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REPORT OF SURVEY CONDUCTED AT

ROCKWELL INTERNATIONAL

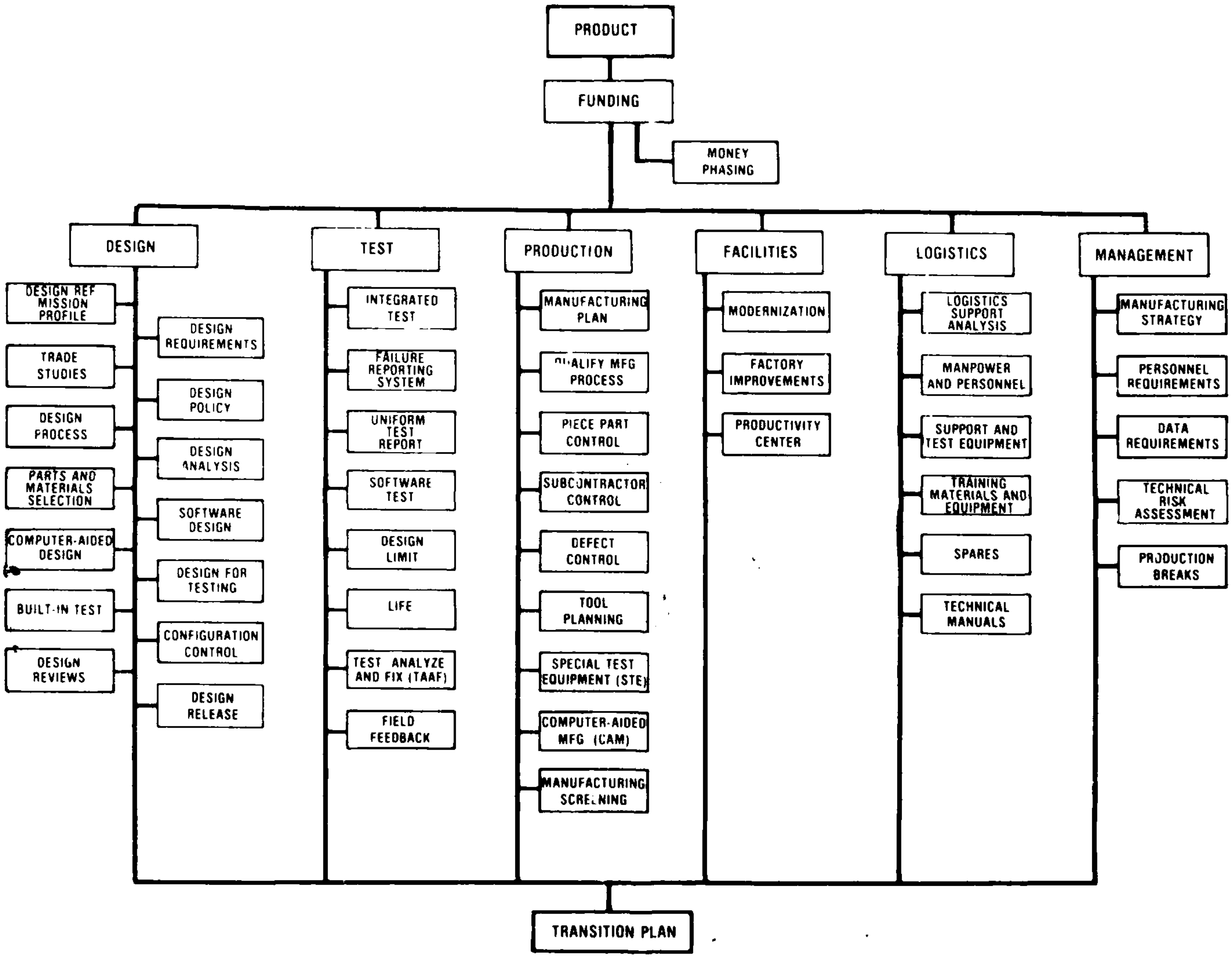
COLLINS DEFENSE COMMUNICATIONS

CEDAR RAPIDS, IOWA

OCTOBER 1987

DoD 4245.7-M, "TRANSITION FROM DEVELOPMENT TO PRODUCTION"

