700 and their line was fully utilized at 800, they could still run 800 units every day, and still make their labor performance.

Another manager from Beta recalls:

> Before [CFM] if you were to walk out onto the floor and ask a supervisor how things were going, he would say "Great, all my machines are running" and you would see tons of WIP sitting around. They were using the theory of 'Keep all My Machines Running'.

High levels of inventory also provided a buffer against unreliable equipment. Many machines used in ELD facilities were prone to frequent short term stoppages: any unplanned machine down time could put the supervisor at risk of missing the day's production target. Supervisors compensated by holding high levels of inventory downstream from unreliable machines. A supervisor from Alpha said, "...if you came up short one day, you always had enough extra to get to your production target."

Finally, high levels of buffer stock de-coupled the production lines so that scheduling could be done separately for each machine with little regard for the rest of the production line. As a manager from Beta said,

> ...inventory was used as a crutch. Every operation could be scheduled out of the [work-in-process] pile that sat in front of it with very little regard for the upstream operations. If we needed something critical, we would look at WIP to see if there was something we could expedite. God help us if we had to build something from scratch.

The inventory accumulation reached such a level that some ELD facilities began to run out of floor space. Lines would frequently run out of the pallets and magazines used to store modules in process. As one materials manager remembers, "...before CFM, at any point in time we would have literally thousands of partially completed modules in between machines on the line." Another said, "...we basically completely ignored the fact that buffers were expensive. We weren't measured against it, so we didn't think about it."

## III. Kicking off the Initiative

### A New Perspective for Ford

The shift towards a leaner production environment began in 1988 when ELD hired a former plant manager from IBM, as its new General Manufacturing Manager (GM). This was an unusual move for Ford as senior positions are generally filled by promoting from within the company. However, some felt that ELD's manufacturing capabilities lagged behind those of consumer products and computer manufacturers, and, as one manager described it, at that time "IBM still had the aura of invincibility". Hiring the new GM was seen as a way of tapping into the knowledge base of other electronics producers. The new GM also felt that there was a substantial difference between electronics manufacturing at Ford and at IBM.

> At IBM, we really managed the facilities by focusing on inventory, both total dollars and turnover, and we always treated people as something that wasn't going away, as a fixed instead of a variable cost. We also didn't have the emphasis on machine utilization that they had in the auto industry.

The contrast between IBM and ELD became increasingly apparent to the new GM as he began to attend meetings at his new employer,

> ...in the first series of meetings that I attended, the topic of discussion was the utilization of a particular piece of equipment in our Beta facility....from IBM I was used to monthly reviews on inventory performance, etc. Here each and every plant was being measured on machine utilization, and nobody was looking at inventory, or the time spent actually adding value.

To the GM, these differences were a symptom of a larger problem faced by ELD's manufacturing facilities. He recalls,

> I felt that nobody was looking at our manufacturing facilities as a system. They were looking at pieces, and, as a result, spent their time trying to optimize each piece. The guy running the solder equipment might be running boards through there like nobody's business, but did that improve the output of the system? I'm not sure anybody really knew that.

To begin to change the traditional mind-set, the GM needed a way to communicate the lessons he had learned about inventory management at IBM. He asked a member of his staff to analyze the time it took a product to make its way through a typical ELD manufacturing line.

> We analyzed [for a sample product] the time elapsed between when a part came in the back dock until the time it left the shop floor, and asked the questions "How long did it take?", and "What was the value added?". We found out [for this product] it took 18 days to make the product and we were adding value to the product 0.5% of the time. When I laid this out for everybody...they were astonished.

## A New Measurement Package for the Division

Seeing the information presented in this way convinced many people that something needed to be changed in ELD's manufacturing operations. The GM and his staff started by developing a new measurement package for the plants. They tried to focus the new measurements on two key ideas; the speed of the operation– measured by total cycle time– and the value added during the time the part was on the shop floor. Translating these ideas into metrics that plants could calculate required further discussion. The GM recalls,

> One of the first debates we had was over how to measure cycle time. Many people thought of cycle time as the cycle time of the equipment. They were looking at reducing the time a part spent on a particular piece of equipment from 20 seconds to 10 seconds. My feeling was when you are at 18 days big improvements are not going to come from focusing on individual machines.

The GM felt that a metrics package focused on the concepts of time and value added was important for two reasons. First, as he remembers, "...back then in ELD we had a focus on doing 50 million things of equal priority...You can't do that, people want simplicity, clarity, and focus." Second, the new metrics, unlike machine utilization, were measures of the performance of the entire manufacturing operation rather than that of a specific machine. The GM said,

> ...the other important thing about cycle time and value add- and I'm not sure I really understood it in this context then- they are process measures, not point in time measures. So when you are looking at cycle time you are looking at a process measure and optimizing the system.

## A New Visitor to the Plants

Adding a new measurement to the plant managers' objectives, however, was not going to be enough to change a company that had operated in a high inventory environment for many years. This wasn't the first time that plant personnel had seen a new program promoted by somebody from the division staff. Many initiatives had been introduced and few had produced lasting change. There was little incentive to make a big investment in a new initiative if it would soon be replaced by a new 'flavor of the month'. In addition, the plants didn't necessarily know how to improve the situation. Recognizing they had excess inventory was one thing, reducing it was another. During his first six months with ELD, the GM spent most of his time at the division office in Dearborn. After the new measurement package was put in place, this changed. In his words,

> ...from then on, I spent 70% of my time on the road. I spent all my time talking to plant managers, letting them know why this was good stuff, and making sure they knew what my expectations were.

All the managers interviewed were in agreement: the new GM was persuasive. A former plant manager from the Alpha facility said,

> ...one thing about [the GM], when he thinks something is important, he will be very consistent. Every single time he sees you he is going to ask you about it. You can count on it. And that's what he did with the plants. Every time he visited, he asked about cycle time.

These visits were an effective tool for convincing managers that MCT was taking a higher priority within ELD. The GM used them as opportunities to show examples of the new mind-set he wanted in the division. He remembers,

> They [people in the plants] wanted to give me presentations in the conference room, and I would say "no, let's go out to the floor"...I would always go out to the production floor and to the warehouse. I wanted to show them examples of what I was talking about. I might look at the shipping labels in the warehouse. If it were May, I would usually find parts that had been received the previous August, and I would ask, "if you aren't using this stuff until May, why has it been sitting here since last August?" It costs us cash, space, and maybe even quality problems.

## IV. Early Efforts: Measurements and Experiments

### Developing Success Stories at Alpha

One of the plants that showed early interest in the GM's new ideas was Alpha. Seeing this the GM tried to convince Alpha's plant manager to try some of the new ideas he was offering. The GM hoped that if Alpha could generate early success, the other plants, seeing this, would adopt the perspective themselves.

> My strategy was to convince him [Alpha's plant manager] to start doing it, get it in one manufacturing line, then spread it to the rest of the facility, and then use that as leverage on the other manufacturing plants.

To Alpha's manager, the GM was offering more than a couple of new measurements; he was promoting a different method of managing a manufacturing operation. He recalls,

> The concept of cycle time and value added were not unheard of at Ford....however, [the GM] had a very different vision about how those measurements could be used to really drive the operation and improve productivity.

Alpha's leader started his effort by assembling his team of managers and discussing the potential of the new approach.

> ...I had a very creative group of people that were willing to try anything that might move the needle forward in terms of quality and productivity....we sat down together and we talked about this idea and decided it looked like it did have merit. We then, very quickly, put together some pilots to try out these concepts.

