CHAPTER 3: CASE STUDY

MILITARY PRODUCTS FROM COMMERCIAL LINES INDUSTRIAL BASE PILOT PROGRAM

3.1 Introduction

The preceding chapters have discussed the evolution of the U.S. defense industry through years of declining defense budgets, limited new program introductions, and acquisition reforms. As documented earlier, a major thrust of acquisition reform has been to foster military-commercial industrial integration. In particular, a number of so called Industrial Base Pilot (IBP) programs have been inititated by the DoD to help expedite military-commercial integration. The Manufacturing Technology Directorate (MANTECH), now a part of the U.S. Air Force Laboratory, has been the lead agency for key initiatives. One of these initiatives is the Military Products from Commercial Lines (MPCL) program.

This chapter will examine this pioneering and successful pilot program, with emphasis on its efforts toward integration of the supply chain with the manufacture of electronic assemblies. In the first section the background and evolution of the program is discussed, along with an overview of the program structure and organization. The next two sections describe the defense and commercial industry business practices separately, followed by a comparison of them. Finally, the last section looks at the approach used by the IBP to overcome the differences in the business practices in each supply chain.

3.2 The Industrial Based Pilot Program

3.2.1 Background

The MPCL program can trace its roots to a major investigation of the defense industrial base initiated by the Air Force Aeronautical Systems Command (ASC) known as "Manufacturing 2005." The study found that future industrial base strategy would require the means to operate in an environment of decreasing defense budgets, changing enemy threats, and the new realities of the commercial marketplace (Kinsella, 1996). One major conclusion of the 1991 study was that the DoD should facilitate the integration of the commercial and defense industrial sectors. To accommodate such an environment, it was recommended that the DoD make adjustments to maintain a much smaller defense industrial base and to encourage organizational culture and business changes to facilitate this smaller and more commercial industrial base.

Six specific areas of the industrial base were identified by the study as areas for focused attention and additional study:

- Integrated Product and Process Development Methods (IPPD)
- A focus on quality
- Commercial and military integration
- International sourcing
- Flexible and Lean manufacturing
- Vertical partnering

Following the recommendations of this study, Wright Laboratories at Wright-Patterson Air Force Base (WPAFB) issued a Broad Area Announcement (BAA) in 1993 requesting proposals to address these areas. It was in response to this BAA that TRW Avionics Systems Division (ASD) proposed the dual-use production of F-22 Raptor and RAH-66 Comanche avionics modules. Specifically, the IBP is one program created to establish the feasibility of this type of integrated manufacturing--a principal component of commercial/military integration (Kinsella, 1996).

