



*REPORT OF SURVEY CONDUCTED AT*

**UNITED ELECTRIC CONTROLS  
WATERTOWN, MA**

*FEBRUARY 1998*

## ***Best Manufacturing Practices***



**BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE  
College Park, Maryland  
[www.bmpcoe.org](http://www.bmpcoe.org)**

# Foreword

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This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at United Electric Controls, Watertown, Massachusetts conducted during the week of February 9, 1998. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at <http://www.bmpcoe.org>. The actual exchange of detailed data is between companies at their discretion.

United Electric Controls has received national recognition over the years, and created a tradition for innovative and resourceful approaches to continuous improvement. The company's reputation for dependable, reliable products is a result of innovative manufacturing techniques, superior design, and a corporate focus on uncompromising quality. Among the best examples were United Electric Controls' accomplishments in KanBan pull production system; visual control; valued employee program; and educational partnerships.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on United Electric Controls expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

A handwritten signature in cursive script that reads "Ernie Renner".

Ernie Renner

*Director, Best Manufacturing Practices*

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# Section 1

## Report Summary

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### Background

United Electric (UE) Controls is a privately-owned company that was founded in 1931. Over the years, the company fueled its growth with focused goals, a tremendous spirit, and a willingness to undertake challenges. In 1987, UE began its conversion from large batch to lean manufacturing under the guidance of Bruce Hamilton, Vice President of Operations. By the early 1990s, the company was already using such methods as KanBan, Kaizen, Single Minute Exchange of Dies, and Poka-yoke in its production operation before most companies had ever heard of them. Today, UE is an international manufacturer of durable, reliable pressure and temperature switches, controls, and sensors which range from simple, low technology units to highly specialized custom designs.

With its corporate headquarters located in Watertown, Massachusetts, UE maintains numerous U.S. and international offices, employs 280 personnel worldwide, and achieved \$35 million in revenues for 1997. Over the years, UE has received national recognition and created a tradition for innovative and resourceful approaches to continuous improvement. In 1990, the company won the Shingo Prize for world-class manufacturing and excellence in productivity and process improvement; quality enhancement; and customer satisfaction. This award is considered one of the "Triple Crown" industrial excellence awards, along with the Baldrige National Quality Award and the Deming Prize. Today, UE's approaches to continuous improvement have expanded and emanate throughout all facets of the business. Among the best practices documented were UE's KanBan pull production system; visual control; valued employee program; and educational partnerships.

Around 1992, UE reduced its wasted space to the extent that operations which were formerly in three buildings were now under one roof. In addition, the company tore down physical barriers between employees; consolidated and/or regrouped various departments (e.g., merger of marketing and engineering resources, colocation of customer service and scheduling); and rearranged operational equipment on the production floor. The result was a very

visible, open environment that promoted communication and cooperation among the employees, and facilitated better control over the production floor. One consolidation (resource library with human resources) led to the creation of the Resource Center. As the central hub of continuous improvement, this administrative function reports directly to the president of the company; supports all departments and work centers; and provides coordination for programs to enhance the productivity, competitiveness, and profitability of the company.

Since its original survey in June 1991, UE continues to advance in quality, excellence, and adaptability. The company's reputation for dependable, reliable products is a result of innovative manufacturing techniques, superior design, and a corporate focus on uncompromising quality. The BMP survey team considers the following practices to be among the best in industry and government.

### Best Practices

The following best practices were documented at United Electric Controls:

Item	Page
<b>Design Control</b>	5
In mid-1992, UE began working toward ISO 9001 certification along with an assessment of its product line. As a result, Design Engineering developed and implemented a well-defined, ISO certified, design control process. This process flowcharts the necessary steps to control the design engineering process, which includes directives to sub-tier Flow Charts and design engineering procedures.	
<b>Design Kaizen</b>	6
UE's Design Kaizen follows the Japanese Kaizen method for continuous improvement in its engineering design operations. The Kaizen methodology teaches that higher levels of performance can be achieved through an ongoing process of continuous improvement; supportive management; 100% participation; simple but reliable solutions; multi-functional teams; employee rewards and recognition; and applicability to all operational areas.	

<b>Item</b>	<b>Page</b>	<b>Item</b>	<b>Page</b>
<b>Computer Numerical Control Quick Set Ups</b>	<b>7</b>	<b>Poka-yoke: Mistake-Proofing the Process</b>	<b>10</b>
UE implemented a quick set-up method for part of its Computer Numerical Control production capability. This method reduced the set-up time for machine tools by 15% to 20%, and enabled the machining area to realize a 50% increase in revenues by redirecting some machining work back to UE from outside contractors.		UE applies Poka-yoke (mistake-proofing) principles to prevent and detect defects in its manufacturing processes. The procedure typically incorporates straightforward, simple tooling fixtures to ensure that various assemblies can only be assembled in the correct manner.	
<b>Customer Sales Level Scheduling</b>	<b>7</b>	<b>Shipping Using a Pull System</b>	<b>10</b>
Responding to customers in a timely fashion is of critical importance in today's market. The Customer Sales Level Scheduling system improved UE's production rate from several days to one every 84 minutes.		In August 1997, UE implemented a pull system for shipping its finished products. As a result, UE decreased the number of short shipments and incorrect part shipments, as well as eliminated many problems associated with its previous method. Orders are now consolidated for shipment which creates fewer transactions.	
<b>KanBan Pull Production System</b>	<b>7</b>	<b>Supplier KanBan</b>	<b>10</b>
UE established a paperless inventory reduction and production control system based on the Japanese KanBan technique. KanBan is a method of pulling production through the factory based on a customer's withdrawal of a finished product (a customer order).		UE has implemented a KanBan approach with some of its suppliers. Of these, some operate as "breadperson" suppliers who deliver directly to the storage location of UE's central stores. In these cases, the supplier comes in and checks the inventory to determine if the quantity of a part has reached the preset safety margin (typically a one-week supply of parts). Other suppliers are notified by UE's purchasing group when the part quantities reach the preset level.	
<b>Levelized Scheduling System</b>	<b>8</b>	<b>Visual Control</b>	<b>11</b>
UE adopted a Levelized Scheduling system which pulls the product through the production floor instead of pushing it. This system is a one-piece flow that promotes production flexibility and shorter leadtimes.		UE applied a Visual Control system within its facility to create a visual factory. The foundation of visual controls is based on the five S's: sort (organization); stabilize (orderliness); shine (cleanliness); standardize (adherence); and sustain (self-discipline).	
<b>One-Piece Flow Manufacturing Overview</b>	<b>8</b>	<b>Action Centers</b>	<b>11</b>
One-Piece Flow Manufacturing describes a reliable method for production flow that is well suited for the low volume production of a wide variety of products. UE's One-Piece Flow Manufacturing system is a masterful blend of many reliable methods that applies the concepts of Lean Manufacturing, just-in-time, Takt time, levelized scheduling, finite loading, KanBan card system, Heijunka box, one-piece flow, and Kaizen methodology.		Action centers are a unique team concept being effectively used at UE for involving the workforce in making improvements and solving problems. Action centers arise spontaneously whenever the need occurs; can be initiated by anyone in the company; and address such areas as general improvements, problem resolution, problem avoidance, testing new ideas, corrective action, or coordination of projects.	
<b>One-Piece Flow Manufacturing System</b>	<b>9</b>		
UE implemented a One-Piece Flow Manufacturing system in its 120/105 manufacturing workcell. This system allows the demand for parts (orders) to drive the manufacturing flow, and produces finished products in lot sizes of one.			

<b>Item</b>	<b>Page</b>
<b>Educational Partnerships</b>	<b>12</b>
One of UE's reliable methods for continuous improvement is its successful educational partnership with Massachusetts Institute of Technology. Through this approach, UE gets the opportunity to have top-caliber engineering talent who work on improving its plant operations for very low cost, and Massachusetts Institute of Technology gets a real factory with real problems for the educational benefit of its students.	
<b>Reliable Methods for Continuous Improvement</b>	<b>13</b>
UE's Reliable Methods for Continuous Improvement greatly improved its ability to provide high-quality products at the lowest cost and in the shortest possible time. The key to continuous improvement is to identify and develop practices in reliable methods, as well as encourage participation from employees.	
<b>Resource Center</b>	<b>14</b>
The Resource Center is the central hub of continuous improvement activities at UE. This administrative function supports all of UE's departments and work centers, but reports directly to the president of the company. The Center provides coordination for ensuring that UE programs work together to enhance the productivity, competitiveness, and profitability of the company.	
<b>Valued Employee Program</b>	<b>15</b>
The Valued Employee Program is a recognition program designed to increase company-wide productivity and quality by encouraging and rewarding employees for their ideas, teamwork, and improvement efforts. Administered by UE's Resource Center, the program is continuously improving through feedback and the result of participation metrics.	