Alpha began by adding some operational definition to the concepts of cycle time and value added. They experimented with different methods for measuring cycle time, and developed different definitions for what constituted a value added operation. While the GM was very adamant about focusing on the new measurements, Alpha's plant manager felt that he was purposely vague when it came to the specifics, "[the GM] didn't give us a lot of the details," he said, "...he probably knew more about it than he led us to believe, but I think he wanted us to take a fresh look ."

As the Alpha group developed working definitions of cycle time and value added, they began to record these measurements on a routine basis for the different production lines. The cycle times for the products were quite long, in many cases well over ten days, but this had been expected. The ratio of value add time to non-value add time, however, was more surprising. The plant manager recalls,

> .. we had a gut feel that our cycle times were going to be pretty long...but what really got us was that even with the very crude definitions of value add time we were using–they are much stricter now–we had astoundingly low cycle efficiencies [the ratio of value add to total production time].

In many cases the ratio of value add time to total production time was less than 1%. Although the numbers were very low, Alpha's leadership saw this as an opportunity. If the value add time was a large portion of the total cycle time it would be very difficult to make improvements without fundamentally re-designing many of the production processes. However, since only a small portion of a part's total cycle time was actually spent in production related activities, there appeared to be room for significant improvement.

With the metrics in place, Alpha began to focus on improving. In the first year of the initiative, as the plant manager recalls, "...things came pretty easily." Manufacturing had not been approached in this way before, and there was a lot of 'low hanging fruit' that could be picked quickly. In the first year, the Alpha group was able to reduce cycle time by a factor greater than two (figure 3). In addition, many of the improvements came without the aid of new tools or methods; just measuring performance in a different way caused people to see new opportunities.

> ...in the first year we started with simple counts at different times during the day, and we started to plot them and to try and understand what was happening. Very quickly our creative engineering personnel came up with clever ways to control the buffers that helped make big improvements.

The results generated in the first year helped people in the plant realize the value of the approach. It also helped generate enthusiasm for the second year's effort.

Although he believed that new tools would be required to make improvements in the second year, Alpha did not focus on creating a standard methodology. "At that time" a manager recalls "...we didn't standardize anything except how we made the measurements." People were encouraged to draw on new information sources, and to generate new ideas to help the plant improve. In addition Alpha's managers gave their staff the freedom to experiment. He recalls,

> If somebody had a better idea about how to manage the buffer, they could try it... During the first two years almost everything we tried we picked up from our own people...by giving them the free reign to start to do some things, they were able to go back to textbooks, business cases, friends they had in other areas that were trying similar things, etc. We tried everything from the Toyota Production System's Kan Ban to doing statistical process control on buffer sizes.

These experiments did come with a cost. The ELD performance measurement system still placed emphasis on keeping machines running. Reducing work-in-process buffers and experimenting with new scheduling systems inevitably resulted in lines being shut down. Shutdowns reduced machine utilization as well as put the plant at increased risk of missing its production schedule. The plant's management team made a special effort not to punish people for the problems caused by these experiments. The plant manager recalls,

> ...the best thing we did was that we didn't kill anybody when they shut down the line, and that happened a lot during this period of time as we experimented with new buffer management systems. We certainly shut it down more than we would have otherwise, but we were willing to do this in order to make more improvements.

The results of their efforts were significant. While some of the new methods introduced were not successful, others were. Those methods that did result in improvement were propagated to the rest of the plant. Within two years Alpha reduced its average cycle time from somewhere between 10 and 20 days to less than three days (see figure 3).

### Following Alpha

In the first six months of the initiative Alpha improved substantially more than the other plants. Following his initial strategy, the GM, with Alpha's assistance, assembled simple case studies of the improvement successes to show to the other plants. The GM also used his position as general manufacturing manager to promote competition between the plants. He made it clear that he considered the other plants to be 'behind' Alpha. Initially, this competitive focus was very useful. Alpha's manager recalls"...by promoting this competition, [the GM] got everybody involved quickly. I would say within nine months everybody was doing it."

## V. From Ten to Four: Manufacturing Cycle Efficiency

### Flow Charting the Process

In the first year of the initiative, the GM led the charge from the division office. His efforts had been focused on raising awareness of the initiative, ensuring that everyone in ELD understood the importance of the effort, and implementing the metrics package. As part of the metrics package, in January 1989 the division set an aggressive new objective for inventory reduction– 50% within five years. Little had been done, however, to introduce a formal methodology for reducing cycle time or increasing the fraction of value add time.

The initiative received additional support in March 1989 when ELD's supply office created a new position to lead the MCT effort. The new initiative leader (IL) was charged with developing and deploying a division wide cycle-time management process. The IL remembers his original instructions as, "Develop a MCT reduction program and get the plants to reduce inventory by 50% in the next five years." He recalls the situation he faced:

> We had two major problems within ELD at the time. First, we had an insufficient method for managing inventory, and second, we had set very aggressive objectives for inventory reduction and we didn't have any foreseeable way of getting there.

The IL's first step was to institutionalize the method of value add analysis that had been piloted at Alpha. The initiative leader and his staff of three began by helping the plants calculate a metric called Manufacturing Cycle Efficiency (MCE). MCE was defined as the ratio of value add time (time in which function or feature was being added to the product) to total manufacturing cycle time. Under this definition any time a product spent in transit between operations, in buffer inventory, on test equipment, or in trouble-shoot and re-work loops did not count as value added time. The results at all the plants were similar to those at Alpha. The IL recalls a product that spent an average of 190 hours on the shop floor of an ELD facility even though value was being added to that product for less than one hour. The plant manager at the Beta facility recalls, "...when we first started to calculate MCE, the numbers were so low we really wondered how relevant they were."

### MCE as a Driver of Improvement

The process of calculating MCE, however, was quite valuable. To calculate the metric, the initiative leader said,

> ...you had to walk through the shop floor and ask the question, "Is this value added?" for every step in the process. By the time you were finished you had flow charted the entire process and really highlighted all the value add stations....After calculating MCE, we really started to understand the process flow of our products. We knew where value was being added, and, more importantly, where value was not being added.

While the MCE numbers were extremely small, the process of obtaining them helped the plants develop a new understanding of their production lines. In the past, production steps set by product engineering had been taken as given. After calculating the MCE measure plants began to question the length of time the products needed to spend in certain areas. The GM recalls,

> We had a line that required a radio to be 'burned-in'[operated at elevated temperature] for 16 hours. I asked "Why?", and they told me because "That's what engineering told us to do". Well, we looked at the failure distribution and it seemed like all the failures came in the first two hours. So first we cut it to eight hours, then to four and so on. This saved time, equipment, and money.

It also caused some to question why certain steps were included in the production process at all. The IL and his staff spent the next year helping the plants evaluate every step in the process based on its ability to add value to the customer. Many time-consuming operations in the process were re-evaluated, some such as 'burn-in' were reduced while others, like conformal coating, were eventually eliminated. The IL remembers,

> The process made us challenge specifications and engineering requirements that we had previously taken as given. For example, it caused us to challenge a spec on conformal coating; why did we need to protect a circuit board from the outside environment when it sits in the passenger compartment of the car? We finally decided after much thought and experimentation that we didn't, so we eliminated it [thus saving twelve hours].

The MCE analysis did more than help the plants eliminate non-value add production steps. It led engineers to re-think the design of new products. Alpha's plant manager said,

> There is an important philosophical change that goes with doing MCE work. If you think about engineering's impact on manufacturing in terms of value added before you design a product, you will design that product differently. You will fundamentally try to design out the non-value added steps in the manufacturing process.

