REPORT OF SURVEY CONDUCTED AT

HUGHES AIRCRAFT COMPANY
MISSILE SYSTEMS GROUP

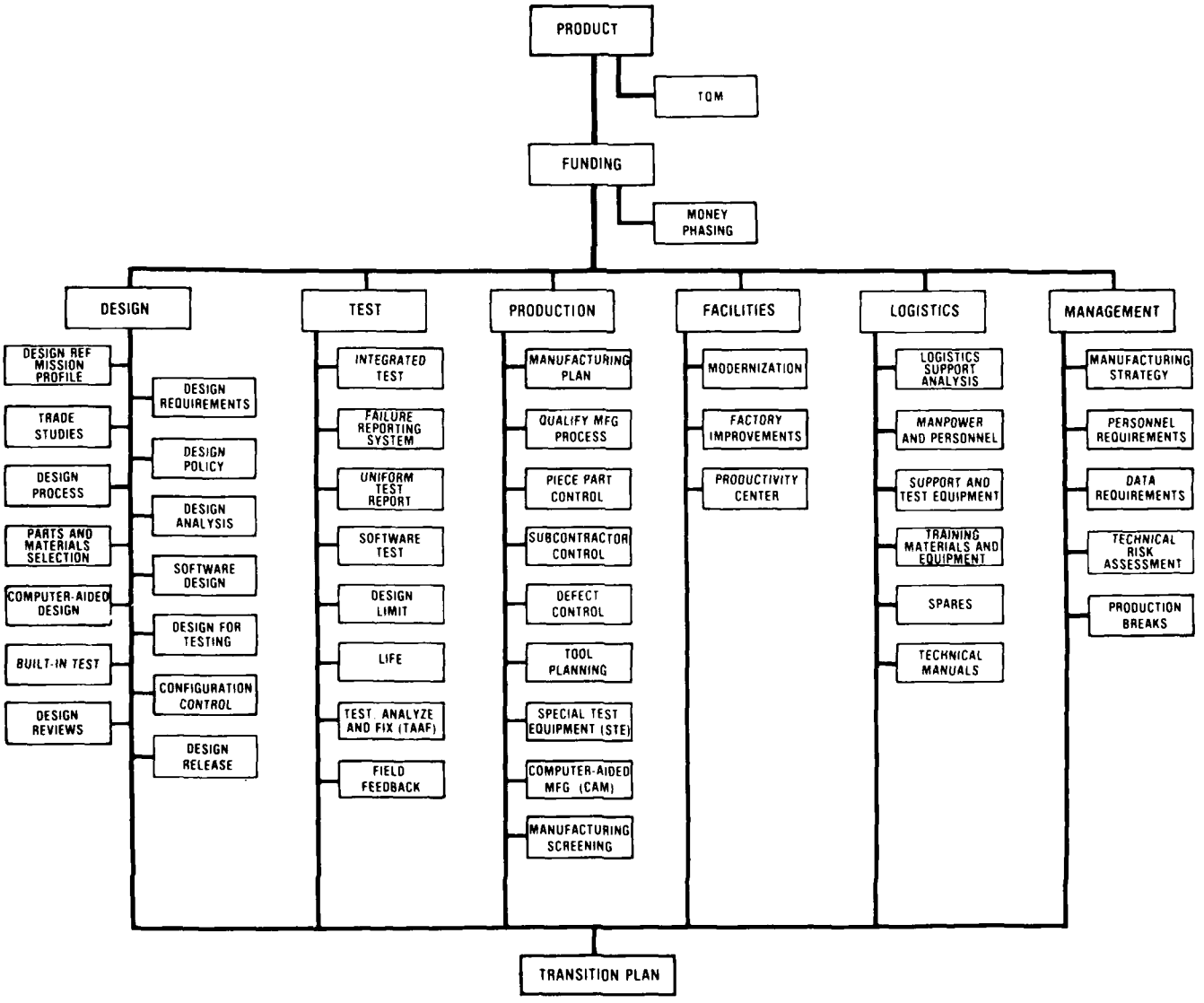
TUCSON, ARIZONA

AUGUST 1988

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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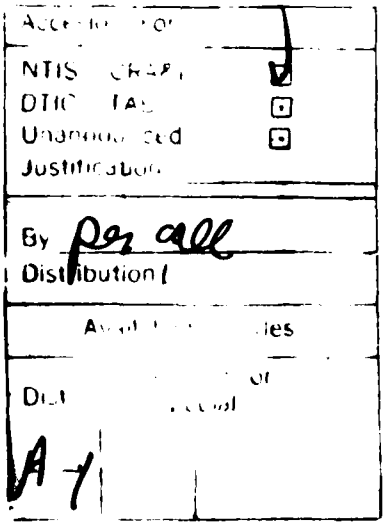