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## ***Information***

The following information items were documented at United Electric Controls:

<b>Item</b>	<b>Page</b>
<b>ISO 9001</b>	<b>17</b>
As with many U.S. manufacturing companies in the early 1990s, UE discovered that it had to become ISO certified in order to become a supplier for the European community. The company's efforts led to ISO certification in December 1994.	
<b>Standardized Work</b>	<b>17</b>
UE recently implemented a Standardized Work (Kaizen) approach for reviewing its production process in the 120 workcell. With this approach, process operators identify incremental improvements for their production process. Presently, the 120 workcell acts as a pilot program where different approaches and techniques can be used to determine the most appropriate method of implementing improvements.	
<b>New Information System</b>	<b>18</b>
UE is in the process of introducing a new company-wide business information system that has been in development for nearly two years. This system will consolidate all company information into a single system that is easily accessible.	
<b><i>Point of Contact</i></b>	
For further information on items in this report, please contact:	
Mr. Charles Long United Electric Controls 180 Dexter Avenue Watertown, Massachusetts 02272-9143 Phone: (617) 923-6900 x122 Fax: (617) 926-9440 Web: www.ueonline.com	

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# Section 2

## Best Practices

### Design

#### Design Control

Prior to 1992, the engineering design operations at United Electric (UE) Controls were typical of many U.S. manufacturers — quick responsiveness to customer requests and specials drove the business. Many projects submitted to Design Engineering called for products with unique specifications and extremely tight schedules. Designs were hurried, and sometimes project priorities; team participation; design optimization and producibility; cost analysis; and documentation could be compromised. Accountability was often difficult to pinpoint. Through all this, UE was completing and shipping products to its customers. However, it soon became apparent that the business could not grow or continue to compete using this methodology. A new look at UE's processes and products was needed.

In mid-1992, UE began working toward ISO 9001 certification along with an assessment of its product line. First, the company eliminated unprofitable products from its sales and concentrated on the more profitable ones. Second, UE used ISO procedures to gain control of its processes throughout all its operations. ISO certification worked as a driving force that enabled UE to make effective use of its resources, improve its products, increase sales, and ultimately gain a larger profit margin. While other groups within UE dealt with their aspect of ISO requirements, Design Engineering addressed its role with remarkable results. As a result, Design Engineering developed and implemented a well-defined, ISO certified, design control process. This process flowcharts the necessary steps to control the engineering design process, which includes directives to sub-tier Flow Charts (FCs) and design engineering procedures. Key elements include:

- **Standard Design and Development Methods** — Provide well-defined processes and procedures through the use of FCs and Design Engineering Procedures (DEPs). FCs show the general steps necessary to control the Design Engineering process (Figure 2-1) including directives to sub-tier FCs. DEPs document the entire step-by-step process and assure standardization in its execution. A Service Request system is in place which clearly identifies assignments, dispositioning, logging, and tracking. Multi-functional teams work together on all new product designs. Design reviews and checklists have also been added to the process.
- **Multi-Functional Teams** — Provide representation by key departments during new product designs, product redesigns, design reviews, and checklists. Teams can involve design, production, test, and procurement personnel as well as suppliers.

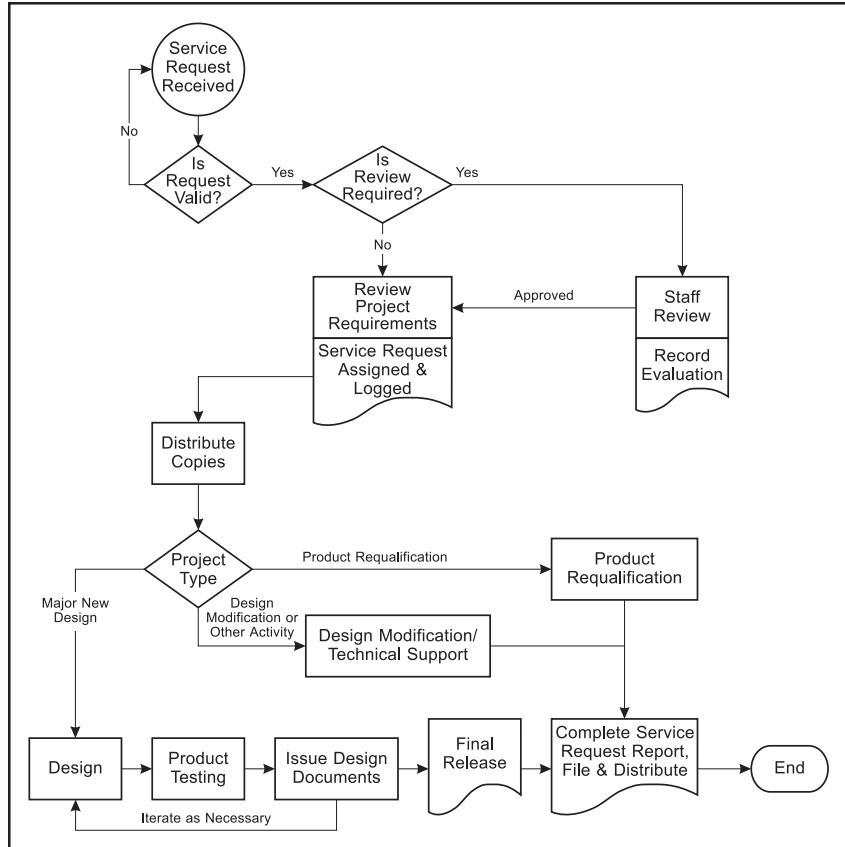


Figure 2-1. Design Engineering Control Process

- **Design Reviews** — Incorporate all aspects of the manufacturing cycle from demonstrating the initial model to fielding the product. By conducting reviews early in the cycle, the product is designed correctly the first time. A checklist ensures coverage of key issues. During the design reviews, the teams assign responsibilities and time commitments, and document all issues, decisions, action items, and assignments.
- **Design for Manufacturability** — Incorporates Manufacturing Engineering requirements into the product design to optimize the production phase. Early in the product design process, a trade-off analysis of requirements is performed. This analysis assures production readiness, process verification, and that an optimal parts flow occurs through the production cell.
- **Controlled Product Release** — Provides a systematic release of new products to the market through a series of in-process design reviews; a final design review; a pre-production run and evaluation; and a final product release approval.

With these controls in place, Design Engineering completely transformed the design engineering operations at UE. Today, UE reaps the benefits associated with a controlled design process such as improved product design, quality, and production release; increased interdepartmental participation; prevention of problems before release; faster time to market; reduced post-release maintenance; and improved traceability and documentation. Most importantly, UE's customer base expanded because of its ISO 9001 certification.

## Design Kaizen

UE's Design Kaizen follows the Japanese Kaizen method for continuous improvement in its engineering design operations. The Kaizen methodology teaches that higher levels of performance can be achieved through an ongoing process of continuous improvement; supportive management: 100% participation; simple but reliable solutions; multi-functional teams; employee rewards and recognition; and applicability to all operational areas. The main thrust of the Kaizen process focuses on allowing the employee to be an effective contributor to the ongoing processes of the company.

Before implementing Design Kaizen, UE employees had little motivation to solve problems or make improvements. As a result, problems were left unresolved and existing processes stayed stagnant.

Employees did not grasp the full relationship between what they did (or did not do) and how it positively (or negatively) impacted revenues. Few incentives and lack of understanding discouraged employees from helping the company reach higher levels of performance.

Over the past few years, UE has made great strides implementing the Kaizen methodology into its continuous improvement process, leading to improvements in products, processes, and factory operations. UE motivates its employees to continuously improve all operations throughout the company as well as the engineering design operations by creating an environment that encourages them to contribute. The company's efforts increased teamwork, morale, problem solving, productivity, quality, and revenue. Design Engineering also developed easy-to-use mechanisms for every employee participating in continuous improvement. Key mechanisms for initiating continuous improvement activities include:

- **Service Request System** — A formal record of request required to initiate an engineering activity that results in changing a product design.
- **Inspection Discrepancy Report System** — A formal record of request required to initiate quality assurance activity as a result of incoming inspection, design, manufacturing, documentation, or field problems.
- **Valued Ideas** — A formalized process for reporting an idea for evaluation or an idea that has been implemented (e.g., variety reduction, production/process improvements, product/design improvements, cost reduction). Valued ideas are typically low technology that can be implemented by an individual or a team.
- **Action Centers** — A formalized process of submitting action items for general improvement, problem resolution, problem avoidance, and exploration of new ideas. Action items are typically of a magnitude and complexity that require in-depth engineering evaluation and management approval.
- **Reliable Methods** — Accepted Total Quality Management methods (e.g., cause-and-effect diagrams; Pareto charts; trend lines) used to effect the continuous improvement process.
- **Recognition and Reward Systems** — A well-defined process for recognizing and rewarding employees for their contribution to continuous improvement.

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With these mechanisms in place, Design Engineering has a 100% participation in its continuous improvement process. Benefits from Design Kaizen include increased teamwork spirit, morale, and motivation for problem solving; tangible results; and improvements in visibility, productivity, quality, and revenue.

## ***Production***

### **Computer Numerical Control Quick Set Ups**

Set-up time for machine tools can be a time-consuming step in the machining process. UE implemented a quick set-up method for part of its Computer Numerical Control (CNC) production capability. This method enables operators to change out tooling much faster than the old method. Previously, operators used Allen wrenches to remove four screws in a tool head on the turret of the CNC machine; replaced the cutting tool on the tool head; and then put the tool head back on the turret. The operator then zeroed out every tool location on the turret so the program could accurately perform the proper machining operation.

Upon converting the CNC machining area to a one-piece flow system, UE needed a quicker method of changing out the machine tools. The company worked with its four tool suppliers, and then selected one to help develop the necessary fixturing. The process now requires the operator to loosen only one screw and snap the tool head out of a quick release socket. The cutting tool is fastened to the tool head, and its location is accurately determined on a measuring instrument. The operator then snaps the tool head back into the turret and tightens the single screw. The measured location of the cutting tool is programmed into the CNC machine.