By the spring of 1990, approximately a year after the IL came to ELD, the division had shown substantial improvement. Average cycle time had fallen to less than five days (see figure 1) and the 'value added' or MCE analysis had improved peoples' understanding of the process flow on the shop floor. As the IL recalls, it had been relatively easy to get people involved in this portion of the initiative,

> MCE was a nice approach... it made a lot of sense to people. It was easy to get people to rally around things like reducing burn-in or eliminating conformal coating, both of which took up a lot of space and cost a lot of money.

## VI. From Four to One: The Theory of Constraints

### From Step Elimination to Inventory Reduction

In late 1989, with the MCE effort well underway in most ELD facilities, the team leading the initiative began to look for a new methodology to support further MCT improvements. The effort to eliminate non-value added operations and to reduce obvious inventory accumulations had been successful, but large amounts of work-in-process buffers sat in front of the operations that remained. Reducing MCT further without cutting these inventories would be difficult. This presented a new challenge. Line supervisors had two good reasons for maintaining the buffers at their current levels. First, the primary goal was still supplying the customer; no manager was willing to reduce inventory if he believed it raised the possibility of missing production targets. Second, line supervisors were still evaluated on labor and overhead utilization. Good labor and overhead performance required keeping machines and people busy, which, in turn, required material to work on.

The IL and others focused on shop floor management as the next opportunity for reducing MCT. As the IL remembers,

> At this point [with MCE established in the plants] I felt the need to do two things- 1) we didn't have any standard shop floor management technique...I couldn't tell a guy on the floor how to manage his process to reduce MCT...and 2) the same 'language' was not spoken at all the plants, we didn't have a common way of even discussing these issues.

Improvement would also require the support and effort of those that worked on the shop floor. Eliminating process steps could be done by higher level managers, but changes in the daily operation of the shop floor required the support of the operators and material handlers. As an ELD supervisor recalls,

> ...at the time people thought "this is important because its important to the general manufacturing manager" but they didn't necessarily feel in their gut that it was important because they didn't understand what was behind it...We needed more than just a definition of MCT or MCE, people needed a better understanding of how the shop floor really worked.

The need for understanding at every level in the organization presented a dilemma. The team leading the effort could only train so many people. They began looking for outside sources that offered both a shop floor management technique and a training program.

In addition to not having a good technique for managing the shop floor, the initiative faced other barriers. Many senior people at the plants still did not consider cycle time to be a 'manufacturing measure'. The group leading the effort worked out of ELD's supply office which was traditionally associated with the materials, planning, and logistics (MP&L) function. Inventory was considered to be an MP&L issue and not a major concern of those on the shop floor. As a former materials control manager from Alpha said,

> ...we (the MP&L staff) had always been concerned about inventory, we measured days supply on hand and turn-over...however, it was never really embraced outside the material control area.

When the MCT metric was announced, many plant managers gave their materials managers the responsibility for reducing cycle time. The IL realized that the 'leverage' in the system did not reside with the MP&L staff,

> After working with the materials managers for a little while, it became obvious to me that they were not able to control MCT. The manufacturing manager would make decisions that caused MCT to go up that the materials manager could not control.

The IL spent a substantial portion of his time and effort convincing the plant managers that MCT was something that they, and the people on the shop floor, needed to be concerned about. "I think I had to convince every plant manager that MCT was a manufacturing metric," he said.

Unreliable equipment and quality problems increased the need for extra inventory. A product team manager from Alpha describes the situation,

> ...supervisors never had time to make improvements or do preventative maintenance on their lines...they had to spend all their time just trying to keep the line going, but this meant it was always in a state of flux, which in turn, caused them to want to hold lots of protective inventory, because everything was so unpredictable. A quality problem might not be discovered until we had produced a pile of defective parts. This of course meant we didn't have time to figure out why the problem happened in the first place, since we were now really behind our production schedule. It was a kind of snowball effect that just kept getting worse.

The task of making further improvements was more complicated than improving the scheduling of the production line (itself no simple task). ELD employed a group of manufacturing simulation experts who studied line design and scheduling, and who, according to the group's leader, had already developed better scheduling procedure. But better schedules weren't enough. If plant managers did not feel inventory was 'their' problem, if supervisors felt the need to keep machines and workers busy, and if extra inventory was required to buffer against unreliable machines and poor product quality, little was going to change.

## Looking for a New Methodology

### *Theory of Constraints*

The team leading the effort started their search for a new shop floor management technique by interviewing consultants who offered methodology and training. Many, they felt, did not understand the complexities of ELD's operations. Among the few that did appear to offer something was the Goldratt Institute which taught the shop floor management philosophy Theory of Constraints (TOC) developed by its founder Eli Goldratt.[1] The Goldratt Institute offered an extensive training class–the Jonah program–that used a 'train the trainers' approach.[2] After two weeks of training each participant would be a certified 'Jonah' who was then qualified to teach the TOC methodology to others.

[1] . See The Goal Goldratt and Cox.
[2] . The name comes from a character in the book The Goal who teaches the TOC method.

In March of 1990, the IL and another colleague went to the two week course as the first representatives from ELD. They found the course interesting and the training method effective. Goldratt's philosophy is based on the observation that, within any production line, there is usually one machine with the lowest production capacity. The production rate of the line is limited by the capacity of that machine. Goldratt calls the slow machine the 'bottleneck' or the 'constraint'. Goldratt's training uses a computer simulator to demonstrate that the constraint is the key to managing the shop floor. The course, the recalled,

> …allowed you to step back and understand the shop floor as a system rather than as a bunch of process areas, particularly if you worked inside of one. Even though your training would lead you to make decisions one way, it led you to a new intuition that helped you make decisions differently.

The director of ELD's manufacturing simulation group saw it as an integrated way of teaching things that his group had learned in their computer studies of ELD production lines:

> I called it 'Shop Floor Scheduling and Coordination Awareness 101'. If you wanted to concentrate in three days everything you would want to understand about the dynamics of the shop floor and how to keep the line running, this was it.

Another manager, who would replace the IL, when he left the supply office said, "...it was probably the most convincing management training that I have ever done."

*Rolling Out the Training*

Almost immediately after they returned, the two attendees of the Goldratt course conducted a training class for all the plant managers and asked each one to allocate two people from their facility to attend the Jonah training. Each plant manager made this commitment. The training became quite popular; at one point Alpha had fourteen Jonahs. The Jonah training was very expensive; ten thousand dollars per person for the two week course. A member of the team leading MCT estimated that ELD spent over three million dollars on the Jonah training before they received any real benefit. The GM felt it was worth it.

> I never really tried to cost justify the training. I just felt that this was the right thing to do given what we were trying to accomplish at the time. I was always willing to allocate money for training, but if people asked for money for new equipment to reduce cycle time, then I would be tough as nails. I just didn't think we were going to solve our problems that way.

Within six months of the first trip to the Goldratt Institute, almost every manufacturing engineer and supervisor within the division had participated in a two day class taught by one or more of the Jonahs. In the following year, 1991, TOC training was given to the operators and material handlers. A staff person at Alpha developed a condensed version of the class called the 'cookie factory'. In this hands-on version the production of cookies replaces the computer simulation. By the end of 1991, most of the operators and material handlers had gone through this version of the class. Since that time both Alpha and Beta have maintained a policy of giving new operators training in TOC.