SECTION 1

INTRODUCTION

1.1 SCOPE

The purpose of the Best Manufacturing Practices (BMP) review conducted at Hughes Aircraft Company, Missile Systems Group (MSG) 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 Hughes MSG in Tucson, Arizona 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 8-11 August 1988 by a team of DoD personnel identified on page 2 of this report. Hughes MSG is primarily engaged in design, development, and production of advanced tactical missile systems.

The results of BMP reviews are entered into a data base to track best practices and manufacturing problems. The information gathered is 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 Hughes MSG 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 Hughes MSG 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." Hughes MSG 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
Alan Criswell (215) 897-6684	**Naval Industrial Resources Support Activity** Philadelphia, PA	**Team Chairman**
Ed Turissini (317) 353-7965	**Naval Avionics Center** Indianapolis, IN	**Team Leader** Design/Test
John Wiegand (812) 854-3240	**Naval Weapons Support Center** Crane, IN	
Dave Zeph (317) 353-7961	**Naval Avionics Center** Indianapolis, IN	
Steve Rapp (812) 854-1694	**Naval Weapons Support Center** Crane, IN	**Team Leader** Production/Facilities
Gretchen Cooper (812) 854-1854	**Naval Weapons Support Center** Crane, IN	
CDR Mark Cooper (805) 756-2571	**NAVSEA DET 519** Long Beach, CA	
Pat Reaves (619) 553-5381	**Naval Ocean Systems Center** San Diego, CA	
Steve Linder (202) 692-1146	**Office of the Assistant Secretary of the Navy (S&L) (RM&QA-PA)** Washington, DC	
CDR Rick Purcell (202) 692-3422	**Office of the Assistant Secretary of the Navy (S&L) (RM&QA-PI)** Washington, DC	**Team Leader** Management/Logistics
Larry Halbig (317) 353-7075	**Naval Avionics Center** Indianapolis,IN	

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 POLICY

Design for Standardization and Assembly

Policies and practices at Hughes reflect the importance of designing for manufacturability as an integral part of the design process. Hughes has established policies for cost reduction and product improvement which stress design standardization to establish uniformity through standardization components and hardware. These goals are accomplished by several means, including the following:

Manufacturing personnel become involved in the design activity as early as the conceptual stage.

Manufacturing provides continually enhanced and upgraded suggestions for the design engineering manuals.

Manufacturing has developed training programs for the design activity on subjects such as electro-mechanical assembly, through-hole printed wiring board assembly, high-speed through-hole PWB assembly, and surface mount PWB assembly.

Engineering Information Database

Hughes Aircraft's Tracked Requirements, Audits and Feedback for Information Control (TRAFFIC) program is a valuable technical information resource. TRAFFIC is a database containing :

Engineering and manufacturing standards
Contractual requirements applicable to various projects
Exceptions to contractual requirements
Military specifications
Configuration management data
Transition from Development to Production Templates

This information, including graphics data, is available on-line at Hughes MSG through personal computers using high-resolution screens for the graphics. The information can be searched for key words or phrases, lists can be created, and hard copy made. This on-line data will eventually replace all printed copies of manuals, standards, and procedures at MSG. The system will ensure the latest information is available to a wide variety of company personnel and reduce the time spent by engineering and production personnel searching for data. The system is versatile, user friendly, and should significantly improve communications within MSG.