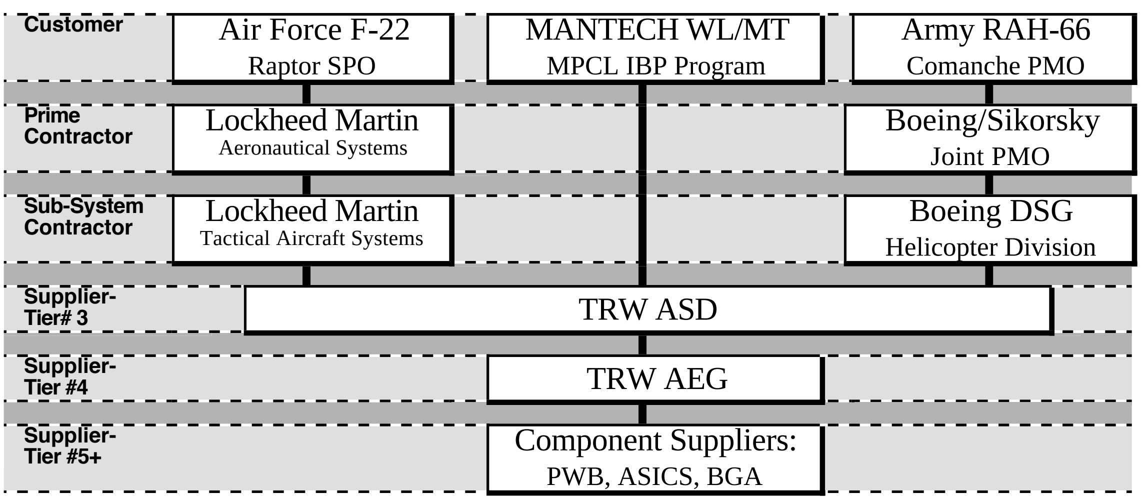
3.2.2 Program Description

The program that TRW ASD proposed for dual-use manufacturing is the Communication, Navigation, and Identification (CNI) Avionics Suite. This electronics suite consists of 38 separate but fully integrated packaged electronics assemblies, also known as standard electronic modules (SEM), designed with common interfacing specifications for installation on the new F-22 Raptor air superiority fighter. Additionally, these modules are jointly compatible with the RAH-66 Comanche helicopter program. At the time of the MPCL proposal to MANTECH, TRW ASD was already the contracted EMD supplier for these CNI avionics modules to both the Air Force and the Army.

The dual-use proposal was to subcontract the manufacture of some of these CNI avionics modules to a commercial division of TRW, which produces electronics for the automotive and heavy industries markets, known as TRW Automotive Electronics Group (AEG). Since TRW AEG produces high volume electronic assemblies that are somewhat similar to the CNI modules, it appeared to be a ripe situation for working through the design, manufacturing, and business issues involved with dual-use manufacturing, while providing TRW with a vehicle for technology transfer between operating units of the corporation.

Although the IBP program entails the Dual-Use manufacture of the CNI modules, it is contractually separate from the contracts let to TRW ASD for the EMD phase of the F-22 program and RAH-66 program avionics systems. Figure 3.1 illustrates these relationships.

Figure 3.1 CNI Electronics Suite Contractual Relationships



(Source: Adapted from Openshaw, 1996)

3.2.2.1 TRW Avionics System Division (ASD) Description

ASD is a subdivision of the larger TRW Space & Electronics Group (SEG) which designs, engineers, and manufactures a broad array of military and space products, from unmanned aerial vehicle systems to electro-optical systems for satellites. In addition to the CNI avionics suite, ASD develops electronic warfare (EW) products, antenna systems, modeling and simulation software, and also provides leading-edge engineering support services at Air Force Logistics Centers (Aviation Week, 1997).

3.2.2.2 TRW Automotive Electronics Group (AEG) Description

The TRW Automotive Electronics Group is a leading high volume tier-1 and tier-2 supplier of electronic assemblies to the automotive and heavy industries markets. The 202,000 sq.ft. production facility, located in Marshall, Illinois, produces an average of 16,404 units/day on six production lines, with annual volume per assembly of 400-800,000 units. These products are delivered to 14 customers in 38 locations. Customers include Caterpillar, Chrysler, Ford, Honda, and numerous other automotive original equipment manufacturers (OEM). Current products include electronic safety systems, such as single point sensors and airbag diagnostic units, and electronic convenience systems, such as body and engine computers, transmission controllers, steering controllers, and seat memory modules (Groth, 1997).

TRW AEG is a full service supplier with strong engineering capabilities. While one customer may design an electronic assembly and simply source TRW AEG to produce and deliver the final product, others require more engineering involvement. This involvement is particularly true with the automotive OEM customers. Although some product assemblies have "core" functional designs developed independently by TRW AEG, the interfacing and packaging requirements at a minimum change between customers. TRW engineers work on IPTs with the OEMs to design products which utilize either new or current "core" electronics to meet the performance specifications and cost targets of these customers (Groth, 1998).

3.2.3 Goals of the IBP Program

The IBP program has the stated goal of demonstrating that military products can be produced on a commercial production line with the following characteristics, compared with those produced on a military line:

- lower cost
- comparable quality
- equivalent functionality

Critical to the success of the IBP are the implications of flexible manufacturing technologies and process technologies which represent key enablers for taking advantage of commercial electronics production lines. Identification of best practices and transferring the lessons learned to the entire defense acquisition community are also key objectives of this program (Kinsella, 1996).