The TOC training efforts were not limited to people in the plants. Early in the process the IL brought Goldratt to ELD for a two-day training session with senior managers at the division headquarters. The IL believes the session was very important in getting continued support for the effort,

> I believe they [the other managers] were taking it as given that the GM was going to do this. However, the session with Goldratt really helped them understand why. By the end they were already talking about how they might apply these ideas to other parts of the division like product development.

### One Day MCT Award

In the spring of 1990, while the team leading the effort began to experiment with the TOC philosophy, the GM set an even more aggressive objective for MCT improvement: The One Day MCT Award. By the fall of 1990 every plant was required to develop a plan to achieve a one day average MCT within five years. Although they had made tremendous progress in the last two years, most ELD facilities were still at four to five days MCT, and even Alpha was still at three days. Many people felt that the one day goal was unrealistic. One member of the GM's staff remembers,

> At the time I thought to myself, "I really hope I get transferred within the next five years because this is never going to happen. This guy just does not understand automotive electronics."

The GM remembers that the goal was not well-received, "When I first announced it [the one day award], a lot of people just doubled over in pain. They really thought I was crazy".

For the GM, getting to exactly one day didn't really matter as much as sending the message that he had high expectations for the division. He believed that 'stretch' objectives could be instrumental in pushing people to a new level of performance. He recalls,

> I didn't know if we could get to one day, and, to be honest, I really didn't care. If a facility was at 18 days and I set an objective of 16.5 days, everybody would have just squeezed a little bit. This way everybody knew they had to make big improvements. If they only made it to two days or three day that still would have been a lot better than 16.5.

Further, once the goal was announced, people began to realize the type of capability that would come with a one day cycle time: Reducing MCT did more than reduce inventory expense, it could have a strategic benefit as well. The IL recalls,

> ...we started to ask the question, "what would a one day MCT give us?" With a requirements change from the customer we wouldn't have to expedite stuff through a process clogged with several days of material, we could just start new material. We would be able to respond to our customer requests more quickly and more effectively.

## TOC at Alpha

*Developing Pilots*

In the fall of 1990 the IL left the supply office and moved to the Alpha facility, first as an area manager, and later as the plant manager. By this time, the plants had largely completed the MCE stage of the initiative, and had developed plans for getting to a cycle time of one day. As with much of the initiative, Alpha played a lead role in developing pilot projects. Managers at Alpha were ready to make some more changes, one recalled,

> ...right away the managers were very accepting. We had training sessions with all the managers in the plant and that went well. Then we sent 15 people to the Jonah training, which was a big commitment for the plant.

In addition to these sessions, Goldratt's book, The Goal, was circulated to all the managers in the plant.

To kick off the use of TOC, Alpha's Jonahs focused on developing early success stories. To demonstrate the effectiveness of the TOC approach, they chose two product lines within the plant that were, in the words of one manager, "...in the most trouble". A product team manager (PTM) recalls,

> ...we focused on the areas of the plant that really needed to increase their attainment [schedule performance] and had large amounts of [buffer] inventory. We [the original team] picked areas where we felt we could show some big results quickly. We could then use those as basic success stories to convince the rest of the plant.

The two pilots were successful. The first of these two lines, which produced an Integrated Relay Control Module (IRCM), started with an average MCT of over one day, and by mid-

1991 it had been reduced to less than four hours . In the second line, which produced air bag diagnostic modules, MCT was reduced by half in less than eighteen months.

*Increasing Attainment*

Just showing that TOC worked, however, was not sufficient to assure that it would be accepted by the rest of the plant. The new 'Jonahs' still had to contend with the fact that schedule attainment and labor performance were key measurables in the plant. Of the two, overcoming the schedule attainment issue was easier. By moving attention to the constraint operation, TOC allowed people to improve the through-put of their lines by focusing attention on the areas that yielded the most benefit. As a manager said,

> ...we were starting to get to the point in ELD where everything was considered to be important. TOC told us that only the constraint machine was important. This really gave us something to focus on.

The focus on the constraint allowed a more rational allocation of improvement effort and maintenance resources. It helped answer such questions as 'Where should I focus my improvement effort?' and 'What machine should I really worry about if it breaks?'. This allowed people to improve the through-put of their lines, which, in turn, allowed them to hit their production targets more easily.

*Overcoming the Labor and Overhead Mentality*

Dealing with labor performance was more difficult. TOC's focus on the constraint requires that other machines in the production line be left idle at certain times during the day. To schedule production lines TOC uses a concept called 'the rope'. When a product is needed, it is first determined when that product will fit into the production schedule of the constraint machine. The length of the rope, the time required for material to make its way from the point of release to the constraint, is then calculated. Material is then 'roped out' so that it arrives at the constraint machine when it is required by the production schedule. In essence the rope works by subordinating upstream operations to the constraint machine. Material is only released when it will be needed by the constraint machine, regardless of whether the upstream machines are idle or busy.

The concept of the rope can be very useful for reducing inventory. One manager claimed that it was the "single most powerful shop floor management tool for reducing MCT at Alpha". However, leaving upstream machines idle was hard for some people to accept. A PTM at Alpha recalls,

> For a lot of the older supervisors who were used to being asked about labor performance on a daily basis, change was pretty difficult...in the past if a supervisor had a negative labor variance due to volume, he would get beat up for it regardless of whether the production from his area was needed by the customer that day.

Just as it was difficult for the line supervisors to accept the new mentality, it was also difficult for the machine operators. They also were accustomed to working in a culture where keeping machines running and keeping people busy was the main focus. As the same PTM said,

> People who had been in the plant for 10 or 20 years had a hard time believing that we weren't going to yell at them if they weren't busy all the time. Their experience told them that they got yelled at for doing nothing. There are still people that haven't fully accepted this.

Changing this mentality required senior leadership to not use labor performance as a key measurable. In Alpha's case it was the plant manager.

> I give a lot of credit to the plant manager. He said, "within these four walls we are not going to worry about direct labor performance", and as soon as the supervisors saw that they were not going to get blamed for bad labor performance, they started to work with us...it gave us the freedom not to worry about it [labor performance] on a day-to-day basis.

This was a difficult change for everyone at Alpha because some people from the division headquarters, particularly in the finance organization, continued to worry about direct labor performance. Another PTM remembers,

> ...it took a leap of faith that the cost savings from reducing inventory would more than outweigh any loss in labor efficiency. And even though the GM was driving this from the division level, some people at that level were not willing to take the leap.

The conflicting messages from the division staff caused frustration for Alpha managers. On the one hand the division's general manufacturing manager was leading a strong effort to reduce inventory. On the other hand the finance organization continued to evaluate the facility based on direct labor performance which would inevitably suffer as inventory was reduced. An operations engineer commented,

> Even today [spring 1995] the staff to staff relationship has not been improved. Finance continues to beat us up for poor performance on things that the rest of the company has decided are no longer key measurables.

## TOC at Beta

*"Get Rid of the Bone Piles"*

The situation was different at the Beta facility. Alpha had been an early adopter of both the MCE analysis and the TOC training within ELD. During the early period of the initiative, the Beta facility was still being built and launched, and had paid less attention to the MCT measure. As the plant became operational at the end of 1990, they were at about an eight day average MCT (see figure 2), well behind the leaders of the division. The one day MCT objective had been announced and there was increasing pressure from the division staff to making some improvement.

Electronic engine controls constitute over 50% of Beta's production volume. To kick-off the initiative on the EEC line a very simple approach was used. As a former EEC scheduler said,

> We would look at the piles sitting around and ask "do we really need these?" and the answer was usually no. It really didn't involve that much effort.