Technical Symposia

Hughes Aircraft holds technical symposia for its employees. Management picks topics it wishes to stress. Outside speakers are invited to augument Hughes personnel. Presentations are documented and published in professional quality proceedings. Speakers are recognized by the inclusion of their career biographies and pictures in the proceedings. This will accomplish the following:

Signal employees on topics of prime interest to management.
Imply corporate policy in the selected area.
Cross-pollinate employees in different management units by the exchange of technical approaches, views, philosophy, etc.
Identify experts who could be contacted by other employees for advice and assistance.
Boost attitudes of professionalism among technical employees.
Recognize outstanding contributors.

"Lessons Learned" Feedback System

Corporate policies and practices at Hughes MSG are sensitive to the lessons learned on past programs. This is made possible by a formal lessons learned feedback procedure.

Manufacturing identifies production problems through the entire life cycle of a product (1) through intimate manufacturing involvement in the design process, (2) during manufacture of proof-of-manufacturing models, (3) during first article reviews, (4) through trouble and failure reports, and (5) through inspection records at product quality inspection points.

The manufacturing corrective action board gathers and passes the information to the Design Process Corrective Action Board (DPCAB), which is the focal point for improving design processes. It is chaired by the vice president for engineering and its members include senior manufacturing and design engineers.

The DPCAB ensures that lessons learned are incorporated into future designs by (1) directing changes to design process practices and procedures, (2) directing changes to company standards, (3) issuing a lessons learned bulletin, and (4) initiating needed training through the Engineer Training Committee.

Engineering Standards and Procedures

Hughes MSG has prepared an extensive series of engineering standards and procedures manuals which cover topics such as:

Standard Parts
Design for Producibility
Design for Testability
Configuration Management
Configuration Control
Engineering Design Management
Systems Engineering
Contract Requirements Flowdown
Design Review
Transition to Production
Design Process Corrective Action
Checking Engineering Documentation

Publication of these standards and procedures is necessary to impose design discipline by company management. Extensively documenting the many aspects of design, development, and transition to production permits all engineering personnel to know company policy and procedures.

DESIGN REVIEW

Design Review Coordinator

Each Hughes MSG laboratory has a designated design review coordinator responsible for ensuring that Hughes standards for design reviews are followed. These standards cover the specialities that must be represented on the design review panel, procedures for identifying action items, etc.

The design review coordinator is responsible for ensuring that action items identified by a design review panel are addressed within a prescribed time period, archiving design review data, and preparing summary reports.

Design review coordinators are senior project or staff engineers. Coordination of design reviews is only one of their responsibilities. They are headed by a division design review coordinator.

Detailed reviews are performed at the unit or sub-system level. The responsible unit engineer organizes the design review and selects the panelists. A monthly schedule of design reviews is distributed.

COMPUTER-AIDED DESIGN

Computer Aided Engineering and Design

Hughes MSG has aggressively implemented both mechanical and electrical Computer Aided Engineering and Design (CAE/CAD). Through the use of extensive circuit simulation, they have effectively eliminated the breadboard cycle from the development of digital systems. Simulations of analog circuits are performed to the extent that the technology permits.

The use of CAE/CAD for mechanical design and drafting has resulted in significant savings:

25% reduction in drafting costs
40% reduction in optics drafting manhours
30% savings in data preparation for optics analysis systems
60% savings in N/C programming
reduction of printed wiring fabrication setup from four weeks to one week.

Hughes Aircraft has invested heavily in CAE for both design and manufacturing. It appears to have placed a priority on integrating data from electronic and mechanical design tools to a single system.

Mentor Graphics software running on Apollo computers is used as front-end electronic CAE workstations. Apollo-Mentor was originally used only for schematic capture and was characterized as under used by Hughes MSG personnel. Apollo-Mentor is now used extensively for digital logic simulation and, to a lesser extent, for analog circuit simulation. Timing analysis and fault and other digital simulations are performed with Teradyne Lasar 6 software running on VAX computers. Printed wiring board (PWB) layout is performed on IBM computers using Interactive PRANCE/CADAM (IPC) software. CADAM is used for all mechanical CAD. Data transfer from Apollo-Mentor to VAX-Lasar 6 and IBM/CADAM is by a simple netlist.