CRITICAL PATH TEMPLATES



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The purpose of the Best Manufacturing Practices (BMP) survey conducted at this facility was to identify their 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 the U.S. industrial base. The actual exchange of detailed data will be between contractors at their discretion. A company point of contact is listed in the report

The intent of the BMP program is to use this documentation as the initial step in a voluntary technology sharing process among the industry.

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SECTION 1

INTRODUCTION

1.1 SCOPE

The purpose of the Best Manufacturing Practices (BMP) review conducted at Rockwell International, Collins Defense Communications (CDC) was to identify best practices, review manufacturing problems, and document the results. The intent is to extend the use of high technology equipment and processes throughout industry. The ultimate goal is to strengthen the U.S. industrial base, solve manufacturing problems, improve quality and reliability, and reduce the cost of defense systems.

To accomplish this, a team of DoD engineers reviewed Rockwell CDC in Cedar Rapids, IA to identify the most advanced manufacturing processes and techniques used in that facility. Manufacturing problems that had the potential of being industry wide problems were also reviewed and documented for further investigation in future BMP reviews. Demonstrated industry wide problems are submitted to the Navy's Electronics Manufacturing Productivity Facility (EMPF) for investigation and resolution.

The review was conducted on 20-23 October 1987 by a team of DoD personnel identified on page 2 of this report. Rockwell CDC is primarily engaged in design, development, and production of command, control, communications, and intelligence equipment.

The results of BMP reviews are being entered into a data base to track best practices and manufacturing problems. The information gathered will be available for dissemination through an easily accessible central computer. The actual exchange of detailed data will be between contractors at their discretion.

The results of this review should not be used to rate Rockwell CDC among other defense electronics contractors. A contractor's willingness to participate in the BMP program and the results of a survey have no bearing on one contractor's performance over another's. The documentation in this report and other BMP reports is not intended to be all inclusive of a contractor's best practices or problems. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

1.2 REVIEW PROCESS

This review was performed under the general survey guidelines established by the Department of the Navy. The review concentrated on the functional areas of design, test, production, facilities, logistics, management, and transition planning. The team evaluated Rockwell CDC's policy, practices, and strategy in these areas. Furthermore, individual practices reviewed were categorized as they relate to the critical path templates of the DoD 4245.7-M, "Transition From Development To Production." Rockwell CDC identified potential best practices and potential industry wide problems. These practices and problems and other areas of interest identified were discussed, reviewed, and documented for dissemination 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 on the factory floor reviewing practices, processes, and equipment. In-depth discussions were conducted to better understand and document the practices and problems identified.

1.3 BMP REVIEW TEAM

Team Member	Agency	Role
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SECTION 2

BEST PRACTICES

The practices listed in this section are those identified by the BMP survey team as having the potential of being among the best in the electronics industry.

2.1 Design

DESIGN PROCESS

Design Process

This facility has a documented eight phase project development process which was developed by a senior management committee. DoD 4245.7-M templates were used to define activities for each phase. Existing engineering procedures were updated, and new ones created, resulting in two project engineering manuals, Project Engineering Operations Manual and Design Engineering Guidebook. These manuals describe and define the design process and product development activities in detail. These manuals delineate product design considerations, design analysis tools/capabilities, product documentation and control, engineering specialty disciplines, support and service functions, and production operations. Detailed operating procedures and guidelines were then provided by the individual engineering disciplines.

COMPUTER-AIDED DESIGN

Computer-Aided Design/Engineering

CAD/CAE usage in the LSI, mechanical, printed wiring board, and software design areas has been implemented with plans to expand into modeling, simulation, test, and analysis. A common database is being defined to integrate CAD, CAE, and CAM. The next scheduled improvement is to provide networking capability to all engineers with a personal computer.

