

AIR FORCE ELECTRONICS MANUFACTURING TECHNOLOGY

OVERVIEW

The Air Force Manufacturing Technology (ManTech) program from the 1970's was multifaceted to leverage funds, companies, strategies, other Air Force laboratories, and weapon systems development programs. Coordination with the Air Force Product Divisions was extensive and employed direct system program office interfacing, studies, and strategy development. Studies and strategies were developed in concert with industry, tri-services, and other government agencies. Major programs were jointly managed and co-funded by other DoD agencies such as DARPA, SDI, NIST, Army, Navy and industry.

Details from three major efforts will demonstrate the approach and results of the Air Force Electronics ManTech Program:

Mid-Wave Infrared (MWIR) Mercury-Cadmium-Telluride (HgCdTe) Focal Plane Arrays

Contractor: Rockwell International Electro-Optical Center, 1987.

Funding: Strategic Defense Initiative (SDI), Passive Sensor Technology Office.

Product Division: Space Division, Los Angeles, CA

Systems: Strategic Surveillance, Tactical Missiles,

Program Goals:

1. Reduce the cost of a hybridized detector 256 X 256 pixel array to 5-10% (or 10 to 20 times cost reduction) of the baseline cost at the beginning of the program.
2. Demonstrate a throughput of 2-20 million acceptable pixels per year in a pilot production run at the end of the program.

Program Results:

Cost reduced from \$32,600 to \$1,700 per acceptable hybridized array: 19 times reduction in cost.

Yield of acceptable hybridized array for baseline run was 1.35% versus 13.8% for the pilot production run: 11 times increase in yield.

Baseline run throughput of acceptable pixels was 0.2 million per year versus 3.5 million acceptable pixels per year for the pilot run: 18 times throughput increase.

In addition, Design of Experiments (DOE) techniques were used successfully and implemented as a cost effective statistical analysis tool.

Phased Array Radar Transmit/Receive (T/R) Modules

Microwave T/R Modules for Phase Array Radars were included in the Electronics ManTech Program over many contracts and years. The T/R modules benefited from many earlier and then-current programs in GaAs applications, electronic packaging, testing, signal processing, and cost reduction. The earlier programs included GaAs field effect transistors for AMRAAM (AIM 120) and solar cells for satellite power conversion. Fortunately, the T/R module also benefited from the Electronics Manufacturing Process Improvement (EMPI) Program approaches with emphasis on Six Sigma process capability, Design for Manufacturing, Assembly, and Testing and continuous improvement. An early design for an active electronically steerable array (ESA) radar required approximately 2000 modules.

Contractor: Westinghouse Electric Corp (Northrop), Texas Instruments (Raytheon), Hughes Radar Systems (Raytheon), Litton Industries, 1989
Funding: Air Force ManTech, Industry Cost-Sharing
Product Division: Aeronautical Division, W-PAFB, OH
Systems: F-22, F-35.

Program Goals:

- Implement Manufacturing Design for Assembly, Test, and Low Cost while progressing to the production cost goal of \$400(1985\$) per module. (The laboratory designed module cost estimate was unaffordable at over \$13,000.)
- Define and implement process models and process capability to reduce defects and increase yield.
- Conduct a producibility demonstration of 550 modules over 20-day period.

Program Results:

Process	Capability
Soldering Reflow	Defects Reduced by 80%
Component Placement	Defects Reduced by 98.2%
Flip Chip Assembly	Yield 95%
Test Time/Module	Reduced from 6hrs to 4minutes
Total Module Yield	Yield 85%

Approximate Cost Per Module	\$2021 (1993\$)
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Program Transition:

Besides the F-22 and F-35 insertion of ESA radars, the Air Force may use newer designs for synthetic aperture radars if needed for the Unmanned Combat Air Vehicle (UCAV) and in the Space Based Radar (SBR). The Navy transitioned many of the production techniques to the Cooperative Engagement Capability (CEC) program with ITT.

Sensor Fused Weapon (SFW) Infrared Sensor

Contractor: Subcontractor to SFW Prime Contractor (Sole Source Award to Developer of Proprietary Sensor Assembly) 1989

Funding: Air Force ManTech

Product Division: Armament Division, Eglin AFB, FL

Systems: Sensor Fused Weapon, Wide Area Anti-Armor Munitions (WAAM)

Program Goals:

1. Develop and verify effective manufacturing techniques, processes, and controls for double element PbS/PbSe infrared detector assemblies.
2. For a production rate of 400 sensor assemblies per day, reduce labor (assembly and test) to 0.3886 hrs/unit and increase yield to 83.49%.
3. From the baseline production of 10 units/day, reduce the cost per sensor assembly from \$2240 each.