2.2 TEST

INTEGRATED TEST

Design Testability Assessment

Hughes MSG has put in place major directive documents requiring products designed by MSG be evaluated for testability assessment. Projects are being evaluated for test thoroughness and fault isolation testing. Hughes MSG's general design for testability philosophy centers on reviewing circuits and making recommendations for incorporating testability criteria before designs are frozen. An important element of this philosophy is MSG's concern for developing commonality in automated test equipment between the development and production phases of a program.

In addition, Hughes MSG has created a testability panel consisting of personnel from *engineering, logistics support, producibility, factory* operations, and standards. The panel serves as a forum for discussing testability problems, lessons learned, and recommendations for improving techniques. The panel also provides consulting services to projects/programs throughout MSG.

2.3 PRODUCTION

MANUFACTURING PLAN

Universal Standard for Magnifying Power

Several years ago, Hughes discovered that many magnification aids are not of the advertised power and there is no recognized optical equation for determining magnifying power and no universally accepted standard for magnifying power.

Hughes corporate established a visual inspection task team leader whose responsibility was to develop near, short, and long-term solutions. The team developed a standard definition, analyzed and described magnifying power for visual magnification, and established realistic functional tolerances. The end result was the design and use of an instrument which measures magnifying power.

PIECE PART CONTROL

Edge Bar Coding of Circuit Boards

The sometimes difficult decision to surrender valuable circuit board real estate in order to accommodate board markings has been eased by developing a method for laser marking the part serial numb· . using bar codes on the edges of boards. Not only can the boards be tracked through the manufacturing process using these markings, but they can be more easily identified among densely packed adjacent boards when servicing the assembled system.

DEFECT CONTROL

Production Quality Indicators

Hughes MSG has implemented a very effective defect reduction and control system. It is a plant-wide process feedback system using points in the manufacturing flow that have been determined critical to the quality of the product. The points are called Production Quality Indicator (PQIs) for hardware manufacturing processes and Production Support Indicators (PSIs) for non-hardware operations; e.g., engineering drawings. The system functions as a real-time process control and also provides information for tracking defect causes and defect reduction. The indicators provide data required for corrective actions to maintain high product quality. These data are prominently displayed on the factory floor and reproduced in key management reports.

Corrective Action Boards

Corrective Action Boards (CABs) are used at Hughes MSG to manage corrective actions at all levels throughout the factory. The boards meet regularly and review data from the work measurement system; the scrap, rework, and repair system; Production Quality Indicator (PQI) and Production Support Indicator (PSI) data; audits; and Team Activity reports. The CABs identify required corrective actions, assign responsibility, and conduct follow-up to ensure actions are completed. The CABs are very effective because they have access to excellent real-time information from the factory floor and can provide the appropriate level of management attention to individual problems.

Scrap, Rework, and Repair (SRR) Reduction System

Scrap and rework are typically major cost drivers in defense electronics but often the elements and sources of these costs are poorly understood and managed. Hughes MSG has developed a very effective system for tracking and managing Scrap, Rework, and Repair (SRR). The system provides a means to accurately identify SRR costs; segregate them into discrete, manageable elements; and establish meaningful reporting and control techniques. Its objective is to understand and control SRR elements to achieve corrective action and cost reduction.

A key element of the Hughes MSG system is recognizing that traditional techniques do not provide the most accurate picture for identifying and effecting corrective action because, while they compare SRR labor hours to total labor hours, they do not account for material cost of scrap or consider product output. The MSG system measures SRR as a percentage of the value of product produced during the same time period. Using the work measurement system (described separately), each element of SRR is identified by a rework code showing whether the cause was related to workmanship, engineering, test, vendor, or process. Using this information, those responsible for performing and managing manufacturing operations can initiate corrective actions and establish SRR reduction goals. Goals are established at multiple management levels from factory level to work center level. Annual goals are set and re-evaluated semi-annually. These goals form the basis of performance measurement and identification of corrective action and also provide the basis for future program estimates and proposals.

SPECIAL TEST EQUIPMENT

Optical Augmented Semi-automatic Inspection System (OASIS)
Optical Semi-automatic Inspection (OSI)

Several years ago, Hughes MSG discovered that many magnification aids were incorrectly marked as to their magnifying power and were poorly designed for inspector comfort. As an outgrowth of their efforts to solve these problems, Hughes MSG designed two special optical inspection systems: Optical Augmented Semi-automatic Inspection System (OASIS) and Optical Semi-automatic Inspection (OSI).