3.2.3.1 "Four Wins"

At the beginning of the MPCL program, a "Four Wins" scenario was defined, which established the expectations of each of the four major players in the program. The "Four Wins" have been used throughout the program as a basis for making management decisions. Below are the Benefits provided to each major constituent (Kinsella, 1996) .

TRW AEG (commercial supplier)

- Increased business potential resulting from qualification for manufacture of military hardware
- Acquisition of advanced process technology
- Acquisition of infrastructure technology

F-22, RAH-66 Program Office

- 50% cost savings for electronics modules
- Functional equivalence
- Schedule compatibility
- Transfer of business practices to benefit DoD systems

MANTECH

- Change agent for a commercial-military industrial base
- Risk reduction for DoD business with commercial manufacturers
- Documentation and transfer of validated practices
- Demonstration of pilot strategy viability

TRW ASD (military contractor)

- 50% lower production Cost
- 50% reduction in design cycle time
- Lean enterprise processes
- Seamless partnering with commercial companies

3.2.4 Organization of the Pilot Program

The organization of the MPCL pilot program was structured around three integrated product teams (IPT), with the tasks required to make the program successful allocated to each . The goals and objectives of each are described below.

Business Practices and Policies IPT. The overall objective of the Business Practices and Policy IPT (BP&P IPT) was to integrate the military and commercial business practices such that TRW AEG was excepting and was impacted as little as possible. To this end, every effort was made to utilize the commercial practices already in place at TRW AEG (IBP BP IPT, 1995).

Manufacturing Infrastructure IPT. The manufacturing infrastructure IPT (MI IPT) was charged with evaluating, defining, and implementing a concurrent engineering environment (CEE) and a computer integrated manufacturing (CIM) system. These are two areas critical to the lean product development and production of the CNI electronics modules to reduce development time, reduce cost, and improve quality. The management of workflow is critical to a successful concurrent engineering environment. These components include product data, communication between participants, design and manufacturing involvement, and concurrent engineering compatible processes (IBP MI IPT, 1995).

Process Technology IPT. The objectives of the Process Technology IPT (PT IPT) were focused on commercial and military integration. Specifically the team was tasked with comparing the military and commercial facility processes, selecting detailed designs to include in the IBP program, developing a cost baseline to understand the cost distribution for the selected designs, and the overall demonstration of Dual-Use compatibility. Additionally, the team was asked to validate the business practices and polices IPT and manufacturing infrastructure IPT recommendations (IBP PT IPT, 1995).

3.2.5 Module Selection

Modules considered for the IBP program were selected from the CNI Systems of the F-22 and RAH-66 Comanche under development at ASG. The IBP program sought to pilot three or more of the modules. The module selection criteria were as follows:

- *Commonality among weapons systems*--to ensure broad applicability and critique of program results.

- *Multiple use within systems*--to maximize production volume/scale economies.
- *High design-to-cost*--to maximize cost savings opportunities of IBP program.
- *SEM-E module construction*--to utilize existing equipment on the AEG assembly line.
- *Automation compatibility*--to minimize line disruption and off-line processes.
- *Digital/Analog Circuitry*--to align technology with AEG capabilities.
- *Common ASG/AEG component suppliers*--to benefit commercial procurement at AEG.

Base on these criteria categories and a weighting for each, the Pulse Narrowband Processor (PNP) module and the Radio Frequency Front End Controller (RF/FEC) module were selected for inclusion in the IBP program. A third module, the Low Latency Signal Processor (LLSP), was selected for a paper design study only (IBP PT IPT, 1995).

3.3 Defense Industry Practices at TRW ASD

This section reviews the business practices and environment at TRW ASD as the "typical" defense industry business. Since the industry is going through such drastic changes, the discussion will focus on the state of the industry in the traditional sense, identifying areas of change when appropriate. The material in this section is referenced to both the IBP released documentation and my site visits in January and February 1998.

3.3.1 Culture

Cultures vary between countries, cities, business, and industries, so the defense community is no different--it is unique. Its difficult to characterize such a diverse group of defense contractors and government departments some generalizations are possible. Based on my visit to TRW ASD, interaction with defense industry engineerings, and my general knowledge of the industry, the defense community can be characterized by the following:

- A culture that is experienced and trained in applying regulations to a product, not in understanding the product itself.
- A focus on obeying rules and laws, leading to a bureaucratic and process driven culture.
- A risk averse culture, which errs on the side of conformity, due to fear of breaking the rules--which are law.
- A focus on meeting military specifications and standards, leading to a "how to" culture.

