REPORT OF SURVEY CONDUCTED AT

HEWLETT-PACKARD
PALO ALTO FABRICATION CENTER

PALO ALTO, CALIFORNIA

JUNE 1992

BEST MANUFACTURING PRACTICES

Center of Excellence for Best Manufacturing Practices
DoD 4245.7 – M
“TRANSITION FROM DEVELOPMENT TO PRODUCTION”

CRITICAL PATH TEMPLATES

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- TRADE STUDIES
- DESIGN PROCESS
- PARTS & MATERIALS SELECTION
- COMPUTER-AIDED DESIGN
- BUILT-IN TEST
- DESIGN REVIEWS

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- DESIGN REQUIREMENT
- DESIGN POLICY
- DESIGN ANALYSIS
- SOFTWARE
- DESIGN FOR TESTING
- CONFIGURATION CONTROL
- DESIGN RELEASE

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- FAILURE REPORTING SYSTEM
- UNIFORM TEST REPORT
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- DESIGN LIMIT
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- SPECIAL TEST EQUIPMENT (STE)
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SECTION 1
EXECUTIVE SUMMARY

1.1 BACKGROUND

The Best Manufacturing Practices (BMP) team conducted a survey at Hewlett-Packard (HP) Palo Alto Fabrication Center (PAFC), in Palo Alto, California. The purpose of the PAFC survey was to review and document its best practices and investigate any potential industry-wide problems. The BMP program will use this documentation as an initial step in a voluntary technology sharing process among the industry and government.

1.2 BEST PRACTICES

The best practices documented at HP PAFC are detailed in this report. These topics include:

- **Sheetmetal Work Order Management** Page 6
  PAFC’s fabrication shop uses an internally-developed software package to manage sheetmetal work orders.

- **Integration of Prototype Build with Production** Page 7
  HP has integrated prototype construction with its production line that has led to a reduced prototype turnaround time.

- **Interoperability of Tools, Tasks, and Computing Environment** Page 7
  PAFC has developed the ability to download a product design and develop the fabrication process, process tooling, and NC programming through CAD/CAM software.

- **Hazardous Waste Minimization Program** Page 8
  PAFC developed a hazardous waste minimization program as a result of the California Hazardous Source Reduction and Management Act of 1989.

- **Shop Safety Program** Page 8
  PAFC’s shop safety program exceeds the corporate and OSHA guidelines for environmental health and safety.

- **Machining and Finishing of Die Cast Parts** Page 8
  PAFC has established and refined a modified Kanban cell for finish-machining front and rear die cast frames.

- **JIT Manufacturing Cell** Page 9
  By instituting a JIT manufacturing cell for two electronic chassis assembly product lines, PAFC has detected production errors early in the process, and significantly reduced the chassis assembly time.

- **Supplier Certification** Page 9
  PAFC uses a supplier program based on internal benchmarking.
Corporate Values and the Hewlett-Packard Way

HP corporate values have become the basis for defining corporate objectives which provide the basis for the decision-making process at HP.

Business Planning Process

Using the HP corporate objectives and values, PAFC has developed a five-step formal planning process.

Internal Communication

HP PAFC uses a variety of methods to support its efforts at communication with its employees. This effort provides for enhanced two-way communication.

Technology, Quality, Responsiveness, Delivery, and Cost Report

PAFC sends a monthly report to its customers that indicates its performance in each of these critical areas.

Window Analysis

HP uses an analysis tool that helps identify the variance between an actual process and desired process and the means of optimizing the process.

1.3 INFORMATION

The following information items are detailed in this report:

- **Preliminary Cost Estimate**
  - Page 15
  - PAFC utilizes a cost estimating program to help prepare cost estimates for its customers.

- **Plastic Injection Molding**
  - Page 15
  - The problem of paint wearing off of letters and numbers on keys was eliminated by PAFC’s development of two-color molding.

- **Aluminum Die Casting, Trimming and Recycling**
  - Page 15
  - By standardizing processes and keeping lot quantities low, PAFC has been able to improve its yield rate in aluminum die casting to nearly 100%.

- **Leadership Development Survey**
  - Page 15
  - HP PAFC uses a leadership development survey to assist in supervisor leadership development.

- **Organizational Survey**
  - Page 16
  - Organizational survey at HP PAFC will be conducted every 15 months and will be used to determine organizational strengths and target areas for improvement.
SECTION 2

INTRODUCTION

2.1 SCOPE

The purpose of the Best Manufacturing Practices (BMP) survey conducted at Hewlett-Packard (HP) Palo Alto Fabrication Center (PAFC) was to identify best practices, review manufacturing problems, and document the results. The intent is to extend the use of progressive management techniques as well as high technology equipment and processes throughout industry and government facilities. The ultimate goal of the BMP program is to strengthen the U.S. industrial base and reduce the cost of defense systems by solving manufacturing problems and improving quality and reliability.

A team of engineers accepted an invitation from Hewlett-Packard to review the processes and techniques used in its facilities located in Palo Alto, California. Potential industry-wide problems were also reviewed and documented. The review was conducted at PAFC on 22-26 June 1992 by the team identified in Appendix B of this report.

The results of BMP surveys are entered into a database for dissemination through a central computer network. The actual exchange of detailed data will be between companies at their discretion.

The results of this survey should not be used to rate PAFC among other companies. A company’s willingness to participate in the BMP program and the survey results have no bearing on one company’s performance over another’s. The documentation in BMP reports is not intended to be all inclusive of the company’s best practices. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

2.2 SURVEY PROCESS

This survey was performed under the general survey guidelines established by the Department of the Navy. The survey concentrated on the functional areas of design, test, production, facilities, logistics, and management. The team evaluated PAFC’s policies, practices, and strategies in these areas. Furthermore, individual practices reviewed were categorized as they relate to the critical path templates of DoD 4245.7-M, “Transition from Development to Production.” PAFC identified potential best practices and industry-wide problems. These practices and other areas of interest were discussed, reviewed, and documented for distribution throughout the U.S. industrial base.