These improvements did not involve any significant change in scheduling techniques or material release. Just making people on the shop floor conscious of the role of inventory resulted in a number of improvements. The TOC training given to the operators played a key role in increasing their awareness of inventory. As an instructor who taught the cookie factory class at Beta said,

> After the training people would pull me aside and say "hey, cookie factory lady look at this", and they would show me a pile of inventory that could be reduced or some other opportunity for improvement...big successes came just by making people aware of the piles.

Efforts to make improvements in other areas of the plant were similar; significant improvement came from making the operators and material handlers aware of excess inventory. A staff member who worked in Beta's Agile Manufacturing Group recalls the strategy she used to make MCT reductions on another line,

> ...we always would focus on " look around you, where do you see parts and why are they there?" We didn't spend a lot of time (with the operators) on the exact calculation of buffers sizes. We didn't worry about whether the buffer should be x units or y units. It looked like a lot of units, so we started by trying to cut the pile in half. Then we would try to cut it in half again, and so on.

Those promoting MCT at Beta also focused on developing visual systems that made it obvious exactly how much inventory was sitting on the line. A member describes her experience,

> First we organized all the inventory in totes...then we color coded it by good stuff, bad stuff, and stuff we didn't know about. Then, finally, we could see how much inventory we really had, and the condition of that inventory...we also found inventory that some people knew about that others didn't. It was shocking.

Besides making people aware of excess inventory, the TOC training and the focus on the constraint operation also allowed production lines to improve their schedule performance. A former supervisor remembers being transferred, in early 1992, to a Thick Film Ignition (TFI) line that was struggling to hit its schedule. His charge was to improve schedule attainment from its, then current, level of 70% to 100%. This was challenging because it appeared as though the line was already running at maximum through-put and could not meet its current target. There was little interest in reducing inventory when they were not hitting the schedule. He recalled,

> We started the effort by trying to find the constraint. It turned out that the previous supervisors didn't know which machine was the constraint. As a result a lot of time was spent keeping non-constraint machines running while the constraint was idle.

Once the constraint was identified, all the attention was focused on keeping that machine running. The though-put of the line improved rapidly. They were able to increase the total through-put of the line by more than 33%, and they reached their goal of 100% schedule attainment in less than six months. In that period they were also able to make substantial reductions in MCT.

*Roping the Panels*

This approach allowed the EEC lines, and others, to reduce their MCTs substantially during the early part of 1991. However, as they approached four days MCT additional reductions became increasingly difficult. Further improvement required making more fundamental changes. At that point, some of the schedulers with significant experience on the EEC line were moved to other areas of the company, and were replaced with a new scheduler who was given one overriding goal, "...to reduce cycle time drastically."

In July of 1991, taking a cue from the theory of constraints, the new scheduler implemented a system of panel roping. Under this system, he controlled the release of printed circuit boards onto the shop floor. Since the circuit board was integral to the EEC module, the new system ensured adherence to the production schedule, and allowed the scheduler to determine the level of work in process inventory. As he explained, "We basically took the control of inventory away from people on the floor and used that as a vehicle for reducing manufacturing cycle time."

However, Beta, like Alpha, had to adapt the TOC for their usage. Since Beta was a new facility, it benefited from the experience that ELD's industrial engineers had gained at other facilities. As a result, the industrial engineers "...did a phenomenal job of balancing capacity through-out the process and as a result we had interacting constraints all over the place." This made it very difficult to determine for a given product and production line exactly which operation was the constraint.

To get around this problem, a particular operation, Odd Component Insertion (OCI) was chosen as the default constraint. OCI was the logical choice for the constraint for a number of reasons; it was the longest of the subassembly lines, and once parts were started on that line they went through a large number of stages with no intervening buffer. It was also the most expensive incremental capacity on the floor. While on any given day it may not have been the constraint, "... it seemed to make sense to schedule off the OCI. We treated it that way and it has been a good vehicle for MCT reduction." Further, since Beta was a new facility, the OCI line had been designed with enough capacity to insure that its timely operation would be enough to hit the required production target. Thus, as long as the OCI line was running all the time, the upstream sub-assembly operations were assured of hitting the daily production targets.

Making the transition to this new scheduling philosophy was by no means easy. Beta was also very worried about making sure it hit its schedules. One supervisor recalls,

> ...there was a lot of fear. We could not afford to uncover big rocks that might cause us to shut down a B&A plant. We had to make these reductions in a controlled, predictable manner.

To insure that problems did not occur, the length of the rope on the EEC line, the amount of inventory in front of the constraint, was reduced slowly and methodically. The same supervisor remembers,

> ... each reduction [in the rope] would wreak havoc on the scheduling at each sub-assembly. This forced everyone to toe the line a bit more and make sure they were in synch with the release.

Many managers were not comfortable with this gradual approach. Some argued for a drastic approach that would cut inventory very quickly. The EEC scheduler recalls,

> ... at high level management reviews, senior people would say 'cut it [inventory] in half and see what happens'. There was big pressure on the 'Just Do It' approach, particularly when we were behind our year end objectives. However, we stuck with the gradual approach and I think it worked pretty well.

At times MCT for the various lines were reviewed on a daily basis by senior plant management. However, the gradual approach was used and ultimately resulted in substantial reductions in MCT.

*Barriers to Improvement at Beta*

Beta also had to face the dilemma of declining labor performance. It was very difficult to convince supervisors with more experience that it was okay to leave machines idle if the output from those machines was not needed by the constraint. The engineering staff at Beta spent a lot of time trying to change this mind-set. However, as another manager remembers,

> Some supervisors never could adapt, and eventually they were moved to another area that was more like an assembly line so that they didn't have to worry about keeping everything running.

There were other ways to attack poor labor performance. For example, they tried to cross train the work-force and cross utilize equipment. Operators were trained on multiple machines or work stations, so that if their services weren't needed in one sub-assembly area they could move and work in another.

Quality problems were a big barrier to reducing cycle time. A supervisor remembers,

> By the time I got there [in 1993] people were already focused on the constraint. However, the line still had a lot of extra inventory because there were serious quality problems and the trouble shoot and repair loops were slow because they had accumulated so much stuff.

This made it difficult to reduce MCT because supervisors continued to produce extra components to buffer against the variability in their production lines.

> In the minds of the OTLs [operations team leaders] they had to hit their pack counts. This meant if you were having a bad day and your yield had fallen from 90% to 80%, you had to run like crazy to hit your target. You could say to the OTL "you are making 20% garbage, stop the line and fix the problem", and they would say, "I can't hit my pack count without running like crazy because trouble shoot and repair is too slow."

These problems led the team assisting the line to focus their attention on improving quality, but to do this they had to speed the trouble shoot and re-work cycle. This also had its own difficulties. An improvement facilitator recalls,

> I tried to document the trouble shoot and repair process, it was so confusing and disorganized it took me weeks just to figure it out. I think people figured "I have 7,000 pounds of stuff around me already, what's the big deal about 500 more." There were just piles and racks of stuff...after a while it just became overwhelming.

To reduce the large stock of defective parts, they started by categorizing the different types of problems in the pile. This helped them collect data about the causes of the quality problems, and it demonstrated management's commitment to actually making fundamental changes.

> Once we started tracking the bone pile [the defective parts], sorting it, categorizing the different types of failures, counting it every day, and assigning problems to different areas, people felt there were going to be some actions taken. We also ran overtime in the repair loops to reduce the mountain, and, as a result, people were motivated because they saw we were actually making a commitment to fixing something.

The result of these actions was a substantial improvement in quality on the line as well as a large reduction in manufacturing cycle time, but, as the scheduler recalls "...it was a very painful process."