DESIGN POLICY

Design Policy

Rockwell CDC has a documented design policy created to ensure quality of design (product integrity). These documents define the basic requirements for engineering activities associated with design, development, testing, and support of their products. DoD 4245.7-M templates were used in creating new procedures. The engineering standards and practices have been tailored to their product line. A comprehensive and thorough design plan with detailed design requirements is required prior to development and approval by management. Design reviews by experts in the disciplines involved are required, with corrective action being a key element in this process.

SOFTWARE DESIGN

Software Design

A Software Development Process has been established which classifies each software development into a software grouping and a development type, plus details the development methodology for each classification. The invoked development methodology addresses the following:

- Cost and Schedule Tracking
- Reviews
- Documentation
- Project Library
- Design Specifications
- Programming Standards
- Code Walk-Throughs
- Unit and Integrated Testing
- Formal Readiness Testing
- Software Transition Process to Collateral
- Post Release Requirements

The Software Development Process was tailored from DOD 2167 and provides for further tailoring as applicable to each software development classification.

CONFIGURATION CONTROL

Configuration Management

Rockwell CDC has an effective configuration control system which has a tailored set of guidelines and standards (Configuration Management Department Methods). Their policy emphasizes the need for adequate configuration management plans for the entire life cycle. The control system is centralized and is required early in the design phase. A minimum/maximun revision system is utilized to control the production build. Each production assembly contains a part number, corresponding revision letter, and serial number for traceability. Extensive automation is planned to document each product as it is built.

2.2 TEST

FAILURE REPORTING SYSTEM

Production Performance System and Failure Recurrence Control

There is a very extensive division closed-loop failure reporting system to accomplish the corporate goal of in-house quality. A Product Performance System (PPS) captures development test, functional test, manufacturing, and field return failure information. The failure data enables pattern and trend analysis, correlation of part failures to test data, cost, and corrective action verification. Failure Recurrence Control (FRC) activity consists of a Failure Review Board which meets regularly to analyze the data and direct the corrective action at all levels of manufacture, test, and support. Totally automating the data collection process and report generation is in process.

The PPS will trend the functional test failures by a multitude of attributes which actually caused the failure. These attributes include both workmanship and component type failures. The workmanship defects can be categorized into the actual type of defect that caused the overall failure, such as solder or wrong part, along with the defective part number. The PPS can also cost out each of the defects that is flagged based on where the defect occurred in the process. Typically, the Failure Review Board will use this cost data in the prioritization of corrective actions.

Functional Test Analysis Program

The Functional Test Analysis (FTA) program, which is in the pilot phase, provides a statistical means to successfully analyze test data generated by equipment under test at the Automated Test Equipment (ATE) stations. The FTA program has the capability to capture all measurable data on every unit run, sorts on any combination of collected data, and displays data in a variety of useable formats. The program maintains six months of test data, provides software capability to analyze daily test problems and functional test trend analysis, permits "what if" limit analysis, and provides a link to match Product Performance Systems (PPS) component failure data with functional test data. Furthermore, the FTA identifies test problem areas to be corrected, statistical data for design engineering analysis, ATE utilizaton, design margins in test limits, and verification of corrective action.

2.3 PRODUCTION

MANUFACTURING PLAN

Factory Transition Plan

The Factory Transition Plan (FTP) is emphasized and supported at the highest levels of management. This plan ties all of the DoD 4245.7-M functional areas together to maximize a smooth transition from development to production. An operating procedure has been developed and put in place which mandates the preparation, approval and execution of a FTP. The operating procedure is also a guideline for preparing and using the plan. The FTP is first generated during the proposal stage or early in the initial design phase and evolves to completion at the end of design. The FTP is the program manager's technical evaluation tool to measure time phased milestone accomplishment of all production related activities that must be accomplished during design, test, and low rate initial production. Strong emphasis is placed on the use of design reviews and periodic meetings to verify that all previous actions have been completed in accordance with the FTP.