The format for this survey consisted of formal briefings and discussions on best practices and problems. Time was spent at PAFC reviewing practices, processes, and equipment. In-depth discussions were conducted to better understand and document the identified practices and problems.

2.3 NAVY CENTERS OF EXCELLENCE

Demonstrated industry-wide problems identified during the Best Manufacturing Practices surveys may be referred to one of the Navy Manufacturing Technology Centers of Excellence. They are identified in Appendix C.

2.4 COMPANY OVERVIEW

The Palo Alto Fabrication Center (PAFC) is located in Palo Alto, California and is a division of Hewlett-Packard (HP). With 285 employees located in a 200,000 square-foot facility, PAFC supports five main fabrication technologies. In the sheetmetal area, PAFC furnishes products for electronic instrumentation or test equipment. The plastic molding area produces a low volume of 200 to 2,000 parts per order for electronic instruments and test systems. A low volume production of 100 to 1,000 parts per order for mature or standard product platforms and electronic instruments is supported by the aluminum die casting and machining area. The cables area generates custom cables used in HP systems applications and in medical products. And the computer cabinet assembly area produces cabinets for the HP 1000 and HP 3000 systems.

The PAFC is one of several HP facilities that provides these services; consequently, it competes with these other internal divisions as well as outside sources for HP business.

2.5 ACKNOWLEDGMENTS

Special thanks are due to all the people at Hewlett-Packard Palo Alto Fabrication Center whose participation made this survey possible. In particular, the BMP program acknowledges the special efforts of Mr. David McLaughlin for enabling this survey to occur.

2.6 COMPANY POINT OF CONTACT

While the information included in this report is intended to be descriptive of the best practices and techniques ob-
served at PAFC, it is not intended to be all inclusive. It is anticipated that the reader will need more detailed data for true technology transfer.

The point of contact for this BMP survey is:

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3.1 TOTAL QUALITY MANAGEMENT

Process Teams for Sheetmetal Parts

In early 1991, a process team organization was established in the sheetmetal area of the fabrication shop at PAFC to enhance the individual pay-for-performance system. The process team organization was tasked to improve cross shift teamwork, create an environment which supports total quality control, and base individual reward on group success.

Four process teams were organized – flat parts (programming, punching, sanding, shearing); form parts (folding, drilling, stamping, welding, and various bench operations); riveting (inserting pins, nuts, labels); and painting/silk screening. Team performance was rated in the areas of productivity (per cent of standard), quality (number of parts returned), delivery (per cent of jobs on time), and rework (per cent of cost). Performance data was continuously gathered by the shop floor control system, and team results, which had been calculated and posted monthly, were also done weekly.

Under the new system, individual pay increases are linked to the success of the overall shop rather than the performance of any one individual or team. This feature was included in the system to ensure that teams would work together to achieve overall objectives. For example, individuals could be moved between teams to satisfy short term needs without concern about how it might affect their own performance ratings. The scoring system still encouraged competition between the teams.

After an initial three month adjustment period, a significant improvement in performance of all teams was achieved. In some cases, teams achieved a 30% improvement in overall performance over the past year.

3.2 DESIGN

COMPUTER-AIDED DESIGN

Worldwide Network and Shared-X

PAFC’s Worldwide Network and Shared-X capability supplies the framework for two or more network workstations to operate in a window as one workstation for limited functions.

Each HP facility has various distributed workstations and computer systems connected to THIN LAN hubs with the hubs connected to a THICK LAN backbone. Each facility’s backbone is linked to a wide area network which provides communication channels between facilities. Shared-X runs under X-WINDOWS which allows a window to be opened on a remote workstation. It also allows either of the workstations to control the cursor and either workstation user to type information in the window. The same information is consequently displayed on both workstations. For example, a typical Shared-X application would display an orthographic raster view of a part in question in the window on both workstations. The customer and PAFC discuss the problem area concurrently on the telephone while both are viewing the part and moving the cursor to highlight the areas of discussion.

Although Shared-X is a new product and performance improvement measurements are not yet available, the capability is expected to significantly reduce communication barriers between remote sites. This in turn will reduce prototyping build iterations and improve schedule performance.

3.3 PRODUCTION

MANUFACTURING PLAN

Customer Support

HP provides design support for product designs produced off-site by internal HP customers. The PAFC group is only one of several organizations in HP capable of providing this design support service, and these organizations compete for the various internal customers.

PAFC Customer Support and Site Engineering groups are dedicated to continuously improving cost, performance, and quality. The Center is achieving approximately 95% on-time prototype delivery to its customers, and that capacity is augmented through out-sourcing with certified suppliers. Customer interaction throughout the process is continually emphasized with Design for Manufacturability (DFM) considered a crucial element. In addition to DFM, customer support and site engineering provides preliminary costing, new part introduction, fabrication process development,
process tooling, and NC Programming. Enhanced computer system and application interoperability has provided efficient process execution for many of the Center’s functions. Support and site engineering provides the bridge for the transitioning of prototype developments into production.

**PIECE PART CONTROL**

**Electric Arc Metal Spray Painting**

The PAFC Fabrication Shop has developed an electric arc metal spray painting procedure to provide an internal metal coating for electro-magnetic interference shielding, radio-frequency interference protection, or electrical grounding. This metal coating is required on many of the plastic cases such as computer cabinets that are produced by the Fabrication Shop. The electric arc spray process provides performance improvements over the previously used flame spraying system.