## The Limits of TOC

*Moving Control Back to the Floor*

The use of TOC produced significant improvement at both Alpha and Beta (and other ELD facilities). The focus on the constraint improved the through-put of many production lines, while scheduling via the rope substantially reduced the piles of buffer inventory that sat between each operation. However, as inventories continued to fall a new problem arose: the bottlenecks started to move. TOC is based on the assumption that within any line one machine is always the bottleneck. At both Alpha and Beta, as inventory began to fall, it became clear that the bottleneck was actually at different machines at different times during the day depending on the product mix. The floating bottlenecks made scheduling increasingly difficult. A PTM at Alpha said, "TOC is theoretically nice, but it starts to break down when you have many machines that all are very close to being a constraint.

Both plants responded to this problem by developing a buffer management system that could be used in real-time by the operators and material handlers on the shop floor. A manager from Beta stated,

> The fact is that with all the interacting constraints, machine breakdowns and other variability, those processes could not be scheduled. The only folks that could manage the process were the operators who knew when machines would go down and material handlers who would see that and react by starting something on other machines.

The systems relied on simple visual cues that made it easy to see how much inventory was sitting in front of the constraint operations. Using a self-directed teams, supervisors, rather than trying to manage the production lines themselves, spent their time providing the required tools and decision skills to the machine operators. As a result decisions about when and which machines to run are made quickly and effectively. This new approach had allowed both areas to continue to make significant improvements. A supervisor recalled,

> Some of the big improvements did not come until we got the mind-set into the operators and the materials handlers....We started by teaching each of the work teams how to manage their line using TOC...the classes were useful, but I felt the real learning came from working with them on their lines on the floor. I would coach them through making actual decisions. I'd let them make the decisions and then we would talk about the results.

The experience at Alpha has been similar. As a PTM said,

> Essentially all the inventory management is now done by the operators themselves. They do all the counting, the majority of the analysis, and contribute to the scheduling.

*Maintaining the focus on Cycle Time and Value Add*

TOC had another drawback. ELD was growing rapidly and a large number of new people came to work in ELD facilities who had not experienced the MCE phase of the initiative. The division's leadership began to realize that when these people tried to use TOC they could not, in his words, "... move the needle forward in the same way." One manager assessed the problem this way,

> ...the thing that TOC was missing was it didn't do what we had done...it didn't spend all the time on understanding the cycle time concepts and value added versus non value added.

As a result the TOC training was modified. The same manager recalls,

> ...we made a conscious decision to go back and be sure that people who came to the division spent some time understanding MCT and MCE fundamentals before getting into TOC.

Alpha responded by developing its own hybrid system that maintains a focus on low inventory. In an effort to develop a visual system that could be used in real time by the operators, Alpha has adapted the Kan Ban system to its needs,

> ...[we have] developed a hybrid Kan Ban TOC system. TOC says ‘keep the constraint running at all times’, Kan Ban says ‘limit the amount of material you have on the floor’. We try to do both.

### Problems with Suppliers

There were other side effects of running a very lean inventory environment. As a manager from Alpha said “....with our buffers so small, a problem with our suppliers could really kill us. We couldn’t cover up their mistakes with the small amount of inventory we had.” A manager from the EEC line at Beta experienced similar problems, “...one of the biggest problems we struggled with, and still struggle with to this day, was running out of parts. With a very lean line, any shortage could cause a problem.”

Both Alpha and Beta attacked this problem by pushing suppliers to improve their attainment, shipment reliability, and product quality. One manager at Alpha said, “We basically forced our suppliers to improve, because if they didn’t, they were going to be visiting us here quite a bit.” While another recalls, “We developed a process in which they had to respond to any problem with a containment action within 24 hours and a long term action plan within five working days.” ELD also began to develop a third party warehousing system, whereby suppliers were required to hold inventory on or near ELD sites. In addition, ELD division staff provided significant support to suppliers. The supply office frequently made trips to supplier facilities to teach them TOC techniques as well as make recommendations for areas in which to improve.

## VII. Results

Over the eight years that it has been in progress, the CFM initiative has produced dramatic success. In 1994 the division hit an average MCT of less than one day (see figure 1). Many people, including the GM also believe that cycle time reduction was the foundation for numerous other improvements. ELD’s financial performance was impressive. The division grew rapidly, and, in part because of the CFM initiative, ELD was able to assimilate substantial growth in both the volume and complexity of the components of it produces with its existing facilities and workforce. In 1988 ELD had a plan to build five new facilities. Largely because a substantial amount of floor space was no longer required to hold inventory, two of those new facilities were not needed. In the meantime, ELD's ability to serve its customers improved substantially. With an MCT of one day, changes in customer requirements can now be dealt with on a daily basis. As a manager from Beta said, "Now we can rip apart the schedule one day in advance and still be able to react and get the stuff out the door."

An additional by-product of the reduction in cycle time was an increase in product quality. As both facilities began to reduce cycle time, quality improved dramatically (see figures 4 and 5). Partially this was the result of a number of other initiatives that were taken on during the same time period. However, reducing cycle time and the level of buffer inventory played an important role in supporting the quality effort. With short cycle times and smaller buffers parts reach test stations more quickly, quality problems are quickly diagnosed, and, when there is a problem, fewer bad parts accumulate in buffer inventories. Resources required for re-work are reduced and the learning cycle is faster. Further, running with low inventory levels gives an extra incentive to improve. A PTM for Alpha said,

> Originally, we forecasted a minor improvement in quality. It turned out to be quite dramatic...as we lowered inventory it unmasked some real quality issues...The feedback of understanding what was really going on sped up dramatically as we reduced inventory.

## VIII. From One Day to ?: Next Steps

In the opinion of many ELD people, the CFM initiative was extremely successful. Yet the question remains, where does the initiative go from here? If a sixteen hour MCT is good, is an eight hour MCT better? Even after seven years of improvement effort, the MCE of many product lines is still less than ten percent. There is clearly an opportunity for future reductions. But at what cost? Have MCT reductions reached the point of diminishing returns? The opinion of many people at both Alpha and Beta is that the MCT reduction effort has run its course and it is time to focus on a new metric. Further, there are additional constraints that may limit the overall impact of additional MCT reductions. A supervisor at Beta summarized the dilemma,

> Where do you want your MCT to go? You want to be as responsive as possible to your customers.... At Beta, if you give us the raw material in the morning, the parts will be done that night....However, the biggest problem right now is how fast do we turn over raw materials. Our logistic system works in one day buckets, so

> cutting MCT any further isn't really going to help us serve the customer any better. There are other measurables which might drive bigger improvements now.

Hitting customer schedules continues to be the overriding concern. Additional improvements have to be made in a way that does not increase the risk of missing the production schedule, and as the inventory continues to fall it becomes more difficult to compensate for disruptions. Increasing reliability of production lines can be expensive. A manager from Alpha sees the issues in terms of costs and benefits,

> The more you 'lower the water', the harder it is to hit your schedule. Any supplier problem or machine down time can cause a big problem...it might cost you a million dollars to increase the reliability of the process so that you can go from four hours to three. Is that worth it?

Many managers in both Alpha and Beta are beginning to change their focus. Improving the performance of the lines requires a new focus on machine up-time or Overall Machine Effectiveness (OME). Two managers from Alpha stated,

> We can't target MCT directly anymore. We've reduced all the obvious inventory. Now we need to attack the problem from a different angle. The only way we can make our new objectives is through improving machine up-time.