There were 19,810 WAAM dispensers planned. Each dispenser housed 40 skeets and 40 infrared sensors. A total of 792,400 sensors would be produced over 10 years. Shelf life required was 10 years plus 1 year inserted in the skeet.

The performance requirements of the sensor assembly were known and fixed throughout the program. The program included the subcontractor's efforts to pursue Design for Manufacturability and improved test equipment and techniques.

Program Results:

<u>Program Milestone</u>	<u>Units/Day</u>	<u>Yield</u>	<u>Labor Hrs/Unit</u>	<u>Unit Cost</u>
Baseline	10	----	----	\$2240.00
Intermediate Run	400	52.37%*	4.11	\$431.31
Production Run	400	46.15%	1.72	\$385.53
Improvements#	400	61.36	0.95	----

Recommendations made to the contractor based on ManTech Program results.

* Yield calculation is questionable.

Cost avoidance in full production resulting from this program was very significant.

Note: After full production was underway, the contractor verbally informed ManTech that the Unit Cost was \$189. This comment was not verified.

COST REDUCTION EMPHASIS IN MANTeCH PROGRAMS

Major studies were conducted that assessed system requirements driving technical needs of the overall ManTech program. Many important Electronics ManTech Program needs led to an emphasis on component availability with cost reduction goals to effect near term system insertion.

Electronics Systems Division Cost Reduction Conference (1978)

Selected Electronics ManTech Projects:

- Improved High Voltage Power Supply Packaging
- Direct Pattern Generation of PWBs
- Improved Manufacturing Processes/Materials for Chassis
- Printed Wiring Board Electro-deposition Processes
- Automated Inspection of Printed Wiring Assemblies
- Electronic CAD/CAM for Reliable Low Cost Subsystems

Air Force/Industry Armament Division Cost Reduction Study March 1980

Selected Electronics ManTech Projects:

- Permanent Magnet YIG Filters (AIM-120)
- GaAs IMPATT Diodes (AIM-120)
- Microwave Integrated Circuits (AIM-120)
- Field Effect Transistors (AIM-120)
- Solid State Transmitter Production Program (AIM-120)
- Thick Film Ceramic Circuit Cards (AIM-120)
- Copper Multi-layer Ceramic Cards (AIM-120)

Other ManTech Projects from AD Cost Reduction Study

- Copper Self-Forging Liners for WAAM
- Air Inflatable Decelerators
- Ammonium Perchlorate Recycling

PROCESS CONTROL AND STATISTICAL ANALYSIS IN THE ELECTRONICS PROGRAMS

Strategy 2000 was an internal programmatic assessment in the early 1980's that led to the theme: Affordable Quality Electronics. The affordability issues of electronics in general were improving in commercial areas such as integrated circuits, hermetic chip packaging, and signal processing. Military applications were hampered by component availability and excessive cost of unique requirements in tactical aircraft, munitions, space systems, and data analysis. Affordable Quality Electronics was a strategy that resulted from an influx of personnel having commercial experience. The primary focus on affordability was the implementation of statistical process control (SPC) under the umbrella of Electronic Manufacturing Process Improvement (EMPI). These approaches provided guidance for the objectives and goals of the Electronics ManTech Program to emphasize lower cost, process control, and technical

transfer of new electronics capabilities that met the performance requirements of Air Force and DoD weapons systems.

Electronics Manufacturing Process Improvement (EMPI)

The EMPI projects employed variability reduction techniques leading to improved process control. Statistical Process Control, based on Motorola's Six Sigma program, began with Design of Experiments to establish if a process is both stable and capable and provides throughput within specification.

Selected Electronics ManTech Projects:

- EMPI for Printed Wiring Assemblies --- Surface Mount Technology (SMT)
- X-Ray Laminography as a Process Control Tool --- SMT Processes
- Low-Cost Manuf of GaAs MIMIC Low Noise Amp --- MIMIC Fabrication
- EMPI for Fiber Optic Gyros --- Coil Winding
- EMPI for GaAs Power Amplifier --- MIC Fabrication
- EMPI for GaAs Flip Chip Assembly --- MIC Bump Fabrication
- Advanced Data/Signal Processing --- HCC/Solder/Test PWBs

COMMERCIAL/MILITARY INTEGRATION AND LEAN MANUFACTURING

Manufacturing 2005 was a top level study with industry, Air Force, DoD leaders, and academia to assess changes in programmatic approaches and industrial leverage to enhance business practices, lean manufacturing, affordability, assured quality, and integrated process team (IPT) management. The Manufacturing 2005 results were demonstrated and implemented by establishing projects jointly-managed and cost-shared with industry.