The metal attaches to the surface by a mechanical bond. Prior to metal spraying, molded plastic parts are masked and abrasive-blasted to provide a rough surface for better adhesion of the metal. In the paint spray booth, parts are loaded into a rotary fixture which allows access to the part and required masking. The gun is fed current carrying wire from two coils. The arcing between the two wires vaporizes the metal. Due to the heat of the metal as it is applied, the operator exercises caution to avoid damaging the part. The spray gun is continuously moved at a range of almost six inches to eight inches from the part. A curtain of oil cycles behind the work area to trap overspray. Because of the hazardous nature of the metal vapor generated by the process, the operator wears a protective helmet into which outside air is pumped.

This simple yet highly effective system provides greater bonding strength than many alternative methods, and the firm bonding of metal particles to each other prevents chipping. In addition, a wide variety of metals such as zinc, copper, and brass can be applied.

**Standard Parts: System II Electronics Cases**

Hewlett-Packard established a corporate standard for modular electronics cabinets (Figure 3-1) in an effort to reduce production costs and create style consistency. This standardization permits construction of many different case sizes and configurations from a common set of part geometries. Standard accessory kits are designed to a range of cabinet configurations such as carrying handles, rack drawers, and sliders. This approach has resulted in quicker time to market and reduced costs for new product research, development, and manufacture.

The standard System II electronics cabinet is designed to fit into Electronic Industries Association 19-inch standard racks. Cabinets offer standard increments of height, width, and depth. Quarter, half-size modules, and/or spacers can be grouped to occupy a standard rack width. Most new electronics products can be developed to fit in one of the existing modular cases. Standard components in the modular system include die cast frame elements and handles, sheetmetal case covers and front panels, gaskets, and fasteners.

Two dimensional drawings, solid models, and technical specification data for the cabinets and their components are maintained on-line in electronic format at PAFC. Design engineers at remote facilities can establish accounts and download the latest versions of technical data for cabinets when new products are developed. A file transfer protocol is used to move design files over the network, and a document holders list is maintained so that users may be notified when specifications are changed.

This standard approach to cabinet design has many benefits. Redundant work by design engineers is virtually eliminated. Often custom cabinets can be developed with only minor modification of existing designs. Manufacturing processes are well-defined for all standard parts, thereby avoiding unforeseen problems at production time. Support data can be repeatedly used by the Fabrication Shop. For example, flat layout patterns for front panels can be quickly modified for new configurations. The system is evolving with the addition of new software capabilities. Changes underway are the incorporation of a Part Data Management system which controls revisions, releases, and data definitions.

**Sheetmetal Work Order Management**

PAFC’s Fabrication Shop uses an internally-developed software package called POLYWOG to manage sheetmetal work orders. The software package analyzes job priority and setup information to create an optimum work order processing sequence. In minutes, this system creates a grouping that used to require several hours manually.

The work order grouping process is initiated with the downloading of the next 20 hours of work for each machine from the shop floor control system. The POLYWOG system sequences work orders based on their priority and minimizing tool changes. For example, a work order grouping which is generated for an NC punch press identifies the initial set of tooling that is currently on the machine; the sequence of jobs to be run across the machine; the tool changes required for each job; the material required for each job; and the standard setup and run times for the job.

The report hard copy printout is provided to the machine operator, the tool crib, and material support staff. The tool
crib ensures that the next several hours of punches are preset and ready for loading at the machine. Material support staff pull sheet stock and stack it in the order it will be used at the machine. Most of the sheet stock used by the shop is purchased from the vendor in a standard 48-inch by 48-inch configuration. This standardization further minimizes setup changes which are required between jobs. A copy of the work order grouping information is attached to each job set of sheet stock in the stack.

Other features of the system include networked computer terminals at each machine tool. The terminals are used by machine operators to update the status of individual jobs. The system also permits the automatic resequencing of any jobs which are not currently in process at any time. The sheetmetal work order management system has significantly improved the flow of work through the sheetmetal shop and reduced the time required for tool changes on the NC machines.

Integration of Prototype Build with Production

Hewlett-Packard integrated prototype construction with its production line at the PAFC that has led to a reduced prototype turnaround time. Prior to integration, HP used the traditional model shop method of building prototypes. Model makers received a prototype drawing and – using their skill and ingenuity – developed the prototype. This approach required the dedication of equipment, facilities, and personnel solely for prototype development (a functional unit), while not always yielding an economically producible item in a production environment.
PAFC decided to close the model shop, and prototype construction was integrated with the production line. The prototype request is now received at the Palo Alto facility and reviewed by manufacturing engineering personnel. Producibility issues are identified and resolved, process plans developed, tooling manufactured, and the prototype made using the same processes and equipment as the eventual production run – if initiated.

Prototypes are identified on the shop floor by highly visible color coded cones. These colors also indicate the order in which the prototypes are to be worked. When a machine operator finishes an operation on an existing order, he checks the incoming job rack for a prototype order and works on it. If one is there, it is the next job worked on. If one is not available, the next production job is set up and run. Using this system, prototypes receive priority at each operation.

Using this integrated system, PAFC is able to identify and address producibility issues prior to production build. In addition, piece part processes are developed and proven prior to production build. Tooling and NC programs are also proven out before production. Dual facilities and equipment are no longer required.