UE's quick set-up method reduced the set-up time for machine tools by 15% to 20%, and enabled the CNC machining area to realize a 50% increase in revenues by redirecting some machining work back to UE from outside contractors. In addition, another important process was developed through the use of a one-piece flow system. The company now videotapes the CNC machining area's processes a few times a week and looks for improvements. This technique resulted in centralizing the tools in one area; moving raw material closer to the worksite; using set-up carts for different jobs; reducing the number of tool suppliers; and using status charts

and other visual aides to help operators perform their tasks. UE's commitment to incrementally improving its processes is providing benefits throughout the entire factory.

### **Customer Sales Level Scheduling**

Responding to customers in a timely fashion is of critical importance in today's market. UE's previous system required a typical leadtime of four to five weeks. The new Customer Sales Level Scheduling system can respond in a day if needed. This system is a byproduct of the Lean Manufacturing approach of doing business.

UE receives orders via telephone, facsimile, or correspondence. As they arrive, the orders are posted on a visual scheduling board. The factory presently handles 136 units per day in its 120/105 workcell, so the visual scheduling board is loaded to this quantity. The customer sales representatives identify the unit's complexity (low, medium, or high). Once the board is fully loaded, the orders are retrieved and scanned into the computer. The computer prints a sequence list that directs the factory personnel to produce the product in a specific order. The computer also organizes the flow of work, so an even mix of complex units are processed throughout the production floor.

Scheduling takes place the day before actual production. Customer sales representatives ensure that the next day's production is established and ready for factory personnel when they arrive. The Customer Sales Level Scheduling system improved UE's production rate from several days to one every 84 minutes. In addition, the new system significantly reduced leadtime from four to five weeks to a single day, and improved UE's ability to meet its customers' requirements.

### **KanBan Pull Production System**

UE established a paperless inventory reduction and production control system based on the Japanese KanBan technique. Before implementing the KanBan system, the factory was full of work orders. Every work order had a priority stamp; some with multiple priority stamps. There was no way to see what the priority sequence should be within the stacks of paper. Many times work orders were duplicated so that the same part was ordered twice.

KanBan is a method of pulling production through the factory based on a customer's withdrawal of a

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finished product (a customer order). When the final assembly work center pulls subassemblies for installation in the final products, the subassembly work center is triggered to pull parts for the subassemblies. The parts work center is then triggered to make parts, which in turn triggers the material supplier to provide material. Parts may be housed in 100-part bins with two or more bins in use at one time. The consumer of a part returns the empty bin to the supplier and receives a full one. The empty bin is placed upside down on the storage shelf as an indicator to the supplier to make more parts. When the correct number of parts per bin has been manufactured, the full bin is placed in storage, typically located near the supplying work center. A full bin is always ready for the consuming work center.

Although the number of parts per bin must be kept as low as possible, it still must be great enough to support production needs. The number of bins and parts per bin are tailored to consumer and supplier capabilities. The process requires a monitor to determine when to adjust the number of bins and parts per bin.

UE reduced its inventory costs by 90% for some parts, as well as its storage and handling costs by using the KanBan system. Scrapped or reworked parts in inventory are also lower in a KanBan system, should the supplying work center not immediately detect a manufacturing problem. Since implementing the new system, UE can go from kitting to final assembly completion in 85 minutes instead of several months.

## Levelized Scheduling System

UE adopted a Levelized Scheduling system which pulls the product through the production floor instead of pushing it. UE's previous (push) system was spread out over three different facilities, and had a leadtime of up to four weeks while production control and sales representatives completed the proper paperwork and scheduling.

The Levelized Scheduling system is a one-piece flow that promotes production flexibility and shorter leadtimes. Production equipment is arranged in the order that employees work instead of being grouped by equipment function. UE also consolidated all of its operations in one building to facilitate better control over the production floor. The system's goal is to pull a product through the floor at a rate equal to the rate of sales. Downstream processes pull small amounts of work from upstream processes at a pace that reflects the customers' demands for

finished products rather than pushing work downstream in batches.

Customer service uses various tools with the Levelized Scheduling system. Visual scheduling boards define the unit loading by day, the rough mix by cycle time, and the overall Takt time (amount of time it takes for a part to go through the workcell). Spreadsheets determine the best mix of high, medium, and low cycle-time products in order to generate the best production flow. A computerized sequence list tells production employees the exact order to build the product.

Benefits of the Levelized Scheduling system include a dependable first-in-first-out approach; a visual status-check capability via scheduling boards; less than two-hour production leadtimes; and the loss of only one unit when defects occur compared to multiple units with a batch system. The system identifies and eliminates waste associated with storage, unnecessary production, inventory movement, and costs related to correcting a defect. The Levelized Scheduling system enables UE to supply its customers with high quality products at the lowest cost and in the shortest possible time.

## One-Piece Flow Manufacturing Overview

One-piece flow manufacturing describes a reliable method for production flow that is well suited for the low volume production of a wide variety of products. UE's One-Piece Flow Manufacturing system is a masterful blend of many reliable methods that applies the concepts of Lean Manufacturing, just-in-time (JIT), Takt time, levelized scheduling, finite loading, KanBan card system, Heijunka box, one-piece flow, and Kaizen methodology.

UE manufactures over 2,000 different varieties of temperature sensing probes and thousands more varieties of pressure sensors, mostly per unique customer specifications from around the world. Previously, UE had a typical leadtime of four to five weeks for customized orders. Since implementing one-piece flow manufacturing, UE reduced its leadtime to two weeks, on average, and can provide same-day response for partial orders from customers.

UE achieved tremendous results by understanding and applying the basic philosophy of Lean Manufacturing and associated reliable methods for continuous improvement. Key factors include:

- Reducing lot sizes to one piece, which leads to production flexibility and shorter leadtimes.
- Pulling production through the process at a rate equal to the rate of sales.

- 
- Producing only what is needed when it is needed (equal to the rate of sales).
  - Using pull systems that connect all islands of production from end to end.
  - Arranging production equipment in the order that employees work instead of grouping them by equipment function.

By applying Lean Manufacturing, UE can also identify and eliminate waste associated with storage, unnecessary production, inventory movement, and cost related to correcting a defect. Associated reliable methods that support Lean Manufacturing include JIT, automation, and Kaizen methodology. In JIT production, processes are arranged as orderly and close together as possible. Downstream processes pull small amounts of work from upstream processes at a pace that reflects the customers' demands for finished products rather than pushing work downstream in batches. Automation refers to automating a process where possible to include mistake proofing (Poka-yoke) and inspection. The operator is alerted only when necessary, such as when a defect occurs. Kaizen methodology encourages employees to be an effective contributor to the ongoing processes by constantly identifying and eliminating waste.

The primary technique that runs the operation on the production floor is the KanBan card system. In one area, UE uses a very simple card form of KanBan based on color-coded paper in a vinyl envelope. Each card, representing one unit, acts as a signal to initiate the production of a test, assembly, or kit. UE also uses barcoding to assist with the paperwork and inventory tracking. KanBan cards and associated work instructions are loaded into the slots of the Heijunka box, which functions as a leveled scheduling tool. Each slot represents three minutes of production time (Takt time) for electro-mechanical switches and one minute for temperature sensors. The process flow coordinator removes a KanBan card/work instruction from the Heijunka box as a signal to build. The work coordinator sets the pace for the entire operation by depositing work at the stations and simultaneously delivering products to their next destination. The KanBan system is used for both stock items and made-to-order parts.

The KanBan system enables UE to be more responsive to its customers' needs. UE significantly improved quality and now produces sensors at a rate of one per minute. In addition, the KanBan system offers minute-by-minute flexibility on the production floor, allowing UE to respond to any volume and variety of product with ease.

## One-Piece Flow Manufacturing System

UE implemented a One-Piece Flow Manufacturing system in its 120/105 manufacturing workcell. This system allows the demand for parts (orders) to drive the manufacturing flow, and produces finished products in lot sizes of one. In the past, work was pushed through the manufacturing area to fabricate finished products for the stockroom, which resulted in large amounts of finished products in inventory. In addition, many piece parts are common among the different products. As a result, UE ran into part shortages whenever priority orders came into the factory because the parts had already been used to build other units now sitting in inventory. UE's capital was tied up in inventory as finished products waiting to be sold.

The One-Piece Flow Manufacturing system uses Heijunka boxes to schedule the production of units based on demand (orders). When orders arrive, the customer service and scheduling group generates the production schedule by part number and options. The group maintains the Takt time of the workcell by taking into account the time required to build that part and the mix of part complexity (low, medium, or high) in the production flow. The Heijunka box is then loaded in three-minute increments (Takt time) by placing the proper card in the slot for the part number to be built.

Production is initiated by retrieving a card from the Heijunka box slot. Then the parts are kitted; the nameplate is stamped; and the kit is taken to the workcell and placed in the incoming location. The first assembler in the workcell takes the kit; checks the paperwork for the model and options required; and performs the assembly steps for the first station. The partially-assembled unit is then passed to the next station where further assembly steps are performed. The unit then goes to the third station where the last assembly steps are completed. If required, the unit will undergo set-point adjustments and/or testing. Finally, the unit is packaged and put in the outgoing location to be picked up for staging before shipping.

Benefits achieved from UE's One-Piece Flow Manufacturing system include the elimination of excess inventory; an order-based assembly line; and the loss of only one unit when defects occur compared to multiple units with a batch system. The production operation is now more efficient, and does not require UE's capital to be tied up in inventory as finished products waiting to be sold.