Design to Cost

The Design To Cost (DTC) program emphasizes teaming for all facets of planning, engineering, and manufacturing to ensure that the product is delivered at or below cost. Preferred parts lists are established, designs are reviewed, and approval by the team as meeting DTC criteria is given. Cost is treated as a design driver, just as performance specifications, maintainability, and reliability. Designers take manufacturability and maximum utilization of factory strengths (e.g., automation) into account to keep cost on target. Performance of parts and material buyers is closely managed and multi-year/lifetime buys are used to incentivize vendors to meet cost objectives. Weekly team meetings are held and documented to continuously focus on DTC objectives and actions. Designer Bill Of Material (BOM) is priced out by purchasing and redesign is considered if BOM pricing exceeds target.

QUALIFY MANUFACTURING PROCESS

Prototype Manufacturing Process

This area is involved in producing out-of-production spares, developmental and some engineering prototypes, special (non-production) items, very low volume (not worth factory set-up time) units, larger volume factory and field reworks, and pre-production units.

The pre-production items must follow guidelines found in their general Factory Transition Plan and the Transition Plan written for that specific product. They make physical producibility changes to the design during prototype assembly. By using production equipment such as a wave soldering machine, certain process control information is determined. This information is fed back to engineering for review and change. The group is presently composed of a Producibility Engineer, a Manufacturing Electrical Engineer, a Secretary, a Foreman, 3 Industrial Engineering Technicians, and 38 Production Technicians (average of 22 years experience).

An Industrial Engineer has a job assignment to a product at the start of the design effort and follows the product through design, product transition line, and into the Action Management Team on the factory floor.

PIECE PART CONTROL

Incoming Inspection and Automated Storage and Retrieval System

Incoming inspection, parts preparation, and parts storage is performed at one location, Salt Lake City, Utah. This facility supports four different facilities at Dallas, Santa Ana, Toronto (Canada) and Cedar Rapids. By consolidating efforts at one facility, Rockwell CDC reduced the total number of different part numbers from approximately 90,000 to 60,000, which proved to be a significant cost savings.

The parts storage and retrieval system at Salt Lake City is automated. The system operates off of one priority, but allows for critical needs to be run at short notice. For example, when a facility is in need of a critical part, it can expect to receive it within 24 hours from the time the order is placed. The storage and retrieval system can process approximately 20,000 lots per month with over 99% accuracy.

The incoming inspection of parts include both functional and solderability testing, both of which can keep up with the production rate of the storage and retrieval system. Their solderability testing incorporates both visual inspection and wetting balance analysis.

Distributed Manufacturing Control System

The Distributed Manufacturing Control System (DIMACS) is an on-line shop floor control system that collects labor expended and tracks material movement through the use of bar code readers and networked microcomputers. Hand-held bar code scanners are located within reaching distance of each operator. Operators wand a bar coded traveler that accompanies the work as the system logs the start and finish time of each operation. The information is sent via port concentrators to a set of Ethernet linked microcomputers. The microcomputers independently update their files and upload data to their labor distribution and accounting systems. Data is also used to track operator efficiency and product inventory. Epson terminals that send data to the Inspection Information System (IIS) are also part of the DIMACS. Terminals are in each Action Management Team (AMT) for immediate access to system data.

DEFECT CONTROL

Automated Inspection Information System

To achieve a pencil-less factory, an Automated Inspection Information System (IIS) has been implemented which allows each inspector to enter inspection results through small "Lap Top" computers.

Factory-wide standardized bar codes for each type of defect are entered through a wand connected to the HX20 EPSON computer at each inspector's workstation. Approximately 65 of these stations are networked to IBM PCs, which can produce various types of reports.

Product quality by part number, type and quantity of defects, or factory department/foreman can be examined and used as a management tool. The system also reports calculations of costs per defect, taking into account how far the defect has advanced through the manufacturing process.