OASIS is a system developed for the repetitive visual inspection of products having separate points to be inspected. The system consists of a stationary optical magnification aid and a computer-controlled table. The table is programmed to present the inspector with inspection points at their best visual aspect for the optimum time. In addition, the system has features which reduce inspector fatigue, thereby reducing the opportunity for error.

OSI is an advanced simple axis microscope designed for solder inspection. It is a 4X/10X long eye relief, enhanced depth perception microscope. The system consists of a one-eye stationary optical magnification designed for inspector comfort. There are plans to incorporate a computer-controlled inspection table which would decrease inspection times.

In the development of the OASIS and OSI, Hughes MSG used a novel optical design which differs significantly from the nearest prior technology.

COMPUTER AIDED MANUFACTURING

Computer Integrated Manufacturing

Hughes MSG has implemented a shop floor CIM system in its microelectronics (hybrid) manufacturing area. The installation provides shop floor control by tracking work-in-progress, controlling where it goes, collecting history and quality data, and routing rework.

Approximately six years ago, when Hughes MSG made the decision to pursue CIM, there were no commercially available packages which fitted their needs. They decided to create a package. This involved designing the hardware architecture and writing all the software.

The computer hardware includes an IBM 3081 and a Computervision CGP/200C CAD/CAM system. Hughes is in the process of standardizing on CADAM as a CAD/CAM system. PC-AT and Motorola 68000 microprocessors serve as the interfaces between the Tandem shop floor host computer and individual workstations. The following equipment is currently integrated into the CIM system:

Quantrad Laser
Universal die attach
Hughes Tucson die verify
Hughes Model 2600 wire pull
K & S wire pull
HP functional test
SSEC seam sealer
AMI burn in
SMI molytab/punch

Interface is made from the operator to the workstation through a combination of bar code readers, touch screens, and keyboards.

Some important features of the shopfloor CIM system are: paperless planning, lot-size-one flexibility, and computer controlled machinery. The system electronically distributes instructions to the operators at their workstations. This insures the operator is following the precise instruction for the work in progress, as well as reducing the amount of paperwork needed. Hughes MSG reports that by implementing the system, they were able to increase production by 330% while maintaining employees at the same level. The commitment to the system is showing benefits in other areas of the facility. There are plans to implement the system in the circuit card assembly area with people now experienced enough to accomplish the task quickly.

Automated Hybrid Production Equipment

Hughes MSG has invested considerable resources in upgrading their hybrid manufacturing facility. In order to automate the facility, Hughes MSG has bought off-the-shelf equipment that can be used for die attach, wire bonding, and package sealing. Through its in-house engineering lab, Hughes MSG has developed equipment where none has been available to meet specific production problems. It is quite innovative to have the in-house capabilities to design and develop unique production equipment.

Two notable items that have been designed and fabricated by Hughes MSG engineers are the auto wire verify system and the auto wire pull tester. The auto wire verify system is semi-automatic equipment used to verify that hybrid components have been wire bonded correctly. This is done after wire bond pull and prior to pre-cap visual inspections. The equipment also has some utility in discovering other defects prior to the pre-cap inspection. A very interesting feature of this system is the overlay of CAD database information on the computer screen to assist the operator in verifying a proper wire bond location. CAD information is used in other areas such as die attach, and this is considered to be a best practice.

The second piece of unique equipment designed and built by Hughes is an automatic wire pull tester. This tester receives test requirements via a CIM interface unit and automatically sets up the parameters necessary to do 100% pull test inspection. Based on the part number under test, the wire locations and pull force are automatically provided to the tester. The tester uses optical techniques in addition to the design data base to locate wires that may have been mis-registered during the bonding process. This tester is currently commercially available from Hughes Carlsbad Industrial Products Division as Automatic Pull Tester Model No. 2600.

Overall, Hughes MSG has done an excellent job in automating their hybrid assembly operation. They have achieved many quality and productivity improvements including: reducing touch labor by more than 50%, reducing scrap by more than 35%, increasing first test yields from 68% to 85%, reducing rework by 25%, reducing production control support by 25%, and demonstrating a 95% inventory accuracy.