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## Poka-yoke: Mistake-Proofing the Process

UE applies Poka-yoke (mistake-proofing) principles to prevent and detect defects in its manufacturing processes. The procedure typically incorporates straightforward, simple tooling fixtures to ensure that various assemblies can only be assembled in the correct manner.

Poka-yoke prevents or detects problems before additional value is added to the parts, and eliminates subsequent inspection steps to determine if the parts were correctly assembled. The process includes a series of questions on a defect such as:

- What was wrong?
- When was it discovered?
- What were the standard elements involved in making the part or assembly?
- What mistakes or errors were made?
- Why were the mistakes made?

This information is used to generate ideas on possible solutions to the problem. For its assembly fixtures, UE uses Poka-yoke devices such as limit switches, assembly templates or counters, and strategically placed pins or sensors on fixtures. Visual aids, detailed equipment set-up sheets, and in-process final assembly checks also aid the Poka-yoke process to ensure that the part was correctly assembled before it leaves the workstation.

UE's fixtures continue to go through the Poka-yoke process as assembly problems are noted. In addition, employees continue to identify other workcells where similar fixturing can be used to eliminate assembly problems.

## Shipping Using a Pull System

In August 1997, UE implemented a pull system for shipping its finished products. The prior practice consisted of placing finished products on a conveyer, or on carts when the conveyer was full. Orders were mixed on the conveyer and the carts. A shipping clerk then entered the finished products into shipping via a computer transaction. Next, the products were reviewed for shipping status, and had their shipping papers generated. Those products with later shipping dates were held and subjected to review each day. Any product with delinquent payments (hold credits) was also held until payment was received from the customer. For those customers who only accepted full deliveries, UE employees would hold the partial shipments until the remainder of the order was completed. In the shipping area, the overpackers chose whatever they

wanted to pack rather than what needed to be packed first. At the end of the day, employees faced a rush to pack expedited orders. Typically, the same customer could receive as many as 15 shipments in a single day.

UE's previous shipping process was completely revamped over a weekend. The conveyer was removed, and distributor carts were set up and located for consolidation of daily shipments. International, no partial shipment, later date, and hold credit carts were also set up and located. UE now creates shipping papers only when the order is about to be shipped, eliminating all manual corrections on the paperwork pertaining to address or priority changes. In addition, UE uses a Heijunka box to schedule and control the flow of work.

Since implementing its new shipping system, UE decreased the number of short shipments and incorrect part shipments, as well as eliminated many problems associated with the previous method. Orders are now consolidated for shipment which creates fewer transactions. Shipping supervisors can determine the status of the shipment by looking at the Heijunka box, and assign additional help as needed. Folders, outfitted on distribution carts, hold the paperwork and indicate the daily completion status of a customer's order by which folder is used. In addition, UE reduced the number of domestic shippers from four to two, even though the volume of shipments has increased.

## Supplier KanBan

UE has implemented a KanBan approach with some of its suppliers. Of these, some operate as "breadperson" suppliers who deliver directly to the storage location of UE's central stores. In these cases, the supplier comes in and checks the inventory to determine if the quantity of a part has reached the preset safety margin (typically a one-week supply of parts). Other suppliers are notified by UE's purchasing group when the part quantities reach the preset level.

In the past, UE purchased parts in advance, stored them in a stockroom, and dispensed them as needed. In 1993, the company began using stock storage at the point-of-use in workcells. However, UE encountered inaccurate part counts, an increase of parts in inventory, and situations where the safety stock was used up without anyone being informed, resulting in production stoppage due to part shortages. In 1996, the company then started its Supplier KanBan system, using central stores for parts. The central stores have 1,550 purchased

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part numbers. A three-week supply of parts is the maximum in these stores at any time.

The first supplier to operate under UE's Supplier KanBan system was the casting supplier. Here, UE notifies the supplier whenever the stock in the central stores reaches a one-week supply. The supplier then ships the product to UE on a pallet which contains a one-week supply wrapped in reusable packaging. After the parts are used, the reusable packaging is bundled and the supplier picks up the packaging when the next delivery is made. Another example is the metal bellows supplier who operates as a "breadperson" supplier. Here, the delivery person goes directly to the central stores and examines the part's bin to see if more parts are needed. If this is the case, the supplier delivers a shipment to UE within the week. Currently, 35 suppliers operate on some form of the Supplier KanBan system, and more are being added.

The Supplier KanBan system is working well for UE. Parts are delivered when needed and no excess stock is maintained. Through a concentrated effort begun in 1997, the company is also decreasing the number of suppliers. The number of suppliers was reduced from 347 to 273 which exceeded UE's goal of 311 suppliers for 1997.

## Visual Control

UE applied a Visual Control system within its facility to create a visual factory. The foundation of visual controls is based on the five S's:

- Sort (organization) — The first S distinguishes between what is and is not needed.
- Stabilize (orderliness) — The second S identifies a place for everything and puts everything in its place.
- Shine (cleanliness) — The third S focuses on cleaning and looks for ways to keep it clean.
- Standardize (adherence) — The fourth S maintains and monitors the first three S's.
- Sustain (self-discipline) — The fifth S advocates sticking to the rules, scrupulously.

UE accomplished the first S (sort) by asking each employee to put a tag on everything in their work area. A green tag meant the item was needed; a yellow tag meant they were unsure if it was needed; and a red tag meant that it was not needed. If different colored tags were on something, then UE talked to the employees about why the item had conflicting tags, and reached a consensus on the item. This eliminated items in the work area which were unnecessary for a job. The second S (stabilize)

was achieved by marking the walls and floors to indicate the location of items (e.g., brooms, carts, wastebaskets, safety eyewear). This method easily identified when an item was missing from its designated location, and reminded the person who last used that item to return it to its proper place. The third S (shine) involved checking machines for oil leaks, examining housekeeping methods, and finding ways to keep the equipment and work areas clean. The fourth S (standardize) was implemented by starting a five-S (sustain) patrol, consisting of a two-person team that monitored what was being done and gave each area a score. UE used the score to determine which areas needed improvement. The company also set up a steering committee to standardize the colors used for signs and to address any other issues that might come up in sustaining the program.

UE developed many visual controls for use in its factory. One example is a stop sign, near eye level, at every safety eyewear station. The sign's purpose is to catch the attention of everyone before they enter an area that requires safety eyewear. Another is the Odd Part Out method. After parts are removed from a bin for assembly, they are placed into separate trays at the assembly area. The product is then assembled by using one part from each tray. This method allows the operator to quickly see if a part was left out during the assembly. UE's visual controls have also resolved previous problems. Many times in the past, an option for a product would be shipped without all of its parts being included. UE solved this problem by using a piece of cardboard with a stamped outline that identified all the parts needed for that option. The operator can now verify that all of the parts are present before the package is shrinkwrapped and shipped.

UE's Visual Control system eliminated unnecessary clutter and equipment from the work areas; established a location for everything; enhanced the cleanliness and maintenance of equipment; and improved safety. The most beneficial aspect of the system is the effect it has on the quality of the end product.

## Management

### Action Centers

Action centers are a unique team concept being effectively used at UE to involve the workforce in making improvements and solving problems. Action centers arise spontaneously whenever the need occurs. An action center can be initiated by anyone

in the company. Applications include general improvements, problem resolution, problem avoidance, testing new ideas, corrective action, or coordination of projects.

When an opportunity for improvement or a problem resolution arises, an employee can call for the creation of an action center. The initiating employee is responsible for getting the appropriate people together to form the team, as well as organizing and scheduling the team's activities. Action centers are formally established as teams, assigned an action center number, and tracked by the Resource Center's staff. All employees have been trained in group decision-making techniques and continuous improvement methods. Tools (e.g., Cause and Effect Diagram with the Addition of Cards) are applied to find root causes and develop solutions. When a team completes its action, all members of the team must sign off on the Action Center Report, indicating agreement with the resolution. Participants are recognized and rewarded through UE's Valued Employee Program.

An average of 100 action centers are formed each year at UE. In 1997, 141 employees participated in at least one action center. The action center concept provides an environment that empowers employees to implement their ideas without any hindrance from management. It is a way to get the right group of people together to focus on solving a problem without finger pointing or blame. Action centers work, and have fueled the engine for change and continuous improvement. They give employees an opportunity to make UE a better and more productive place to work.

## Educational Partnerships

UE believes in utilizing public resources, whenever possible, which can help the company at low or no costs. One effective way is through public/private partnership approaches — an outgrowth of networking between regional academic institutions like Harvard and the Massachusetts Institute of Technology (MIT), and public organizations like the Greater Boston Manufacturing Partnership (GBMP) and the national Manufacturing Extension Partnership. Boston has many world-class academic institutions, but very few of these have established linkages and relationships with manu-

facturing companies in the region. However, as government research and development budgets are being reduced, more universities are looking for ways to replace the lost revenue.

UE developed an effective partnership with MIT which provides significant benefits to all involved. The relationship was a byproduct of UE's participation in GBMP. In recent years, GBMP has worked to bring universities and manufacturing companies together. Much of the focus for this activity has centered on projects to develop lean manufacturing methods. The partnership between MIT and UE resulted in a Design Engineer program. MIT needed real-world manufacturing facilities for its students, and UE wanted world-class engineering assistance but lacked the resources to obtain it. GBMP was the catalyst that brought the two together.