The Computer-Aided Assembly Line Inspection System (CAALIS) is a unique in-house solution to economizing the electronic assembly inspection process. CAALIS allows the inspector/operator to perform the inspection and annotate the defects through a sequence of voice commands without stopping to write anything down on paper. This approach saves vast amounts of time and yields much more comprehensive and accurate inspection data.

The computer ties the defect to a precise location on the assembly. The CAD database is used to print out an assembly drawing containing the defect codes tied to the appropriate location on the assembly. Repair instructions are also printed on the drawing. The defect data is stored and used to generate next day reports to supervision/management for the previous day's performance.

CAALIS utilizes unique mechanical/physical concepts to establish spacial location (XYZ) and points of defect for the Unit Under Inspection (UUI). CAALIS employs voice activated interfacing to a 10X-30X inspection microscope to allow the operator to inspect the entire assembly without interruption for paper annotation of defects.

The CAALIS is programmed to accept up to 82 different defect codes. The operator "teaches" CAALIS to associate each code to a voice command. The UUI is mounted in a hand held fixture referenced onto the system and then inspected. The operator inspects the assembly under the microscope, turning the UUI in any desired direction for best viewing. When a defect is found, the operator holds the UUI steady, depresses the foot pedal, and tells the CAALIS the defect code which applies. At the time of foot pedal depression, the three planar mounted spark gaps installed on the hand held fixture are sequentially fired. Spacially separated microphones located in the CAALIS inspection booth detect the sequential spark gap firings and triangulate the exact location of the UUI and the defect.

COMPUTER-AIDED MANUFACTURING

Shared/Common Database Between Engineering and Operations

The common database, Engineering Design Center/Manufacturing Design Center (EDC/MDC), between engineering and operations minimizes transition time from design to production by the following:

Eliminates paper drawings and the inherent risk of communication and configuration management errors.

Drives manufacturing Bill Of Materials (BOM), Material Resource Planning (MRP), and material movement systems with most current parts and material requirements.

Controls manufacturing operations of assembly, test and inspection with latest engineering data.

Accelerates and facilitates engineering change control.

EDC/MDC resides on a ComputerVision CAD/CAM system within engineering. PWB/PWA design data is uploaded from a CADNETICS system while mechanical design data is uploaded from an ANVIL-APOLLO workstation system. Both uploads take place over the engineering network. The engineering database is accessed via the operations network to drive the TOPICS BOM/MRP and Manufacturing Graphics and Integrated Control System (MAGICS).

Manufacturing Graphics and Integrated Control System (MAGICS)

The Advanced Manufacturing Technology group is developing a network of sixty IBM PC-AT type workstations with EGA color graphics which will provide step-by-step circuit board assembly instructions. By the use of a foot switch, the operator progresses through the assembly and receives special instructions on the screen as necessary.

These stations will also be used by inspectors having a touch screen and a zoom function to input defect information by component or board position. The inspection results can then be called up by part number and serial number on a similar workstation by the rework operator who sequences through the items needing touchup, etc. The graphic information source for all this is the common database of the EDC/MDC system. The software for the graphics is a joint development, but will be sold by Development Software Company. The system is expected to be in operation by May/June 1988.

Computerized Material Routing System

The Computerized Material Routing System (CRAFTS) is used to increase the work flow and reduce the Production Foreman workload. The kits are received from the Salt Lake City facility. The data tracking system accepts the data, such as kit numbers and shortages, from the kits that are received. The data entry is typically performed using a bar code system. Once this data is entered into the system, the kit is either stored in a small automatic storage and retrieval system that uses a MOBOT, a vertical removable storage system and a robot, or is routed to a specific workstation that will perform a function on the kit.