2.4 FACILITIES

MODERNIZATION

Central Stores

An automated material handling system has been installed which attempts to track each part that enters or leaves the system. The small-parts hardware consists of eighteen Richard-Wilcox 2050 rotating bin carousels and an IBM PC-AT and Intermec 8635 bar code printer at each carousel connected to a 3-Com network server. This system is linked in turn to a Tandem computer for inventory control and to the IBM system for Material Requirements Planning (MRP). The software, developed by Hughes MSG and Intermec for the carousels and by Hughes MSG for MRP and inventory control functions, provides on-line control capabilities at all levels.

Black conductive corrugated paper trays are used in the carousels instead of plastic. At an average cost of $1.46 each, versus $24-$30 for conductive plastic, they represent a substantial cost savings even when considering average service life.

Kitting is not done at the end-of-carousel pick-put stations, but rather at a single kitting station. As items from the carousel stations are fed via conveyor to the kitting operator, the item bar codes are wanded. Adjacent to the operator are racks containing various kit totes, each having a signal light associated with its rack position. The operator simply places the part in the illuminated tote, and the terminal notifies when a kit is complete.

The potential cost reductions are significant. Floor space has been reduced from 225,000 to 24,000 square feet, seven locations have been consolidated to one, three shifts were reduced to one, overtime has essentially been eliminated, and pick-put times average 60 seconds.

Current operation is essentially paperless, helping create inventory accuracies greater than 95%. Industrial Engineering feels that most of the remaining inaccuracies are created by their single remaining piece of paper, a receiving "induct" form, and is studying methods to electronically streamline this.

Engineering Analysis Laboratory

The Engineering Analysis Laboratory provides plantsite technical engineering support for components, materials and processes. It also provides components and materials failure and chemical and metallurgical analysis.

What makes the approach a best practice centers about the failure analysis-destructive physical analysis concept and its application to problem solving, corrective action, and problem avoidance. Failure analysis is a science and, as such, is used to determine the reason for failure whether related to a component, solder joint, or metal fatigue, for example. By then taking this analysis, a corrective action can be implemented that really corrects the problem. This is a key ingredient to any successful part of corrective action implementation and the resulting improvement to reliability.

Failure analysis laboratory equipment

Magnaflux real time X-ray, MXF-150M
Cambridge 200 and 90 scanning electron microscopes
Princeton Gamma Tech System 4 X-ray analyzer
Tegal plasmoline plasma etcher, 211

Chemical analysis laboratory

Hewlett Packard Model 5995 gas chromatograph/mass spectrophotometer
EG7G Model 384 analyzer
Varian 3700 gas chromatograph
Analect Fourier 6160 transform infrared spectrophotometer
Liquid chromatograph
Dynamic mechanical thermal analyzer, Polymar Labs DMTA2
Perkin Elmer TA&7 thermal analyzer
Perkin Elmer 3030B atomic absorption spectrophotometer

Metallurgical Laboratory

Cambridge 600 stereoscan scanning electron microscope
Kevex X-ray analyzer
Leci DM400 microhardness tester
Wilson Rockwell hardness tester
Hollis & Multicore meniscographs
Instron Model 1125 universal tensile tester

2.5 LOGISTICS

TRAINING MATERIALS AND EQUIPMENT

Personnel Development

Hughes has established a formal training program for the advancement of engineering personnel in the disciplines of project (unit) engineering. The advantage of company training over general management training is that specific company policies, procedures and standards can be taught.

Specific topics covered are:

The role of the Project (Unit) Engineer
Design for quality
Design disciplines
Design resources
Design for transition to production

The courses are taught by Hughes project engineers and managers. Courses are held one night per week for two hours over sixteen weeks.

2.6 MANAGEMENT

MANUFACTURING STRATEGY

Planning Packaging

The planning package contains the step-by-step process instructions required for operator assembly of the many complex devices fabricated on the Hughes MSG factory floor. A package is generated for each assembly. The techniques, equipment, and processes are developed with high yields, high reliability, and low cost in mind. Considerable discipline and control are demonstrated to ensure correct instructions are available to the operator. Each package is thoroughly reviewed before release to the manufacturing floor. As instructions evolve and before final release, they are completely checked out with the operator, equipment, procedure, and product. The package is currently paper, but it is in the process of being integrated into the Computer Integrated Manufacturing (CIM) paperless factory program.