The first graduate engineering student from MIT came to UE in 1994. This led to an alliance with MIT and GBMP to develop lean manufacturing methods. More graduate students began working on projects at UE to solve production problems and develop lean methods of production. In 1996, an MIT professor launched a graduate lean production system design course using UE as the laboratory for the course. Twenty students enrolled in the program in the spring of 1997. As part of the course, each student spent at least one day a week at UE working on specific problems or improvement opportunities. An action center was formed for each student project and formally tracked. The students received 50% of their support from MIT and 50% from UE. At the completion of the semester, the students submitted reports on their projects and presented them orally to UE. Table 2-1 is a list of topics undertaken by the students.

**Table 2-1. 1997 MIT Graduate Student Projects at UE**

- |  |  |
|--|--|
| • 12 Series Cell Design  | • Heijunka Scheduling  |
| • Axiomatic Design of a Thermal Testing Process                                  | • Implementation of a KanBan Control System to Support CNC Setup Reduction |
| • Axiomatic Design of Ergonomics in Manufacturing System Design                  | • Lean Manufacturing in the Spectra 10-Series Cell                         |
| • Design and Control of Manufacturing System                                     | • New Product Development Process Proposal                                 |
| • Development of a Standard Work Process for a Single-Piece Flow Assembly System | • Parts Picking Process Project  |
| • Development of Single-Piece Process Flow for Belleville Springs                | • Single-Piece Parts Picking and Conveyance                                |
|  | • Transforming a Batch Epoxy Process to a Single-Piece Production          |

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The program provided resounding success for both UE and MIT. UE gets the opportunity to have top-caliber engineering talent who work on improving its plant operations for very low cost. MIT gets a real factory with real problems for the educational benefit of its students. Graduate engineers coming out of this program are more valuable as potential employees because of the real-world experience and knowledge they have gained. This year, 58 students are signed up for the program which is probably more than the company can handle. The work done by the students provides UE with solutions to difficult problems. UE is so positive about the partnership with MIT that the company considers it to be one of its reliable methods for continuous improvement.

## Reliable Methods for Continuous Improvement

UE's Reliable Methods for Continuous Improvement greatly improved its ability to provide high quality products at the lowest cost and in the shortest possible time. The key to continuous improvement is to identify and develop practices in reliable methods, as well as encourage participation from employees. The leadership, vision, and resources provided by UE created a favorable environment for change, based on using reliable methods in small steps, and has produced impressive gains and benefits.

Over the years, UE has received national recognition and created a tradition for innovative and resourceful approaches to continuous improvement. In 1991, UE was using such reliable methods as KanBan, Single Minute Exchange of Dies, and Poka-yoke in its production operation before most companies had ever heard of them. Today, the list of methods has been expanded, and continuous improvement emanates throughout all facets of the business. Understanding the meaning and relationship behind these methods are critical to their application. UE's reliable methods include:

- Flow Manufacturing (one-piece flow) — Requires factory processes to be aligned in a sequence of production and properly balanced so as to minimize storage between processes. Typically, a workcell contains all operations needed for production, and crossed-trained technicians handle the operations within that cell. Changeover from model to model is smoothed through the Single Minute Exchange of Dies Concept to allow flexible production of many different models each day.
- Five S's — Refers to five Japanese words which describe the importance of good housekeeping. Most factories are repositories of superfluous benches, machines, fixtures, cabinets, and inventory. Before beginning improvements, a facility addresses the five S's: (seiri) unneeded items should be thrown out; (seiton) items remaining should be organized in a visually clear manner; (seiso) the factory should be spotlessly clean; (seiketsu) equipment should be maintained; and (shitsuke) workers should follow existing rules and standards.
- Seven Wastes — Refers to non-value added work such as the seven wastes (storage, transportation, over-production, processing, motion, defects, and waiting) which must be identified and eliminated. This method requires managers and workers to examine their workplace from an entirely different viewpoint. Waste identification and elimination is essential to implement any part of lean manufacturing.
- KanBan (card or sign) — Refers to a simple inventory control system that integrates information flow with material flow. In this system, a product is produced and stored in the producing work center along with a card. Next, the product is withdrawn (pulled) by the consuming work center when needed. As the product is withdrawn, the card is left with the producing work center as an order to make more products. This technique is largely responsible for reducing excess inventories.
- Single Minute Exchange of Dies (SMED) — Refers to a Japanese concept aimed at reducing all factory set-ups of one hour to one minute. SMED techniques are a means of eliminating over-production from running large batches, not a method of decreasing process cycle time.
- Quality Control Tools — Consists of a broad variety of charting techniques that affect problem solving (e.g., Cause and Effect Diagrams, trend lines, histograms, Pareto charts). The techniques identify causes and cures for complex problems, and typically require the participation of several different departments for solutions.
- Jidoka (autonomation with a human touch) — Involves the modification of machines so they automatically shutdown upon the detection of defects. This concept eliminates the need for workers to stand-by and watch for defects; frees up the operators to handle other processes at the same time; and increases their productivity.

- Standard Operations — Emphasize that people, equipment, facilities, and techniques are required to produce a product. Standard operations include a diagramed process flow of a work sequence, the posting of piece parts' cycle times, and time measurements for manual and mechanized work.
- Lean Manufacturing — Describes the system which encompasses a broad range of techniques determined to reduce costs by eliminating waste from the production process. Lean Manufacturing is often described pictorially as a house with a Total Quality Management foundation, a floor of Flow Production, and pillars of Just-In-Time and Jidoka.
- Total Quality Management (TQM) — Describes a proactive, company-wide quality system. Inspection of parts is largely replaced by thoughtful planning, control, and continuous improvement of processes. Employees in all functions are educated and empowered to identify and eliminate waste.
- Just-In-Time (JIT) — Means to produce only what is needed by using a minimum of materials, labor, equipment, and facilities.

UE does not force or overemphasize the use of any particular method, but instead encourages a blending of those methods that best fit a situation. Reliable methods are merely a tool for continuous improvement, and share several characteristics — they are simple, inexpensive, and can be implemented by production floor employees, design engineers, test technicians, procurement personnel, and virtually anyone in the organization. UE educates its employees in great depth on the use of reliable methods, and provides incentives for continuous improvement. Management removes barriers and constraints that impede change, and empowers its workforce to make changes. Employees are encouraged and supported in transitioning their ideas into action.

UE's Reliable Methods for Continuous Improvement is blended throughout all facets of its operations — the factory is neat and clean; everything is in its place; the work flow is smooth; there are no wasted motions; and inventories are minimal. Through its reliable methods, UE reduced its inventories from \$10 million to \$2 million; increased its throughput by 30%; consistently delivers products on time 100% of the time; and improved new products' design-to-production cycles by 50%.

## Resource Center

The Resource Center is the central hub of continuous improvement activities at UE. This administrative function supports all of UE's departments and work centers, but reports directly to the president of the company. This arrangement assures independence and top-level visibility for continuous improvement initiatives. Most of the programs administered and supported by the Resource Center have been in operation at UE for many years. With a staff of two, the Center provides coordination to ensure that these programs work together to enhance the productivity, competitiveness, and profitability of the company.

A lending library is maintained in the Resource Center and offers a broad selection of publications related to continuous improvement methods. These books are purchased by the company, but selected by the employees. Employees who select a publication are asked to do a book report so others can learn why the book is worth reading. All of the books are available for check out by employees. The library is also an excellent resource for self learning. A new addition to the library is the book swap section which includes general interest books such as fiction and children's literature. Employees who take a book from this section must bring in a book to swap with it. This method provides a constantly changing selection of books. The Resource Center also maintains equipment and office supplies for employees to borrow. Equipment such as video and Polaroid cameras; tape recorders; overhead projectors; and slide projectors can be checked out for use in presentations and training sessions.

The Valued Employee Program which recognizes and rewards employees for participation in continuous improvement efforts is administered by the staff of the Resource Center. Forms for Action Centers, Valued Ideas, Tours, and Book Studies can be picked up in the Center. Designated boxes in the Resource Center are used to receive completed forms and for submitting articles to the monthly *You-E-News*. Other forms such as designing/planning training sessions and educational programs are also available at the Center, along with binders containing a variety of training curricula so employees can plan their personalized programs with assistance from Resource Center personnel, if necessary.

The Resource Center supports all of the employees through numerous programs, resources, and

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activities. Since most of UE's continuous improvement activities are self directed by employees, the Resource Center provides a cost effective way to make sure that the efforts are coordinated and that employees have everything they need to make UE a better company each day.

## Valued Employee Program

The Valued Employee Program is a recognition program designed to increase company-wide productivity and quality by encouraging and rewarding employees for their ideas, teamwork, and improvement efforts. All employees may participate, including part time and temporary employees. The Valued Employee Program, itself, is continuously improving through feedback and the result of participation metrics. The program is administered by UE's Resource Center.

The key to the Valued Employee Program is to provide incentives that encourage employees to participate in company-approved activities which promote continuous improvement. There are two categories for employee participation: (1) Valued Ideas and (2) Reliable Methods and Continuous Improvement. In the Valued Ideas category, employees submit ideas for improvements in productivity, quality, morale, waste elimination, or cost savings. A prompt evaluation is made by the Resource Center to determine if the idea is something that can be implemented. If so, the employee receives an award of \$25. Employees then earn a maximum of one chance in either the monthly Valued Ideas Drawing for implemented ideas, or the monthly Participation Drawing for non-implemented ideas. Even though an idea is not implemented, the employee still receives recognition and the chance to win a valuable award just for making an effort to submit an idea.