Each of the workstations in the routing system is designated by function so that each of the kits is routed to the proper workstation in the most expeditious manner. CRAFTS uses conveyors, automatic guided vehicles (AGV), and operators to move the kits from the storage area to the actual workstation. The majority of the workstations are connected to either the conveyor system or the AGV. CRAFTS is also flexible such that it can run in three different modes: all manual, partially manual, or fully automatic. In the manual mode, both data entry and kit storage and retrieval use operators; in the partially manual mode, the data entry uses a bar code system with manual storage and retrieval; and in the fully automatic mode, the data entry is accomplished using a bar code system with the storage and retrieval system using a three-axis robot. CRAFTS has proven to be successful in reducing workloads and increasing the work flow.

2.4 FACILITIES

FACTORY MODERNIZATION

Computer Controlled Vapor Phase Soldering System

A vapor phase soldering system that integrates a Hewlett Packard desktop computer and a HTC vapor phase soldering machine is utilized. While most vapor phase solder machines control the process by regulating the time spent in the preheat and vapor chambers, Rockwell CDC controls the process by regulating the board temperature and utilizing a thermocouple which is attached to the board. When the temperature of the board reaches predetermined temperatures, the HP desktop instructs the machine to raise or lower the board. The process is totally temperature driven and product dependent. This method has proven to provide reliable and consistent solder joints. CDC has also incorporated a vapor recovery system with significant savings achieved through reduced chemical usage.

FACTORY IMPROVEMENT

Printed Wiring Assembly Cleaning Line

A custom developed computer contolled aqueous wash system is used to clean high density boards with surface mount components. Both solvent and aqueous washes are required. The solvent wash provides the required cleaning of flux from underneath the components while the aqueous wash is required to properly remove all solder mask material. Both cleaning tanks are continuously monitored by a computer for chemical content. As predetermined limits are exceeded, the system automatically adjusts to ensure that the proper chemical content is maintained. The computer also controls a nightly automatic internal cleaning cycle. The combination of both the nightly controlled solvent and aqueous cleaning has proven to adequately remove required contaminants the first time through. The computer also controls all process parameters, such as conveyor speed, to optimize throughput.

Printed Wiring Assembly Area

The PWA area efficiently integrates manual, semi-automated, and automated equipment for assembling high density boards that incorporate a mixture of surface mount and through hole components. It is evident that optimization of process control through statistical experimental design contributes significantly to the development of the processes that are used in the area. The area is complemented by various material handling and data collection systems that maximize the time operators perform value added work. A factory improvement project to reduce throughput times is in the planning process.

2.5 MANAGEMENT

MANUFACTURING STRATEGY

Statistical Process Control System

A computerized statistical process control (SPC) system was developed to provide management visibility on workmanship and process trends from visual inspection. The system aids in identifying and tracking potential process improvements.

The system obtains its data from the EPSON and CAALIS data collection systems. The SPC system collates the data into a file which contains the necessary information to calculate, by part number, the daily average number of defects per thousand possible defects, the preceding thirty daily averages, and the upper control limit. When out of control conditions exist, the cause is identified and corrective action is taken.

Work Measurement (Compliance with MIL-STD-1567A)

The Cedar Rapids facility employs an MTM based work measurement system that has been validated by the Air Force as compliant with MIL-STD-1567A. The system has been validated at three out of four Rockwell CDC sites. The fourth site, Salt Lake City, is expected to be validated during fiscal year 88.

Rockwell CDC is in the process of transitioning to the PC based 4M system which will enable the generation of standards supported by MTM. The 4M system architecture will facilitate the utilization of these standards for estimating, performance measurement, and other related tasks.

Management's Philosophy Towards Automation

It is evident that management's approach is to automate whenever it is economically justifiable. This means that automated production equipment is developed in-house if there is no commercially available equipment to do the job. As a result, the following equipment has been developed in-house:

Pick and place robot for populating boards

Voice entry semi-automated inspection station (CAALIS)

Computerized batch aqueous cleaning system

Computer controlled vapor recovery system for vapor phase soldering equipment

PERSONNEL REQUIREMENTS

Action Management Teams

Action Management Teams (AMT) are small groups of employees that support a common product line and are given total responsibility for management of their production line. Each AMT is physically located on the factory floor with easy access to the production lines which they support. The AMT is supported by the Distributed Manufacturing Control System (DIMACS), a shop floor system that allows the team to manage the production line utilizing its own IBM personal computer.