And,

> Now we are focusing on OME. At this point, by focusing on OME, we will be able to reduce MCT more than if we focused on it directly. Inventory is less of a problem than machine reliability.

While the plant's focus appears to be changing, the division staff associated with MCT may be slower to adapt. The division office continues to set objectives for reducing MCT. Many plant people, however, question the worth of those objectives.

> Sometimes these objectives start to take on a life of there own. People quit thinking about them, or asking whether they make sense. Now when people ask for further reductions I always ask "Why?"... We need to keep it in the back of our minds so is doesn't start to grow, but we shouldn't use it as a driver anymore.

## IX. Lessons Learned by Participants

### The Importance of Senior Leadership

#### *Setting the Vision*

At the end of every interview, each subject was asked to list the factors that he or she felt were instrumental to the success of the initiative. There was remarkable agreement on the most important factor; the initiative was successful because the senior leadership of the division made it happen. What constitutes 'making it happen' is less clear. The GM saw his own role this way,

> I had very good people working for me, and I wanted to give them a sense of urgency and empower them to really be the best. I spent my time convincing them, teaching them, training them, spending time with them so that they understood this was my biggest priority, and then showing them results...not just dictating.

However, while he spent much of his time trying to promote and support the initiative, it was important to the GM to have people in his organization that shared his vision. He recalls,

> It's not all mystical and magical...you can't teach and convince forever...sometimes I had to call the guys in, eyeball to eyeball, and say, "Hey, this is the way we are going to run the business. Now what would you like me to do to convince you? or would you like to do something else?" and sometimes people would choose something else...I moved a lot of people but I tried to do it constructively and with some dignity.

Alpha's plant manager also believed that senior support at both the division level and the plant level was critical to overcoming the 'inertia' of the organization,

> Looking back on it [CFM], if the top guys weren't supporting it, it would have been a very difficult process.....the organization throws up so many impediments, there are all kinds of reasons people will come up with for why something won't work– most of which are false– but if you don't have enough senior people saying "I really think this will work, just try it" it probably won't work....It really helped that the GM and I were on the same wavelength. Most of the time, if we thought it would work, we would just do it.

*Changing the Objectives*

People at the plants viewed the role of senior leadership a little differently. Whereas people in the division offices frequently mentioned the fact that the GM and others were consistent and their commitment never wavered, those in the plants felt the influence of top level commitment through their performance objectives and the commitment to training. The leader of MCT, who worked very closely with the GM, described his role this way:

> The GM was a very visible manufacturing manager at the time. He asked a lot of his plants, and rewarded them well when they achieved those objectives. That kind of support is key to getting the job done.

The dominance of the labor and overhead mentality was broken because the plant managers allowed people in the plants to risk poor performance on some metrics in order to achieve better results on others. A manager from Alpha described it this way,

> I define management commitment by a willingness to change the measurables. They were willing to accept that we couldn't have our cake and eat it too. One day we were evaluated on labor efficiency and the next day we were evaluated on cycle time. It changed our entire focus.

People at the plants felt that the impact of the change in the metrics could not be underestimated, particularly because it broke with the standard Ford practice, "This was a big change," said one manager, "...normally they add new measurables without removing old ones and tell you to do well on both, even if some are directly in conflict." In addition, the new objectives weren't limited to managers and supervisors; everybody was responsible for MCT. A manager from Beta stated,

> The real key to success was getting the objectives down to the working level and then giving them the tools and the coaching and teaching to help them achieve those objectives.

*Commitment to Training*

The influence of senior level support also was felt through the extensive commitment to training, particularly in the Theory of Constraints. TOC training was very expensive in terms of both dollars and time. The Jonah classes not only gave people an opportunity to learn, it sent a strong signal that management was committed to the effort. In the words of one manager, "Management made this a priority. They spent money, and they gave senior people two weeks to attend the Jonah training." Further, the training was not limited to managers. Almost every operator and material handler took some form of a TOC class. Another PTM from Alpha recalls,

> The extensive roll-out of training made a big difference. Nobody in this plant could say that they didn't have the opportunity to learn about TOC. I thought, at the time, it was a waste to train 1,500 hourly workers, but it really helped.

*Developing a New Culture*

Other managers felt the influence of senior level support through the new culture being created within the plants. The initiative required the support and the contributions of everyone in the organization. Making this happen required a big change in the status quo. Improvement required accurate information about the state of the production system, and getting this required a new mind-set. As a PTM from Alpha said,

> We [management] have taken the fear out of telling the truth. If inventory levels are high, let's figure out why and manage their reduction...I don't believe that it is ever an employee's intention to disrupt the operation. There are two theories, one says 'there's a problem let's fix it', the other says 'we have a problem, someone is screwing up, let's go beat them up'. To make improvement we could no longer embrace the second theory, we had to use the first.

## Other Contributors to Success

*Success Breeds Success*

There was less consensus on the other important factors. Many people did mention the ability to generate results very quickly. If those involved had not been able to generate success stories quickly, it would have been more difficult to generate additional commitment and enthusiasm. Realizing this, managers in both facilities actively selected areas for pilots in which they felt the new methods could produce big changes quickly.

*An Inside Job*

A final factor frequently mentioned was that in many cases those that did the improvement work were the ones who worked on the floor on a daily basis and had to live with their changes. Although ELD went to outsiders for training, almost all the changes were made by in-house people. As a manager from Beta said,

> The people who made it happen, the champions...they had to live it and implement it. The person who did the scheduling was in charge of implementing this, not an outsider that really didn't understand the line...the people who did the actual implementing had to be the ones to champion the entire process.

Figure 1

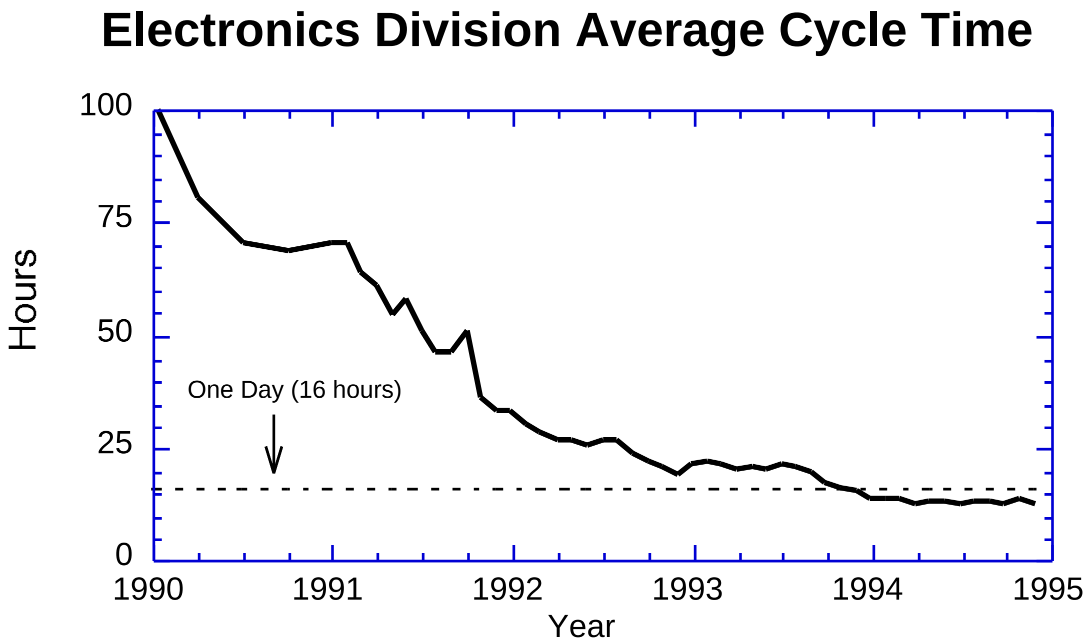
Electronics Division Average Cycle Time
100
75
50
25
0
Hours
One Day (16 hours)
1990
1991
1992
1993
1994
1995
Year