PERSONNEL REQUIREMENTS

Career Enrichment Program

As part of its strategic plan to position itself competitively over the next decade, Hughes MSG has begun its Career Enrichment Program (CEP). The CEP is a joint management-union effort designed to enhance work force productivity by providing hourly workers with career advancement and increased pay for skill development. Team spirit will be cultivated even as individual productivity is rewarded. The goal: achieving a competitive, stable, and cohesive work force.

The program was developed using lessons learned from other companies with similar programs. Good communications between the union, management, and initial participants were key to developing a spirit of trust and cooperation. Gradual implementation using pilot programs over the next 18 months is planned. Workers are encouraged to acquire additional skills to fill new job classifications which combine several former classifications into one job. Other features of the program include: no jobs lost as a result of the program, extensive OJT and skill training, tuition assistance and training programs instituted at local schools, pay for new knowledge or skills even if not used, and career-path advancement.

The CEP is an aggressive program for achieving major cultural change within the company that, at inception, appears well planned and readily managed.

SECTION 3

PROBLEM AREAS

3.1 DESIGN

DESIGN POLICY

Incorporation of Military Specs & Standards into Corp. Databases

Hughes MSG is experiencing problems obtaining military standards and specifications in a format that will allow it to enter them into the automated requirement/document database. Hughes has worked with Defense Standardization Program Office, Defense Electronic Supply Center, Naval Forms and Publications Center, and Air Force ESD/AVSE, but has not yet received the documents in an automated format.

Hughes MSG also stated that present military standards/specifications page formats are not compatible with typical personal computer 80 character/line formats. Inputters are forced to either extend the screen or to wrap the ends of sentences on the monitor.

Availability of MIL-SPECS on Electronic Media

Hughes MSG appears to have done an excellent job of making it's engineering procedures and practices available on most of its computer terminals. Hughes MSG has also manually entered some key MIL-SPECS. It would like to have all MIL-SPECS available on-line, but there is no official source on electronic media.

Hughes MSG has identified several agencies who have electronically transcribed MIL-SPECS to electronic media. In particular, Defense Electronic Suppply Center (DESC) has a considerable number of these specifications entered into a Wang word processing system. However, DESC refuses to furnish a copy of this media despite the Hughes MSG offer to pay for the copying and media costs and to sign a release in the event of errors in the electronic transcriptions.

It would be to the DoD's advantage to provide MIL-SPECS already available on electronic media to interested contractors and to establish a program and policy to make official MIL-SPECS on electronic media as soon as possible.

3.2 PRODUCTION

MANUFACTURING PLAN

Inspection to Specific Military Standards

Hughes MSG stated that both WS6536 and DOD-STD-2000 still need attention and, if not changed, will cause major difficulties and extensive non-reliability related cost increases to the inspection process and to the product itself. Hughes MSG interdepartmental correspondence of 30 July 87 (Ref. 5D60.7-87/215) and Hughes MSG letter of 16 Sept. 87 (Ref. T-24456) detail further changes to 6536 and 2000.

SECTION 4

SUMMARY

Hughes MSG has implemented a defect reduction and control system through the collection of data at critical points in the manufacturing flow. These points, called Production Quality Indicators (PQIs) for hardware manufacturing processes, provide the data required for corrective actions to maintain high product quality.

Information is available to enhance the product design process through the Hughes Aircraft's Tracked Requirements, Audits, and Feedback for Information Control (TRAFFIC) program database. Hughes MSG has stressed, through policies and programs, that a product is to be designed for testability

Hughes MSG has instituted a successful Computer Integrated Manufacturing (CIM) system in their hybrid microelectronics manufacturing area.

The point of contact for this BMP survey is:

Mr. Eugene Vitale
Manager, Manufacturing Technology Systems
(602) 794-1612

Hughes Aircraft Company
Missile Systems Group
Bldg. 801, MS G10
P.O. Box 11337
Tucson, AZ 85734