**COMPUTER-AIDED MANUFACTURING**

Interoperability of Tools, Tasks, and Computing Environment

PAFC continually strives for enhanced cost, performance, and quality for its internal customers. One means of achieving this goal is the ability to download a product design and develop the fabrication process, process tooling, and NC programming through CAD/CAM software. The internal customer develops the product design and forwards a request for a preliminary cost estimate and/or prototype build. This request is made by E-Mail to the Customer Support Engineer (CE) at PAFC. The CE downloads the customer’s three-dimensional sheetmetal body and/or two-dimensional orthographic layout files in the local system. The CE displays and reviews the graphics information for completeness and for DFM. Discrepancies and producibility issues are addressed with the customer before continuing the process.

Both the customer and PAFC CE use the ME-30 three dimensional and ME-10 two-dimensional (subset of ME-30) mechanical design application software packages. The software runs on HP-9000, 300 and 400 Series workstations under HP-UX (HP’s UNIX operating system). The workstations are connected through a cadre of worldwide client/server networks. E-Mail appears in a window on the workstations and graphic files are transferred using File Transfer Protocol.

After the initial screening of the product design data and order placement, the generation of data for the prototype build process begins. The ME-30 product graphic files are translated into IGES and then into Merry Mechanization’s SMP-81 application software. The SMP-81 package integrates the three-dimensional sheetmetal body unfolding into a flat pattern, the automatic dimensioning of the flat pattern, and the generating of NC data process steps. SMP-81 FORM allows the CE to identify the surfaces to be unfolded. Part thickness, top surface, and features to be suppressed are digitized while in FORM. SMP-81 Flat View then unfolds the three-dimensional sheetmetal body and dimensions the flat pattern. SMP-81 NC TAPE scans the flat pattern database and matches recognizable shapes to the Tool Data Files/Database. The flat pattern and NC punch program are graphically viewed by the NC Programmer. Modifications can then be made to the NC punch coordinates by the programmer. When acceptable, the NC data file and tooling setup files are generated. Upon request, the NC data and tooling information are downloaded to NC punch press equipment.

Between 30% to 40% of the sheetmetal prototypes use the CAD/CAM three-dimensional sheetmetal body process. The impact of this process is a 10-times reduction in process development time over a process using paper designs. Although PAFC encourages its customers to develop the designs using three-dimension modeling, it also has a two-dimensional orthographic process using the ME-10 graphics software. Between 60% to 70% of the prototypes currently use the two-dimensional process. Some paper is developed between CAD and CAM in the two-dimensional process.

**3.4 FACILITIES**

**FACTORY IMPROVEMENTS**

**Hazardous Waste Minimization Program**

As a result of the California Hazardous Source Reduction and Management Review Act of 1989, PAFC developed a hazardous waste minimization program to promote reduction of hazardous waste at its source; encourage recycling of waste that cannot be reduced at its source; and promote handling practices that minimize environmental threats. The PAFC Fabrication Shop prepared two reports required by the Act – a Source Reduction Plan and a Hazardous Waste Management Performance Report.

Hazardous wastes generated by the Fabrication Shop encompass waste water and oil, waste paint, aluminum and steel dust, waste trichloroethane, zinc sludge, paint booth sludge, aluminum and mineral oil (Figure 3-2). (Water-
Hazardous waste source reductions at PAFC include changes in raw materials, operational improvements, changes in production processes, and product reformulations (Figure 3-3). Hazardous waste reduction actions which have been taken as a result of the program include installation of level controls in spray paint booths, recycling of Trimsol and machine oil, installation of sludge separators in paint booths, development of a chemical management program, elimination of a Brite Dip etch process, changing of Brite Dip chemicals, recycling aluminum dust, and degreasers removal.

The Hazardous Waste Minimization Program has achieved a 69% reduction in quantity and 73% reduction in cost of hazardous waste disposal from 1987 to 1991. The program is continuing to investigate new methods of reducing waste and monitoring the introduction of new processes which generate hazardous waste streams.

Shop Safety Program

PAFC has established a strong safety program which exceeds both corporate and OSHA guidelines for environmental health and safety. Examples of aspects of the safety program include additional safety guards on machine tools; elimination or minimization of many hazardous materials; daily operator safety checks on all machines; monthly preventive maintenance checks on hoists; monthly self-inspection of work areas by staff from the area and non-work area staff; monthly staff safety meetings; standard safety forms to record action items; and cross-trained emergency response teams. Standard safety issue forms identify the safety discrepancy, the priority of the safety item, ownership responsibility, and the date that it was completed. This progressive safety program is proactive and as a result, very few serious accidents have occurred at the PAFC facility.
Machining and Finishing of Die Cast Parts

A modified Kanban cell was established at the PAFC for finish-machining front and rear die cast frames. The cell has significantly reduced finished parts turnaround time, costs, and scrap and rework. Prior to creating this cell, personnel pulled basic die cast frames from stock on a lot basis, and individual machines, jigs, and fixtures were set up for the particular part being machined. The entire lot was then processed through machining and finishing. This approach led to high inventory, WIP, and rework costs if defective castings were found late in the processing cycle. The procedure was followed for all parts produced from castings.

The modified Kanban cell includes sanding machines and a specialized transfer machine capable of performing all required drilling and tapping on the different processed frame types. The transfer machine, designed and built by PAFC personnel, includes 15 stations. Pre-processing and post-processing equipment has been moved into the immediate area, and the cell is self-contained with the exception of plating and painting.

Rearranging the operational sequence also allowed for early detection of defective die castings before additional labor costs were incurred, thereby reducing rework. Each operation was studied for work content and processing time. When the pacing operation or constraint was found, that operation was improved to bring the line into balance. The cell is currently operated by seven personnel, and all different frames can be processed through the same cell. Final machined parts are degreased, cleaned, and immediately forwarded to the paint operation for final finishing. The painting, drying, and baking operation is conveyorized at a controlled rate and allows finished parts to be packaged as they come off the paint line. Disposable corrugated cardboard inserts are used on the painting trays to minimize rack clean-up and reduce hazardous material disposal.