Figure 2

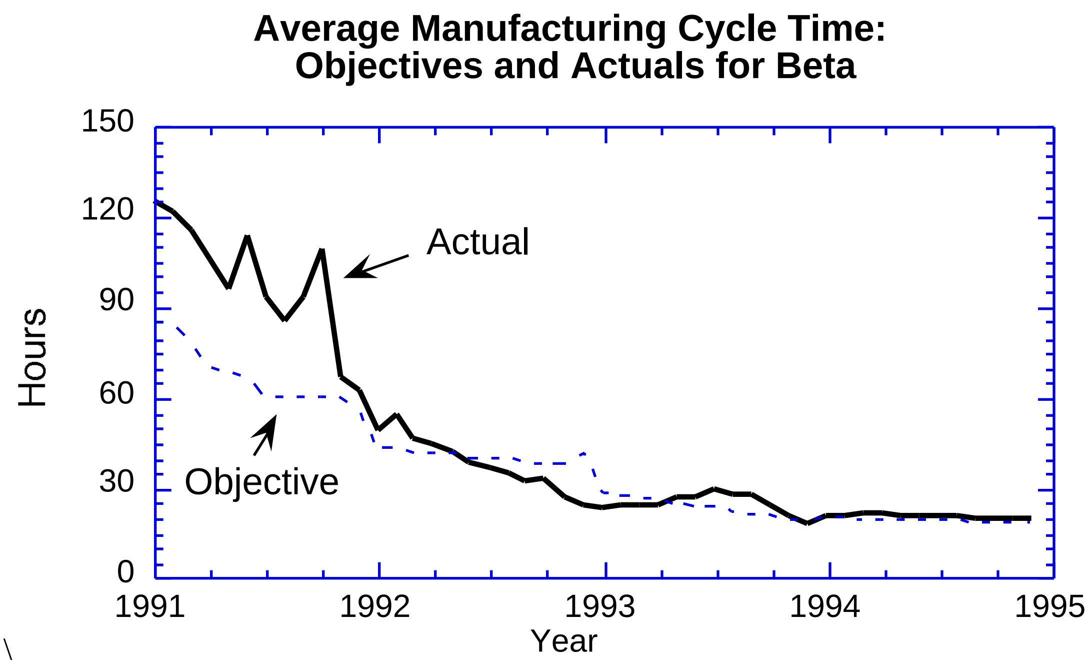


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Figure 3

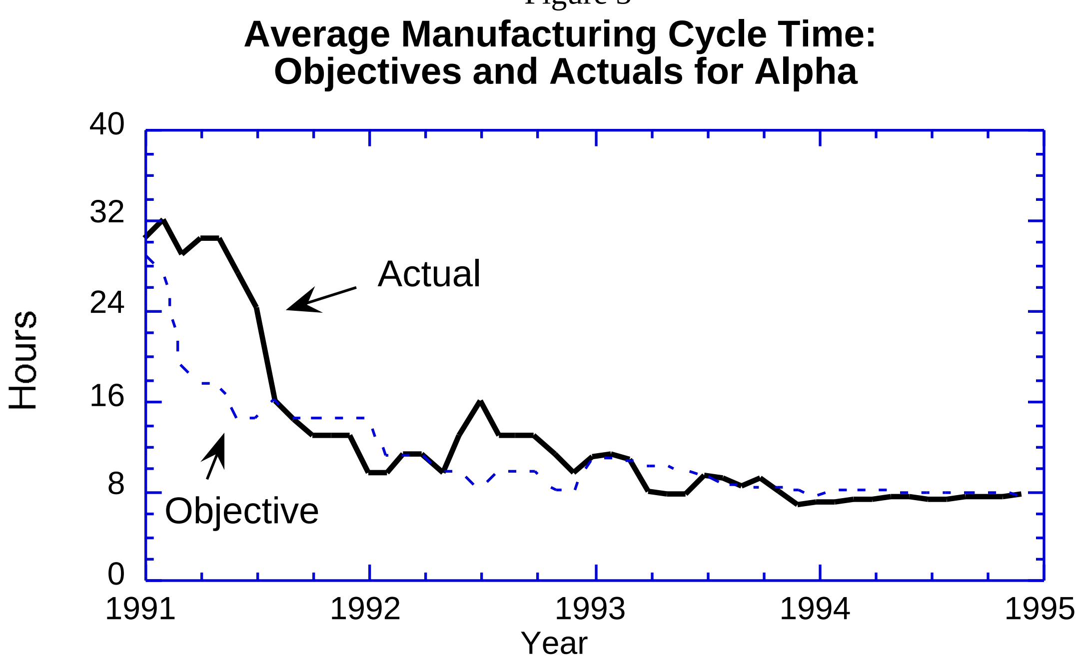

Figure 4

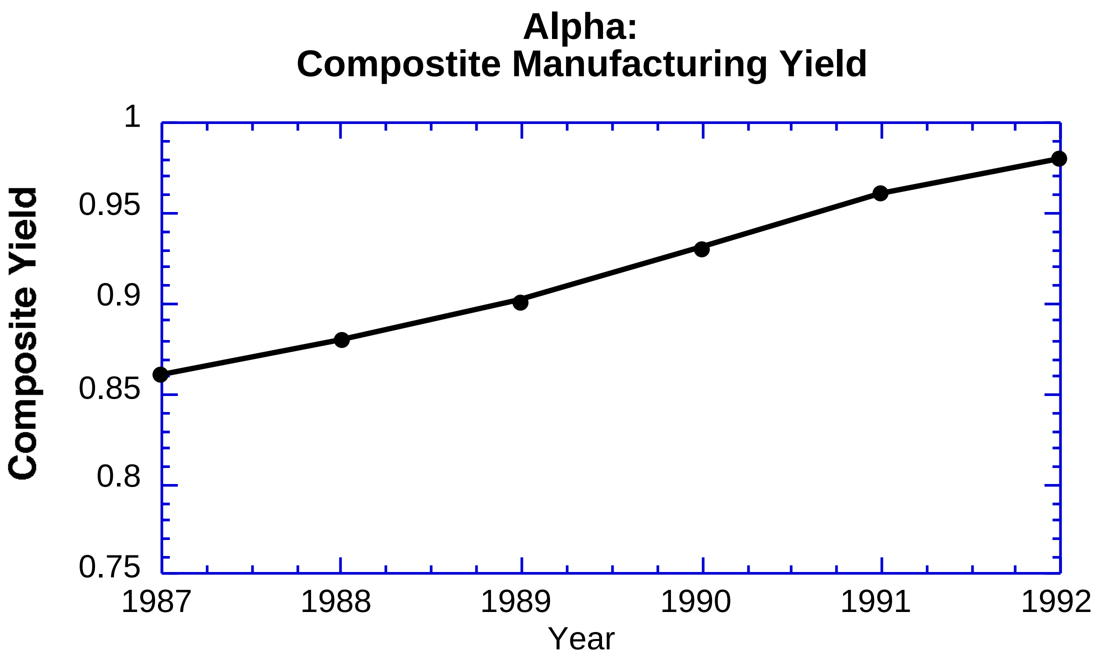


Figure 5