The projects were called Pathfinders and Industrial Base Pilots.

- The Pathfinders were small efforts to test approaches or study alternatives to develop further in the Pilot programs.
- The Industrial Based Pilots were larger programs managed with a System Program Office (SPO) and the major contractor to effect ownership and rapid technical insertion if adequately demonstrated.

Industrial Base Pilot Programs

Military Products from Commercial Lines (TRW Electronics)

The IPT co-managed the efforts to produce military electronics on a commercial electronics line at lower cost and comparable quality to those produced on a dedicated military production line. The contractor, TRW, selected an avionics module used both in the F-22 (ATF) and in the RAH-66 (Comanche Helicopter) as the test article. Design for Manufacturability was implemented and business practices were evaluated for commonality and overlap. The final demonstration projected the cost

would be reduced by 38% with a reduction in weight of 19% with the same quality and performance.

Military Products Using Best Commercial/Military Practices (McDonnell Douglas)

The IPT had the objective to jointly manage the program with AF personnel, Contractors and the C-17 SPO together in full partnership in business environments to achieve gains in affordability. The IPT organization included the Defense Contracts Management, Northrop Grumman Vought-Commercial, McDonnell Douglas Aerospace, C-17 SPO, and ManTech personnel. The production article was a new designed Advanced Composite horizontal tail which could replace the current tail on the C-17. The final acceptance was a full scale structural test that exceeded performance requirements. The program demonstrated a reduced production cycle time with lifetime savings accruing to the C-17.

ELECTRONICS MANUFACTURING PROGRAM UP TO THE EARLY 1980's

Radiation Hardened Integrated Circuits (1972-83)

- Silicon on Insulating Substrate Devices
- MNOS Memories for Satellites
- Radiation Hard CMOS/SOS Microprocessors
- Radiation Hard Analog/Digital Converters Characterization
- Large Scale IC Product Testing
- Operational Amplifiers for Missiles and Satellites
- Microprocessor Support Circuits
- CMOS/SOS Read-Only-Memories
- Nonvolatile Memories

Traveling Wave Tubes (TWT) (1973-84)

- Miniature TWT (ECM)
- Dual Mode TWT (ECM)
- TWT Amplifier for Space Systems (CCCI)
- Millimeter Wave TWT (CCCI)
- EH Band TWT (ECM)
- IJ Band TWT (ECM)
- Klystron Power Amplifier (CCCI)
- Space TWT and TWTA (CCCI)
- Advanced Dispenser Cathodes (CCCI)

Electronic Packaging (1976-82)

- Improved Manufacturing Processes for Polyimide Printed Circuit Boards
- Conformal Coatings for PWBs
- PWB Processes/Control
- High Reliability Wire Bonding in Hybrid Circuits
- High Speed Digital Processing Packaging
- High Reliability Pkg using Hermetic Chip Carriers with Compatible PWBs

GaAs Solar Cells (1981)

Manufacturing processes, handling, test, and delivery of GaAs solar cells to provide satellite power required for classified communication and reconnaissance satellites.

Infrared Materials (1973-82)

- ZnSe High Power Lased Windows (ALL)
- FLIR Fabrication and Assembly
- ZnS Infrared Dome
- Numerically Controlled Machining of IR Materials
- Infrared Focal Plane Array Testing
- Detector Grade Intrinsic Silicon
- ZnSe/ZnS Sandwich Type FLIR
- IR Maverick Detector Arrays (AGM-65D)

Microwave Solid State (1974-83)

- GaAs Production (Epitaxy)
- GaAs Microwave Substrates
- Precision Extruded Aluminum Waveguides (AWACS)
- Ferrite Phase Control Modules (AESAs)
- Ferrite Phasers (AESAs)
- Stress Compensated Crystal Resonators
- High Reliability Packaging of MICs
- Pave Paws UHF Power Transistors

Batteries (1976-84)

- Ni-Cd Batteries
- Lithium Batteries for Life Support Applications
- Ni-H₂ Battery Cells (Space Power)
- Thermal Battery Production (Tactical Missiles)

Wire Harness Manufacturing

By improving the processes for wire and cable handling, termination, and connectors, harness manufacturing control and quality for system insertion were demonstrated. (B-1)

FINAL NOTE: ManTech 2015: Air Force Manufacturing Technology Strategic Plan, was completed in 2002. It was conducted under Contract F33615-00-D-5543. The study was led by UTC with principal subcontractors GRC and Anteon. A separate document for the Electronics Systems Sector was prepared by Mr. Fenter and presented to Mr. William Russell, Chief, Electronics Branch, ManTech Division. This report evaluated and recommended Themes and Initiatives for consideration.