PAFC has realized dramatic results by implementing this cell. Changeover or setup time from one frame type to another has been reduced from two or three hours to five minutes each. Productivity has increased from 22 parts per hour to 100 parts per hour, and rework costs have been greatly reduced. A true pull system for manufacturing has also been developed.

PRODUCTIVITY CENTER

JIT Manufacturing Cell

HP PAFC developed and instituted a JIT manufacturing cell on two of its Electronic Chassis Assembly product lines. Knowing that customer needs for these assemblies varied daily and that turnaround time was critical, HP devised a method of satisfying these needs in the shortest possible time. One chassis assembly contained 34 separate parts, the other 155 separate parts, and throughput in the factory of any one component could require up to 30 days. Assembly time would add two or three days.

HP organized a JIT cell which guaranteed same-day delivery of either of the assemblies. PAFC initially produced a 28-30 day inventory of each of the individual piece parts. These parts were stored in the final assembly area and the assemblies were built as needed. A month-end inventory of the piece parts is now conducted and replenishment orders are initiated for inventory replacement. Punched blanks are delivered to the cell where final forming, riveting, and gasketing operations are performed along with the final assembly. Off-line operations such as welding and screening are coordinated by the cell operators.

The cell is operated by two people who are cross-trained to perform any of the required operations. The cell operators decide what needs to be done each day and who is going to do it. They maintain an inventory of anticipated daily delivery requirements and keep the subassembly inventory in balance.

Quality programs with the piece parts have been virtually eliminated as the cell operators are responsible for piece part fabrication through final assembly. By carrying low inventory, any production errors that may occur are caught early and do not affect delivery of final chassis assemblies. Delivery time of completed chassis assemblies has been reduced to two hours.

3.5 LOGISTICS

LOGISTICS SUPPORT ANALYSIS

Supplier Certification

HP PAFC’s Business, Technology, Quality, Responsiveness, Delivery and Cost (BTQRDC) program outlines the objectives of the company’s supplier certification. The goal of this program is to help suppliers understand how HP procurement personnel source, select, and monitor the performance of fabricated parts used in its products. Suppliers are selected through a benchmarking process, and those selected suppliers commit to a program of continuous improvement in product quality and reliability, improved customer service, and an accelerated new product introduction schedule. HP offers the preferred supplier the opportunity and techniques to develop and effectively manage its area based on experience gained through a working relationship with Hewlett-Packard. HP also requires preferred suppliers to complete an environmental questionnaire and comply with EPA guidelines.
PAFC has baselined and benchmarked its own internal sheetmetal, plastic molding and die casting processes. The baseline is used to benchmark HP’s suppliers and each supplier is rated against the six BTQRDC categories. Categories receiving high scores are investigated for best practices, and categories receiving low scores are identified for improvements. The rating system uses weighted scores with a maximum obtainable score of 460 points.

Supplier certification reflects HP’s commitment to a continuous, long term development partnership with its selected suppliers. The expected benefits are high quality supplier parts that are delivered on-time to HP at optimal cost. Although the supplier certification is a new program, the procedures, performance matrix, and certification process have been defined and are being executed. The HP supplier certification process is diagrammed in Figure 3-4.
MANUFACTURING STRATEGY

Corporate Values and the Hewlett-Packard Way

HP has developed and defined its own set of organizational values and corporate objectives. These basic values and objectives have come to be known as the HP Way. These values serve as the basis for meeting corporate objectives which are the foundation for the business decision process at HP.

There are five underlying organizational values that guide HP in working toward common objectives for the corporation.

- Respect for individuals
- Focus on a high level of achievement and contribution in HP products and services, and in the performance of its personnel
- An uncompromising commitment to integrity
- The achievement of common objectives through teamwork
- The encouragement of flexibility and innovation

These values underlie the company’s common objectives which focus on profit, customers, technical fields of interest, growth, employees, management, and citizenship. Core values define the company’s relationship to its customers and its employees. HP maintains that the central purpose of its business is to satisfy real customer needs and that those needs can be satisfied only with the active participation and dedication of everyone in the company. This drives the company’s commitment to quality and to its employees. HP places great value on the individual employee and focuses on providing employment security based on performance, recognition, and sharing in the company’s growth and profitability. A key objective is profitability that is reinvested in the company to provide self-financed growth. Fields of interest are chosen to build upon the company’s technological strengths and the customer base to provide a steady flow of new products to existing markets as well as expansion into new markets. Other objectives include emphasis on individual initiative and creativity, and citizenship within the community.

These values and objectives are more than abstract ideas at HP. They are an integral part of the culture and business processes and are clearly evident in daily activities. They have built a sense of teamwork and commitment that enables the company to adapt successfully to the rapid changes it is experiencing in technology and the marketplace.

Business Planning Process

The planning process at PAFC is based on the HP corporate objectives and values. Using these as a foundation, PAFC has developed a formal planning process to inject these principles into strategic business planning. In January 1992, the management staff met to discuss changes for the future and derive a set of values. They developed 12 PAFC operating values, and these values serve as a set of beliefs to guide actions and provide a set of shared expectations for all facility personnel.

With the operating values as a framework, the management team developed two or three key objectives. These objectives focus attention on the areas that PAFC needs to emphasize to be successful. Current key objectives are concerned with quality, responsiveness, and management. An organizational alignment process is applied to ensure that the organization is structured properly to best achieve the objectives. Department plans are developed and implemented. Progress is tracked by a formal quarterly review process both at the department and facility levels.