In the Reliable Methods and Continuous Improvement category, employees have many ways to earn a chance in the monthly Participation Drawing. Employees can give an oral presentation of a book study report; submit an article or work on the publication of the monthly *You-E-News*; participate in a company-sponsored health and wellness pro-

gram; be a tour guide or speaker; write discrepancy reports or complete on-time corrective actions; pass an internal audit; meet training qualification standards; and, with prior approval, qualify by performing special projects or activities. Chances can also be earned by employees who form or participate in Action Centers, upon the problem's resolution.

The program offers several levels of awards. The monthly Valued Ideas Drawing awards ten \$100 prizes for Valued Ideas. The monthly Participation Drawing awards ten \$100 prizes, tickets, and UE gift items for Reliable Methods and Continuous Improvement. In addition, the employee with the highest level of involvement in continuous improvement (as measured by the total number of eligible events completed during the month in both award categories) is named the Employee of the Month. Prizes include their picture in the front lobby, a parking space, and \$100. The employee of the month is not eligible for other prizes in the monthly drawings, and can only win this award once in a calendar year.

There are also two annual drawings — the Valued Ideas Annual Drawing and the Participation Annual Drawing. Employees who have implemented at least three Valued Ideas during the year will receive one chance in the Valued Ideas Annual Drawing; awards include a cruise/vacation worth \$2,500 and other prizes. Employees who have participated in 12 eligible events during the year receive one chance in the Participation Annual Drawing; awards include a cruise/vacation worth \$2,500 and other prizes. A total of about 65 to 70 prizes are given out at the annual drawings. UE's annual budget for the Valued Employee Program is about \$80,000 for cash and prizes, and about \$15,000 for tickets.

The Valued Ideas Program has proven to be a very effective approach to get all of the employees to participate actively and repeatedly in continuous improvement activities. In most cases, UE gains small improvements that add up to big savings which increases the company's profitability and improves its products. The program helps to generate about 100 Action Centers per year, and approximately 1,200 ideas per year of which 85% are implemented within the first month. In 1997, employee participation in the program was 100%.

## Section 3

### *Information*

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#### *Production*

##### ISO 9001

As with many U.S. manufacturing companies in the early 1990s, UE discovered that it had to become ISO certified in order to become a supplier for the European community. UE had modeled its quality system after U.S. standards such as MIL-I-45208 and MIL-STD-45662, but now needed some extensive changes for ISO certification. The company began by gathering information from professional journals and interviewing its customers to determine the best method of proceeding. Teams were established to address all elements of the ISO 9001 quality standard. Project leaders were sent off-site to obtain lead assessor training, and then returned to train the other team members.

UE's procedures not only had to be updated to the current processes, but they had to be modeled after the ISO quality elements. The company accomplished this task by having operators document their processes. Internal audits were performed and corrective actions were taken. In 1992, UE selected a registrar and had a pre-assessment done. The assessors found no major findings, but did identify numerous items that required corrective action. To emphasize the urgency of achieving ISO certification, UE made it the number one priority in its 1994 Business Plan. Resources were then refocused and redeployed to review the company against the ISO elements. As a result, the company's efforts led to ISO certification in December 1994.

UE gained much from going through the process to become compliant. The amount of money spent on discrepant products (as a percentage of sales) dropped from approximately 1.6% in 1994 to 0.73% in 1997. The number of returned goods authorizations were reduced from a little over 2,000 to less than 1,300. Supplier discrepancies also fell from almost 1,100 to a little over 400. Today, UE's simpler quality system is designed for continuous process improvement, has produced major cost savings, and enables the company to successfully compete in a world market.

#### Standardized Work

UE recently implemented a Standardized Work (Kaizen) approach to review its production process in the 120 workcell. With this approach, process operators identify incremental improvements for their production process. Previously, Engineering performed the reviews and provided the results to the workcell operators for implementation. This method did not work very well because Engineering spent little time looking for improvements, and lacked first-hand knowledge of the detailed process. A better method was needed. UE now lets the process operators handle the review and improvement aspect of the entire 120 workcell operation. A team leader and a group leader work with other operators within the workcell and with Engineering to investigate potential improvements.

The 120 workcell team spends up to 0.5 hour per day reviewing a particular aspect of the process and looks for ways to perform the operation easier, quicker, and cheaper. By using a Kaizen approach, operators can identify a simple improvement to increase quality and ease, or reduce time and cost. This approach consists of listing process steps in detail, performing time studies, reviewing consolidation of processes, and sharing improvement techniques among operators. Other aspects of the production process that are reviewed include fixturing, employee comfort, and overall work environment.

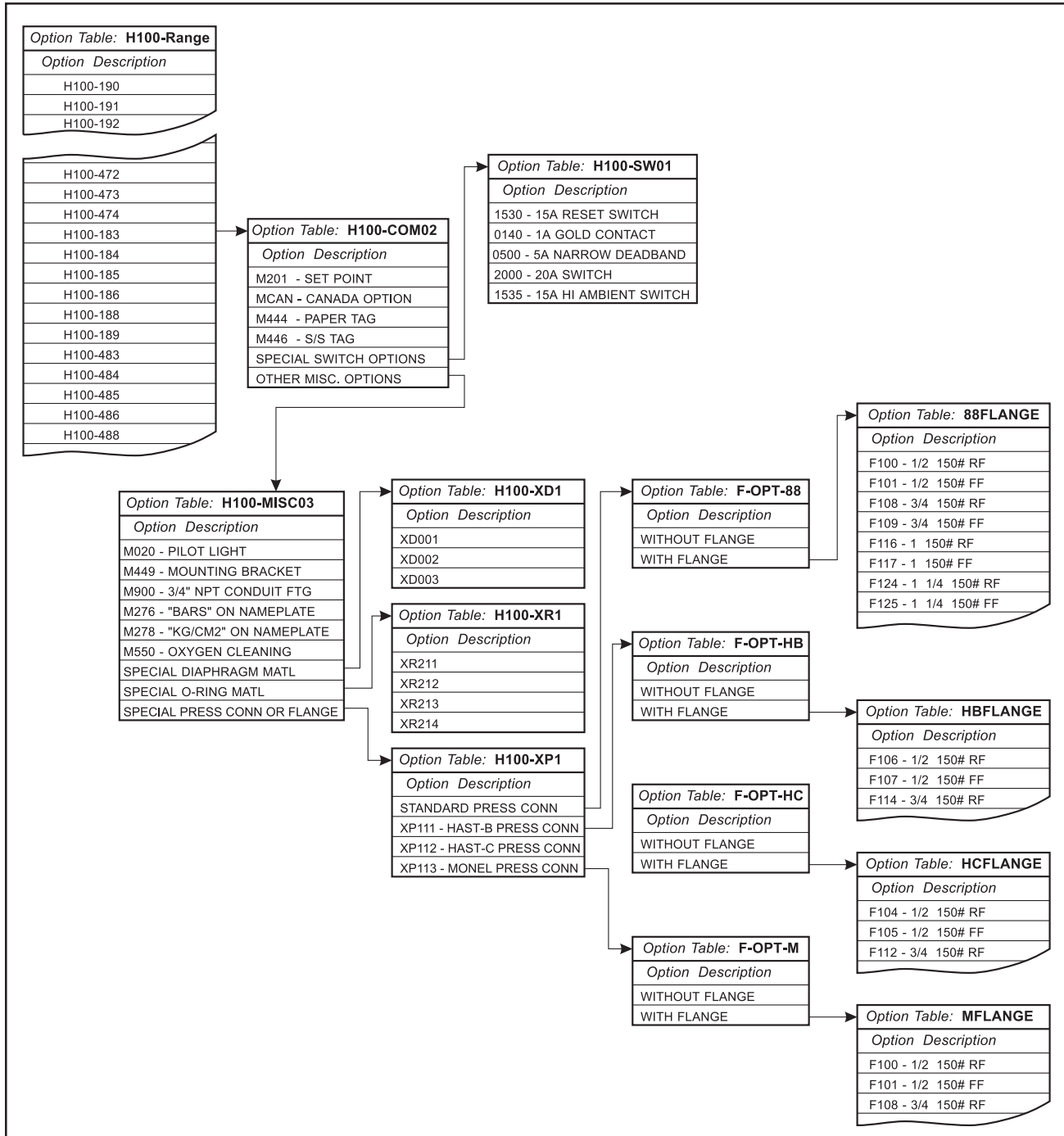
The Standardized Work approach for improvement is relatively new at UE. The company plans on turning over all of its processes to its employees. Presently, the 120 workcell acts as a pilot program where different approaches and techniques can be used to determine the most appropriate method of implementing improvements. In addition, the 120 workcell team will work with other workcell groups within the factory and share its findings. Once fully implemented across the company, the Standardized Work approach will achieve considerable savings for UE and its customers through incremental improvements.

# Management

## New Information System

UE is in the process of introducing a new company-wide business information system that has been in development for nearly two years. This system will consolidate all company information

into a single system that is easily accessible. Previously, UE had many manual and paper-based systems in use throughout the company. Many of the automated systems and databases were incompatible which made sharing information difficult. Most of UE's engineering data was not available online, and the company had no system in place to assure control of product configurations or options. As a



**Figure 3-1. H-100 Configurator (Models 183-189, 483-489)**

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result, many errors, inaccuracies, and frustrations were commonplace for everyday business.