Each team is comprised of a line assembly supervisor, test supervisor, production coordinator, expeditor, industrial engineer, manufacturing electrical engineer, and a quality assurance engineer. AMT participation is an integral part of their job. The team leader is chosen by the team. Team performance is measured in the following key areas: labor, quality, scrap, loss in production, work in process, and schedule. The goals within each area are set by each team, but they must support goals of upper management. One member from each team gives a presentation once a month at a meeting with the director of production operations, plant manager, department manager, and the quality asssurance manager. Presentations are rotated between team members.

It is significant to note that merit reviews are based on team performance as well as individual performance. The AMT has proven extremely successful in keeping the product lines going, keeping decision making at the lowest level, and utilizing employee creativity through improved teamwork.

Operations Streamlining

Streamlining is a methodology used for the purpose of analyzing tasks performed by employees and comparing the relative costs of these tasks. The process requires each employee to keep track of the time expended on various work tasks. After the amount of time spent on a task is determined, a rigorous methodology to rank its relative importance to the organization is employed. This analysis indicates when an employee or an entire department may be investing too much time (cost) in a low priority activity, or conversely, not placing sufficient emphasis on a high priority task.

The results of this analysis are used to generate a large amount of cost reduction projects. These projects are actively tracked by management and are an integral part of the Productivity Improvement Program. It should be noted that as a result of the last analysis (1984), approximately 60 jobs were eliminated, although all of these reductions were accomplished through reassignment and attrition. There were no layoffs as a result of this program.

SECTION 3

PROBLEM AREAS

The practice listed in this section was identified by Rockwell CDC to the BMP survey team as being a potential electronics industry wide problem.

3.1 LOGISTICS

SUPPORT AND TEST EQUIPMENT

Time Phasing of Delivery of Test Equipment

Rockwell CDC has expressed a concern regarding requirements for the delivery of test equipment. Typically, final configuration test equipment is required to be a deliverable along with the prototype weapons hardware. This requirement is based on the need to evaluate test equipment at the same time that the hardware is evaluated. However, this forces the test equipment designer to try to hit a moving target, since the test equipment must constantly change to accomodate hardware changes. This process is costly to both the Government as well as to the vendor.

It was proposed that action be taken to time phase the delivery of test equipment in one of two ways. The first is to require delivery of only prototype test equipment for operational evaluation, with the final configuration deliverable to be made at a later time. The second proposal is for the vendor to make recommendations for the test equipment during the development phase, but to not make actual deliveries until a later date. Under this scenario, the vendor would have to assume greater responsibility for depot level maintenance during the interim.

SECTION 4

SUMMARY

Many best practices were observed during the BMP survey at Rockwell CDC. Employee motivation and attitude towards producing a quality product seemed to be very visible. Management reinforces these ideals by planning and establishing a positive working environment with an attractive appearance by having such features as carpeted work areas.

The centralized receiving, inspection, and automated storage and retrieval facility in Salt Lake City supports the four manufacturing plants in Dallas, Santa Ana, Toronto, and Cedar Rapids.

Manufacturing technology developments resulted in systems such as the Computer-Aided Assembly Line Inspection System (CAALIS) for inspection and annotation of defects while utilizing CAD product data.

Integration and interfacing of CAD, manufacturing, and inspection data is being accomplished. Additionally, material movement, labor tracking, and other information systems are being integrated into a Computer Integrated Manufacturing factory environment. All of these systems and improvements are being planned and focused from a total factory perspective with the goal of a quality transition process.

The point of contact for this BMP survey is:

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His, in addition to that of Mr. Herm Reininga, Vice President of Operations for Rockwell CDC, cooperation, time, and quality of effort in preparation and hosting of this survey while actively participating in the Best Manufacturing Practices Program is greatly appreciated.