PAFC uses a five step process for developing business strategy. The process is applied separately in each of the major technological areas in which the facility operates. These steps involve the following:

1. The process begins by making a determination of who the customers are and what are their needs. Key customers are called “stakeholders.” The stakeholders are all internal HP organizations who are involved throughout the process and who participate actively in reviewing and defining the business strategy. As part of determining the stakeholders and their needs, the process helps define what is strategic for the stakeholders and provides them a competitive advantage.

2. The customer’s necessary products and services are then determined by assessing current and future impact of the particular technology on the customer’s business and which products or services within the technology provide key competitive advantages.

3. Similar businesses are benchmarked. The companies to benchmark are often determined by the customer. Both internal and external suppliers are benchmarked using the customer’s key competitive advantage business factors. Needs identified through benchmarking are mapped to existing business strategies. Benchmarking by PAFC is used as a tool to determine if the facility should continue to function as an internal supplier for the technology, or if HP would be better served by an external supplier.

4. The fourth step is to understand the financial implications. This involves an analysis of the cost advantages
to HP divisions of alternative business strategies, barriers of exit and entry, and investment needed to support alternative strategies. A major difference here from previous planning methods is that the focus is on value added to HP rather than the objective of keeping work in house and people employed at PAFC. This effort is successful because of HP’s commitment to its people in providing alternative employment options if their jobs are threatened by elimination of a technology or product line.

5. Step five is the analysis of potential problems such as the risk of divestiture if it is determined that the business area should be eliminated. This is a critical decision because once eliminated, the cost of re-entry will usually be prohibitive.

At the completion of this process, recommendations are made to the stakeholders by business area. Each recommendation is expressed in terms of a business value proposition that defines value added minus the price of obtaining it. A plan is provided for the required investment or the purchase of products and services with specific objectives over a three-year period. A first year tactical plan is developed which includes a technology plan, resource plan, and if necessary, an outsourcing plan. If it is determined that an external supplier is the best source, PAFC will often provide best value by serving as a virtual source by managing the purchase of the products or services from the external supplier.

The strategy and recommendations are reviewed by the stakeholders and the decision is made to implement or re-evaluate. The most unique aspect of this process is that the strategy may require eliminating a business area for PAFC. Because of HP’s strong guiding objectives and values, this process provides a strategy that is best for HP while protecting the employment of those involved. It supports the growth and profitability of the company and often provides new opportunities for growth and development for employees.

PERSONNEL REQUIREMENTS

Internal Communication

Effective internal communication is a key element at PAFC to ensure employees remain motivated and directly involved in the company’s success. Successful communication with all employees requires several efforts and approaches to guarantee that both macro and micro views of the company are provided to employees in a timely and effective manner. This communication must take the form of both broad overviews of company direction and well being, and also show the individual employee’s role and importance.

Hewlett-Packard uses several means to accomplish this goal including:

Twice yearly CEO addresses. Twice a year the CEO conducts a live broadcast to all HP employees presenting a business report on the company’s performance and announcing the employee bonus. All employees are awarded a bonus as a percentage of their regular salary. This bonus is the same percentage for all employees from the CEO to production floor workers and is based on the semi-annual performance of the company as communicated by the CEO.

Monthly pep rally. A monthly pep rally is held for all site employees and is hosted by the operations manager who provides all employees with an overview of the site’s accomplishments, problems and future direction. He fields questions and provides recognition. Other information of a general interest is also disseminated.

Monthly forum. A monthly forum is used to provide a common meeting ground of all site supervisors and managers. This management team is strengthened because of the idea sharing and problem solving techniques fostered by this gathering. These meetings help eliminate group boundaries, promote teamwork, and improve morale.

Weekly work group. A weekly work group meeting is scheduled to discuss all material relevant to the individual work group.

Newsletter. A bi-monthly newsletter is published to disseminate administrative information to all employees.

Bulletin boards. Bulletin boards are centrally located to provide information on company current events, recognition, new policies and guidelines, available training programs, and local community job opportunities.

Organizational survey. An organizational survey is conducted to facilitate two-way communication.

Leadership survey. A leadership development survey is conducted to facilitate supervisor/employee communication.

This HP approach has enabled the company to demonstrate adherence to its stated values of trust and respect for the individual; focus on a high level of achievement and contribution; and achieve common objectives through teamwork by providing continuous two-way communication that provides employees with an assessment of the company’s accomplishments and future direction. It also enables the employee to communicate his concerns and critique his supervisor’s efforts.
DATA REQUIREMENTS

Technology, Quality, Responsiveness, Delivery, and Cost Report

PAFC initiated a formal monthly report to all its customers to report on the facility’s monthly performance in the areas of technology, quality, responsiveness, delivery, and cost (TQRDC). PAFC originally received the TQRDC report from its customers; as many as 30 of these reports would be received monthly. As a result, considerable time would be spent combining and using the information to generate improvements. PAFC felt it could better serve its customers if it originated the report and supplied the information to the customer. This action allowed it to consolidate up to thirty reports into one, focus on problem areas, identify production goals and provide a valuable two-way communication tool to its customers.

The report provides narrative information on the site technology, capabilities and cost structure, and metrics on quality, responsiveness and on-time delivery. Results to date include an improved customer relationship and a 30% improvement in quality and timeliness over the past 12 months.

Window Analysis

HP has invested heavily in providing training to all supervisors at PAFC in subjects such as process control and analysis tools. One of the most widely used tools at the site is window analysis. This analysis tool helps identify the variance between an actual process and the desired process, and provides information for optimizing the process.

An application of this methodology is shown in Figure 3-5. This example problem involved reconciling the site’s inventory control system (ICS) with the actual on-hand inventory. Variances between system records and the actual inventory on-hand were costing over $2000 per month. The team that conducted the analysis brainstormed problem causes using standard tools such as cause and effect (fishbone) diagrams, process deployment flowcharts, and Pareto analysis.