With the new system, company-wide business and engineering information will now be available from a single source and accessible throughout the plant. UE's New Information System is a client-server system. Engineering data, drawings, and documentation can now be accessed accurately and in real time. The new system will manage all transactions from a single database and enable the business to run more efficiently.

Extensive preparation was required to reduce and standardize all of the company's data, bills of material, models, etc. for entry into the new system. This preparation required a great deal of work, but was a tremendous benefit to the company. Next, an extensive review and clean-up of UE's large product line was conducted. This effort resulted in the consolidation of product lines and reduced the variety of products built. More than 8,000 product variations were reduced to just 1,700. Additionally, all products were structured for the new UE Lean Manufacturing production methods. A product configurator capability was also implemented in the

system. This capability provides self-documenting information on each product that can be assembled based on numerous product configurations and options. Figure 3-1 illustrates how the configurator works to select the correct configuration's documentation from the many permutations and combinations of product families and options for an H-100 pressure switch. An engineering knowledge database has been built into the system to provide online product information for use by sales and marketing personnel for responding to customers' questions and inquiries.

Although the New Information System is currently in the pilot stage, the process of preparing the information for entry into the system has already streamlined and improved all business operations at UE. The system will provide real-time access to accurate data. Product order entry validation for standard and specially configured products will be rapid and accurate, and produce self-documenting bills of material and other reports. The system will also provide improved product cost roll-ups and reduce workloads in all areas of the plant.

# Appendix A

## *Table of Acronyms*

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<b>Acronym</b>	<b>Definition</b>
CNC	Computerized Numerical Control
DEP	Design Engineering Procedure
FC	Flow Chart
GBMP	Greater Boston Manufacturing Partnership
JIT	Just In Time
MIT	Massachusetts Institute of Technology
SMED	Single Minute Exchange of Dies
TPS	Toyota Production System
TQM	Total Quality Management
UE	United Electric

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# Appendix B

## ***BMP Survey Team***

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<b>Team Member</b>	<b>Activity</b>	<b>Function</b>
<b>Larry Robertson</b> (812) 854-5336	<b>Crane Division</b> <b>Naval Surface Warfare Center</b> Crane, IN	<b>Team Chairman</b>
<b>Cheri Spencer</b> (301) 403-8100	<b>BMP Center of Excellence</b> College Park, MD	<b>Technical Writer</b>

### **Team 1**

<b>Larry Robertson</b> (812) 854-5336	<b>Naval Surface Warfare Center</b> Crane, IN	<b>Team Leader</b>
<b>Nick Keller</b> (812) 854-5331	<b>Naval Surface Warfare Center</b> Crane, IN	

### **Team 2**

<b>Rick Purcell</b> (301) 403-8100	<b>BMP Center of Excellence</b> College Park, MD	<b>Team Leader</b>
<b>Larry Halbig</b> (317) 306-3838	<b>Raytheon Indianapolis</b> Indianapolis, IN	

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# Appendix C

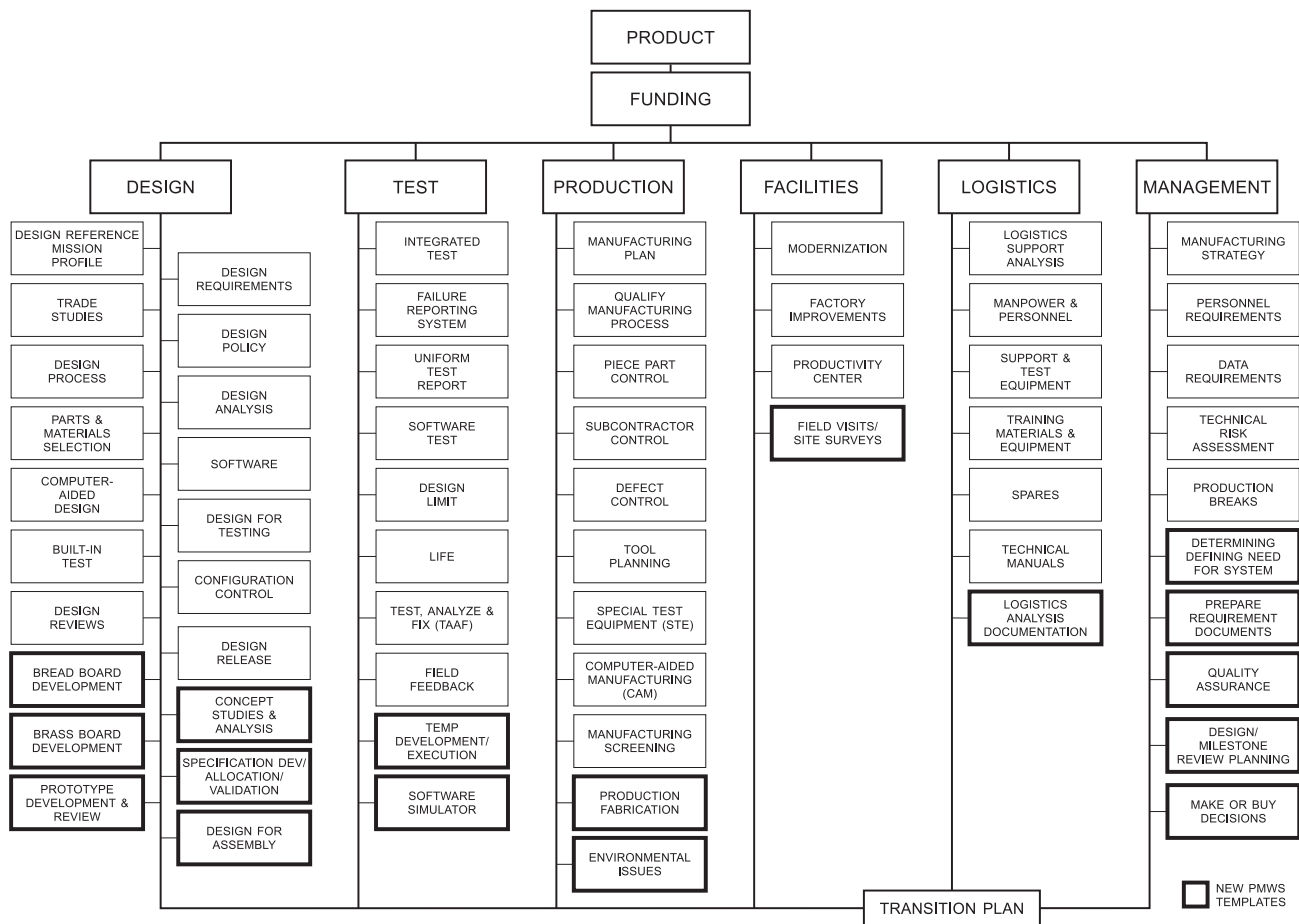
## Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools— or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition

process by addressing it as an *industrial* process that focuses on the product’s design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

### “CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



# Appendix D

## ***BMPnet and the Program Manager's WorkStation***

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The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at <http://www.bmpcoe.org>), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.

PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.

**KnowHow** is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

**SpecRite** is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition person-

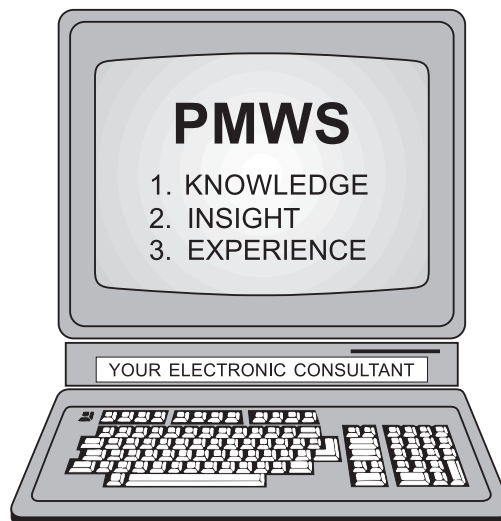
nel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

**TRIMS**, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been

observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at <http://www.bmpcoe.org>. To receive a user/e-mail account on the BMPnet, send a request to [helpdesk@bmpcoe.org](mailto:helpdesk@bmpcoe.org).