In the window analysis, the x-axis represents the actual inventory on hand and the y-axis represents what the ICS shows as on hand. Procedures are characterized in terms of known and practiced, known and unpracticed, and unknown. The intersections of the x and y axes provide indications in four areas:

1. Procedures to prevent defects are known and utilized - the ideal situation
2. Procedures to prevent defects are established but not followed - an adherence problem
3. Procedures to prevent defects are established but operating personnel are not aware of them - a communication or training problem
4. Procedures for eliminating the problem do not exist - this problem requires further data collection or experimentation.

In the case of the inventory system, the window analysis revealed an adherence problem and the need for the addition of simple standard procedures. When these were identified and applied, the cost of defects was reduced from over $2000 per month to less than $50. This tool has been applied successfully in numerous processes over the past several years by supervisory personnel at PAFC.

FIGURE 3-5. WINDOW ANALYSIS
SECTION 4
INFORMATION

4.1 DESIGN

PARTS AND MATERIAL SELECTION

Preliminary Cost Estimate

Cost estimates at PAFC are facilitated through the use of a cost estimating program. Cost estimates, developed for several reasons, may include a request by the customer for an estimate on prototyping and follow-on fabrication cost for a particular design change. Estimates may also be generated for budget purposes or for process improvement baselines. Some cost drivers considered during the estimate are design complexity, fabrication process, part uniqueness, quantities required, material types, and tolerances.

The cost estimating software runs in a window on the HP workstations. The program guides the CE through a series of questions and answers about the product and process. After the questions have been answered, the program calculates product costs for various part quantities. “What if” calculations can easily be made by changing various cost drivers and rerunning the program. The customer can then make appropriate modifications based on the estimates.

During the estimating process, the PAFC CE may take the opportunity to suggest part feature changes that will result in cost reductions and schedule improvements. The cost estimating program can also be run by the customer which facilitates making decisions as early as possible in the design cycle.

4.2 PRODUCTION

PIECE PART CONTROL

Plastic Injection Molding

The PAFC has plastic injection molding capabilities with an added feature of two-color molding. With this added feature, the problem of paint wearing off of letters and numbers on keys and switches has been eliminated. The process involves molding the base part with the identifying nomenclature (letters and numbers) raised and of one color. While the parts are still in the machine, a second overcoat of a contrasting color is molded onto the base part, leaving the nomenclature exposed in its original color.

FACTORY IMPROVEMENTS

Aluminum Die Casting, Trimming and Recycling

HP has standardized the design of its System II instrument cabinet line so only approximately 37 different basic die castings are required. These basic parts are mainly in the front frames, rear frames, handles, and struts. All these parts are cast at PAFC. Depending on the specification and end use requirements, all parts are cast from either 360 aluminum alloy or 443 aluminum alloy. Die casting of many other parts is also accomplished at this facility.

Due to extensive process improvement efforts, PAFC has been able to improve its yield rate from the 50% to 60% range to near 100%. A standard procedure keeps the last part run on a given die with that die until the die is used again. By using this procedure and keeping lot quantities low, unseen defects are discovered early in the next piece part processing step and immediate corrective action can be taken such as dies reworked, machines checked for malfunctions, or material analysis performed.

With the recent addition of a spectrum analyzer, the PAFC is now able to recycle all of its own die cast waste material. Instead of selling this material as scrap and then buying virgin material ingots, it remelts the waste, adds magnesium as required, and reuses the material. This has resulted in a raw material cost reduction of approximately 50%.

Standardization of basic casting designs, raw material reclamation, standardized processes on the shop floor, and machine modernization have dramatically reduced costs and lead times for die casting at PAFC.

4.3 MANAGEMENT

PERSONNEL REQUIREMENTS

Leadership Development Survey

A leadership development survey at PAFC is being used to assist in supervisor leadership development. This survey consists of over 60 questions designed to assist managers/supervisors in assessing their strengths and weaknesses by channeling and improving the feedback they receive from subordinates.
The survey is administered to all personnel working under the supervisor. After the survey has been processed and analyzed, the manager’s supervisor will use the results to help the manager set goals and target needed improvement in the areas of team building, leadership, coaching, and individual skill improvement. Follow-on surveys help measure the manager’s corrective programs and their effectiveness. Additional benefits are anticipated because this system is expected to reinforce the concept that team feedback is important:

- values are stressed;
- expectations are clarified;
- shortcomings are exposed and addressed early;
- successful practices are identified and reinforced; and
- minimal time is spent on low value-added activities.

Organizational Survey

PAFC has just completed the administration of its first organizational health survey with the participation of all site employees. An organizational survey is used to determine organizational strengths and target areas for improvement. The questions assessed organizational strengths and weaknesses in the areas of management and supervision, communication, relationships, work environment, performance, development, and contribution and reorganization. After the survey, indicated areas of need for improvement will be the subject of process action team involvement. It is anticipated that this process will be repeated at approximately 15-month intervals to promote continuous improvement in all applicable areas.
# APPENDIX A

## TABLE OF ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTQRDC</td>
<td>Business, Technology, Quality, Responsiveness, Delivery and Cost</td>
</tr>
<tr>
<td>CE</td>
<td>Customer Support Engineer</td>
</tr>
<tr>
<td>DFM</td>
<td>Design for Manufacturability</td>
</tr>
<tr>
<td>HP</td>
<td>Hewlett-Packard</td>
</tr>
<tr>
<td>ICS</td>
<td>Inventory Control System</td>
</tr>
<tr>
<td>PAFC</td>
<td>Palo Alto Fabrication Center</td>
</tr>
<tr>
<td>TQRDC</td>
<td>Technology, Quality, Responsiveness, Delivery and Cost</td>
</tr>
</tbody>
</table>
## APPENDIX B