# Appendix E

## ***Best Manufacturing Practices Satellite Centers***

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There are currently seven Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The seven BMP satellite centers include:

### **California**

#### **Chris Matzke**

BMP Satellite Center Manager  
Naval Warfare Assessment Division  
Code QA-21, P.O. Box 5000  
Corona, CA 91718-5000  
(909) 273-4992  
FAX: (909) 273-4123  
cmatzke@bmpcoe.org

#### **Jack Tamargo**

BMP Satellite Center Manager  
257 Cottonwood Drive  
Vallejo, CA 94591  
(707) 642-4267  
FAX: (707) 642-4267  
jtamargo@bmpcoe.org

### **District of Columbia**

#### **Margaret Cahill**

BMP Satellite Center Manager  
U.S. Department of Commerce  
14th Street & Constitution Avenue, NW  
Room 3876 BXA  
Washington, DC 20230  
(202) 482-8226/3795  
FAX: (202) 482-5650  
mcahill@bxa.doc.gov

### **Illinois**

#### **Thomas Clark**

BMP Satellite Center Manager  
Rock Valley College  
3301 North Mulford Road  
Rockford, IL 61114  
(815) 654-5515  
FAX: (815) 654-4459  
adme3tc@rvcux1.rvc.cc.il.us

### **Michigan**

#### **Maureen H. Reilly**

SAE/BMP Satellite Center Manager  
3001 W. Big Beaver Road, Suite 320  
Troy, MI 48084-3174  
(724) 772-8564  
FAX: (724) 776-0243  
reilly@sae.org

#### **Roy T. Trent**

SAE/BMP Automotive Manufacturing Initiative  
Manager  
3001 W. Big Beaver Road, Suite 320  
Troy, MI 48084-3174  
(248) 652-8461  
FAX: (248) 652-8662  
boulder@ees.eesc.com

### **Pennsylvania**

#### **Sherrie Snyder**

BMP Satellite Center Manager  
MANTEC, Inc.  
P.O. Box 5046  
York, PA 17405  
(717) 843-5054, ext. 225  
FAX: (717) 854-0087  
snyderss@mantec.org

### **Tennessee**

#### **Tammy Graham**

BMP Satellite Center Manager  
Lockheed Martin Energy Systems  
P.O. Box 2009, Bldg. 9737  
M/S 8091  
Oak Ridge, TN 37831-8091  
(423) 576-5532  
FAX: (423) 574-2000  
tgraham@bmpcoe.org

# Appendix F

## *Navy Manufacturing Technology Centers of Excellence*

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The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

### **Best Manufacturing Practices Center of Excellence**

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:  
Mr. Ernie Renner  
Best Manufacturing Practices Center of Excellence  
4321 Hartwick Road  
Suite 400  
College Park, MD 20740  
(301) 403-8100  
FAX: (301) 403-8180  
ernie@bmpcoe.org

### **Center of Excellence for Composites Manufacturing Technology**

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:  
Dr. Roger Fountain  
Center of Excellence for Composites Manufacturing Technology  
103 Trade Zone Drive  
Suite 26C  
West Columbia, SC 29170  
(803) 822-3705  
FAX: (803) 822-3730  
rfglcc@glcc.org

### **Electronics Manufacturing Productivity Facility**

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:  
Mr. Alan Criswell  
Electronics Manufacturing Productivity Facility  
Plymouth Executive Campus  
Bldg 630, Suite 100  
630 West Germantown Pike  
Plymouth Meeting, PA 19462  
(610) 832-8800  
FAX: (610) 832-8810  
<http://www.engriupui.edu/empf/>

### **National Center for Excellence in Metalworking Technology**

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve

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manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:

Mr. Richard Henry  
National Center for Excellence in Metalworking  
Technology  
1450 Scalp Avenue  
Johnstown, PA 15904-3374  
(814) 269-2532  
FAX: (814) 269-2799  
henry@ctc.com

### **Navy Joining Center**

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:

Mr. David P. Edmonds  
Navy Joining Center  
1100 Kinnear Road  
Columbus, OH 43212-1161  
(614) 487-5825  
FAX: (614) 486-9528  
dave\_edmonds@ewi.org

### **Energetics Manufacturing Technology Center**

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:

Mr. John Brough  
Energetics Manufacturing Technology Center  
Indian Head Division  
Naval Surface Warfare Center  
Indian Head, MD 20640-5035  
(301) 743-4417  
DSN: 354-4417  
FAX: (301) 743-4187  
mt@command.nosih.sea06.navy.mil

### **Manufacturing Science and Advanced Materials Processing Institute**

The Manufacturing Science and Advanced Materials Processing Institute (MS&AMPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&AMPI:

Mr. Henry Watson  
Manufacturing Science and Advanced Materials  
Processing Institute  
ARL Penn State  
P.O. Box 30  
State College, PA 16804-0030  
(814) 865-6345  
FAX: (814) 863-1183  
hew2@psu.edu

- **National Center for Advanced Drivetrain Technologies**

The NCADT supports DoD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

Point of Contact for NCADT:

Dr. Suren Rao  
NCADT/Drivetrain Center  
ARL Penn State  
P.O. Box 30  
State College, PA 16804-0030  
(814) 865-3537  
FAX: (814) 863-6185  
[http://www.arl.psu.edu/drivetrain\\_center.html](http://www.arl.psu.edu/drivetrain_center.html)

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- **Surface Engineering Manufacturing Technology Center**

The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

Point of Contact for SEMTC:  
Dr. Maurice F. Amateau  
SEMTC/Surface Engineering Center  
P.O. Box 30  
State College, PA 16804-0030  
(814) 863-4214  
FAX: (814) 863-0006  
[http://www.arl.psu.edu/divisions/arl\\_org.html](http://www.arl.psu.edu/divisions/arl_org.html)

- **Laser Applications Research Center**

The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

Point of Contact for LaserARC:  
Mr. Paul Denney  
Laser Center  
ARL Penn State  
P.O. Box 30  
State College, PA 16804-0030  
(814) 865-2934  
FAX: (814) 863-1183  
[http://www.arl.psu.edu/divisions/arl\\_org.html](http://www.arl.psu.edu/divisions/arl_org.html)

**Gulf Coast Region Maritime Technology Center**

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:  
Dr. John Crisp  
Gulf Coast Region Maritime Technology Center  
University of New Orleans  
Room N-212  
New Orleans, LA 70148  
(504) 286-3871  
FAX: (504) 286-3898

# Appendix G

## *Completed Surveys*

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As of this publication, 101 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program  
4321 Hartwick Rd., Suite 400  
College Park, MD 20740  
Attn: Mr. Ernie Renner, Director  
Telephone: 1-800-789-4267  
FAX: (301) 403-8180  
ernie@bmpcoe.org

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<b>1985</b>	Litton Guidance & Control Systems Division - Woodland Hills, CA
<b>1986</b>	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
<b>1987</b>	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
<b>1988</b>	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C <sup>3</sup> Systems Sector - Needham Heights, MA
<b>1989</b>	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
<b>1990</b>	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

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- 1991**      *Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA  
Norden Systems, Inc. - Norwalk, CT  
Naval Avionics Center - Indianapolis, IN  
United Electric Controls - Watertown, MA  
Kurt Manufacturing Co. - Minneapolis, MN  
MagneTek Defense Systems - Anaheim, CA  
Raytheon Missile Systems Division - Andover, MA  
AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ  
*Resurvey of Texas Instruments Defense Systems & Electronics Group* - Lewisville, TX
- 
- 1992**      Tandem Computers - Cupertino, CA  
Charleston Naval Shipyard - Charleston, SC  
Conax Florida Corporation - St. Petersburg, FL  
Texas Instruments Semiconductor Group Military Products - Midland, TX  
Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA  
Watervliet U.S. Army Arsenal - Watervliet, NY  
Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA  
Computing Devices International - Minneapolis, MN  
*(Resurvey of Control Data Corporation Government Systems Division)*  
Naval Aviation Depot Naval Air Station - Pensacola, FL
- 
- 1993**      NASA Marshall Space Flight Center - Huntsville, AL  
Naval Aviation Depot Naval Air Station - Jacksonville, FL  
Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN  
McDonnell Douglas Aerospace - Huntington Beach, CA  
Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY  
Philadelphia Naval Shipyard - Philadelphia, PA  
R. J. Reynolds Tobacco Company - Winston-Salem, NC  
Crystal Gateway Marriott Hotel - Arlington, VA  
Hamilton Standard Electronic Manufacturing Facility - Farmington, CT  
Alpha Industries, Inc. - Methuen, MA
- 
- 1994**      Harris Semiconductor - Melbourne, FL  
United Defense, L.P. Ground Systems Division - San Jose, CA  
Naval Undersea Warfare Center Division Keyport - Keyport, WA  
Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA  
Kaiser Electronics - San Jose, CA  
U.S. Army Combat Systems Test Activity - Aberdeen, MD  
Stafford County Public Schools - Stafford County, VA
- 
- 1995**      Sandia National Laboratories - Albuquerque, NM  
Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA  
*(Resurvey of Rockwell International Corporation Collins Defense Communications)*  
Lockheed Martin Electronics & Missiles - Orlando, FL  
McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO  
*(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)*  
Dayton Parts, Inc. - Harrisburg, PA  
Wainwright Industries - St. Peters, MO  
Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX  
*(Resurvey of General Dynamics Fort Worth Division)*  
Lockheed Martin Government Electronic Systems - Moorestown, NJ  
Sacramento Manufacturing and Services Division - Sacramento, CA  
JLG Industries, Inc. - McConnellsburg, PA
- 
- 1996**      City of Chattanooga - Chattanooga, TN  
Mason & Hanger Corporation - Pantex Plant - Amarillo, TX  
Nascote Industries, Inc. - Nashville, IL  
Weirton Steel Corporation - Weirton, WV  
NASA Kennedy Space Center - Cape Canaveral, FL  
Department of Energy, Oak Ridge Operations - Oak Ridge, TN

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**1997**

Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL  
SAE International and Performance Review Institute - Warrendale, PA  
Polaroid Corporation - Waltham, MA  
Cincinnati Milacron, Inc. - Cincinnati, OH  
Lawrence Livermore National Laboratory - Livermore, CA  
Sharretts Plating Company, Inc. - Emigsville, PA  
Thermacore, Inc. - Lancaster, PA  
Rock Island Arsenal - Rock Island, IL  
Northrop Grumman Corporation - El Segundo, CA  
*(Resurvey of Northrop Corporation Aircraft Division)*  
Letterkenny Army Depot - Chambersburg, PA  
Elizabethtown College - Elizabethtown, PA  
Tooele Army Depot - Tooele, UT

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**1998**

United Electric Controls - Watertown, MA