### BMP SURVEY TEAM

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Agency</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larry Robertson</td>
<td>Crane Division</td>
<td>Team Chairman</td>
</tr>
<tr>
<td></td>
<td>Naval Surface Warfare Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crane, IN</td>
<td></td>
</tr>
<tr>
<td>Amy Scanlan</td>
<td>BMP Representative</td>
<td>Technical Writer</td>
</tr>
<tr>
<td></td>
<td>Oak Harbor, WA</td>
<td></td>
</tr>
<tr>
<td>Dave Kuchler</td>
<td>Aircraft Division - Indianapolis</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td>Naval Air Warfare Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indianapolis, IN</td>
<td>Design/Test</td>
</tr>
<tr>
<td>Steve Ratz</td>
<td>Aircraft Division - Indianapolis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Naval Air Warfare Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indianapolis, IN</td>
<td></td>
</tr>
<tr>
<td>Chuck McLean</td>
<td>National Institute of Standards and Technology</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td>Gaithersburg, MD</td>
<td>Production/Facilities</td>
</tr>
<tr>
<td>Don Hill</td>
<td>Aircraft Division - Indianapolis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Naval Air Warfare Center</td>
<td></td>
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<tr>
<td></td>
<td>Indianapolis, IN</td>
<td></td>
</tr>
<tr>
<td>Rick Purcell</td>
<td>BMP Representative</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td>Washington, DC</td>
<td>Management/Logistics</td>
</tr>
<tr>
<td>CAPT O. B. Powell</td>
<td>OASN (RDA) PI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Washington, DC</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C

NAVY CENTERS OF EXCELLENCE

Automated Manufacturing Research Facility
(301) 975-3414
The Automated Manufacturing Research Facility (AMRF) – a National Center of Excellence – is a research test bed at the National Institute of Standards and Technology located in Gaithersburg, Maryland. The AMRF produces technical results and transfers them to the Navy and industry to solve problems of automated manufacturing. The AMRF supports the technical work required for developing industry standards for automated manufacturing. It is a common ground where industry, academia, and government work together to address pressing national needs for increased quality, greater flexibility, reduced costs, and shorter manufacturing cycle times. These needs drive the adoption of new computer-integrated manufacturing technology in both civilian and defense sectors. The AMRF is meeting the challenge of integrating these technologies into practical, working manufacturing systems.

Electronics Manufacturing Productivity Facility
(317) 226-5607
Located in Indianapolis, Indiana, the Electronics Manufacturing Productivity Facility (EMPF) is a National Center of Excellence established to advance state-of-the-art electronics and to increase productivity in electronics manufacturing. The EMPF works with industry, academia, and government to identify, develop, transfer, and implement innovative electronics manufacturing technologies, processes, and practices. The EMPF conducts applied research, development, and proof-of-concept electronics manufacturing and design technologies, processes, and practices. It also seeks to improve education and training curricula, instruction, and necessary delivery methods. In addition, the EMPF is striving to identify, implement, and promote new electronics manufacturing technologies, processes, materials, and practices that will eliminate or reduce damage to the environment.

National Center for Excellence in Metalworking Technology
(814) 269-2420
The National Center for Excellence in Metalworking Technology (NCEMT) is located in Johnstown, Pennsylvania and operated by Concurrent Technologies Corporation (CTC), a subsidiary of the University of Pittsburgh Trust. In support of the NCEMT mission, CTC’s primary focus includes working with government and industry to develop improved manufacturing technologies including advanced methods, materials, and processes, and transferring those technologies into industrial applications. CTC maintains capabilities in discrete part design, computerized process analysis and modeling, environmentally compliant manufacturing processes, and the application of advanced information science technologies to product and process integration.

Center of Excellence for Composites Manufacturing Technology
(414) 947-8900
The Center of Excellence for Composites Manufacturing Technology (CECMT), a national resource, is located in Kenosha, Wisconsin. Established as a cooperative effort between government and industry to develop and disseminate this technology, CECMT ensures that robust processes and products using new composites are available to manufacturers. CECMT is operated by the GreatLakes Composites Consortium. It represents a collaborative approach to provide effective advanced composites technology that can be introduced into industrial processes in a timely manner. Fostering manufacturing capabilities for composites manufacturing will enable the U.S. to achieve worldwide prominence in this critical technology.
APPENDIX D

PREVIOUSLY COMPLETED SURVEYS

BMP surveys have been conducted at the companies listed below. Copies of survey reports for any of these companies may be obtained by contacting:

Best Manufacturing Practices Program
Office of the Chief of Naval Research
Office of Advanced Technology (341)
Attn: Mr. Ernie Renner
Arlington, VA 22217-5660
Telephone: (703) 696-8482

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
(Computing Devices International)
Government Systems Division
Minneapolis, MN
December 1986

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

General Dynamics
Fort Worth Division
Fort Worth, TX
May 1988

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
Cedar Rapids, IA
October 1987

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988
Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
St. Louis, MO
January 1989

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
La Mirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C3 Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company-Georgia
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991
Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced Technologies
and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyards
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Information gathered from all BMP surveys is included in the Best Manufacturing Practices Network (BMPNET). Additionally, calendar of events and other relevant information are included on BMPNET. All inquiries regarding the BMPNET may be directed to:

BMP Director
Office of the Chief of Naval Research
Office of Advanced Technology (341)
800 North Quincy Street
Arlington, VA 22217-5660
Telephone: (703) 696-8482
FAX: 703) 696-8480