- A culture focused on product performance, not on cost.
- A culture of individuals who are committed to the safety and well-being of our armed forces.

3.3.2 Sources of New Business Opportunities

Military business opportunities are generally disclosed by the DoD through a BAA and request for proposal (RFP) announcement in the Business Commerce Daily. Since the DoD represents approximately 85% of the market, this is the critical method for finding new opportunities. This is the formal method of procurement announcement, however more than likely informal discussions of the procurement prior to the official announcement have circulated throughout the defense community.

3.3.3 Business Practices

The material in this section on the Business Practices at ASD is referenced from the IBP BP IPT documents of 1995 and 1997.

3.3.3.1 Quality Systems

The military standard has been MIL-Q-9858A. This specification has been superseded by the international quality standard ISO 9001.

3.3.3.2 Parts Control

Military parts approval at TRW ASD falls under MIL-STD-965 Parts Control. This standard requires a lengthy approval processes through three bodies; internally at TRW ASD, at the contractor, and finally by the Parts Control Board (PCB).

3.3.3.3 Workmanship Standards

TRW ASD uses the MIL-STD-2000A workmanship standard. The standard requires inspection, customer oversight and audits, and approval of training programs. This standard requires 100% inspection unless defect rates are less than 2700 PPM, as defined by the military standards defect criteria. The standard also requires that rework cannot be performed by assembly workers until the product to be reworked has been inspected.

3.3.4 Product Design and Development

3.3.4.1 Design Specifications

The specifications used in the design of defense products have traditionally been military specifications (MILSPECS). Reform initiatives have recently removed the requirement for use of these military unique specifications and standards, replacing them with industry specifications and standards whenever possible. This change was implemented as a mandate from the DoD with immediate effect and no gradual implementation, which has been challenging given how entrenched the military acquisition process is in the use of MILSPEC's. In product design, specifications are used for things like material call outs, testing procedures, and environmental operating requirements. These specifications are very detailed and explicit regarding how a design should meet a requirement and are rigid. These specifications are sometimes referred to as "how to" specification(Myers, 1998).

3.3.4.2 Product Design

The design of military electronics systems follow the philosophy of placing priority emphasis on performance only. Typical designs incorporate many very complex application specific integrated circuits (ASICS), very dense printed circuit board (PCB) component population, extensive use of digital circuitry, moderate use of RF circuitry, and little use of analog circuitry. Performance in military electronics is delivered through not only the processing speed and capability of the design, but also through the harsh environmental conditions in which the components are capable of operating. For example, extreme operating temperatures have lead to the use of ASICS which are encased or "packaged" in ceramic materials and are hermetically sealed (IBP PT IPT, 1995).

The method of attaching components to the PCB in the CNI electronics modules is called "surface mounting." This method entails screening the PCB with a very thin pattern of solder paste, similar to how a T-shirt would be "silk screened," followed by automated placement of components on the surface of the PCB in the paste, and finally the board and components are heated in a re-flow oven for the paste to melt and cure, affixing the components to the PCB (Everett, 1998). The two major benefits of surface mount processing are close placement of components for very high density PCB population and minimized overall assembly thickness versus more conventional through-hole attachment.

Design for Manufacturing (DFM) is not used to the same extent in the design of defense products as it is in the design of high volume commercial products. Component size and placement are determined based on design requirements for performance and physical requirements for spacing. The high per unit assembly cost forces mid-stream engineering changes to be performed on complete or semi-complete assemblies, leading to the use of jumper wires and "cuts" that are not conducive to easy manufacture. The manual assembly environment and low volume production allow the flexibility for these methods of product design to exist. Essentially, design and performance are of higher priority than manufacturing efficiency.

3.3.4.3 Product Validation & Testing

Since the products, assemblies, and individual components are expensive and produced in low volume, testing is usually limited to a very small sample size. Development tests are done on 100% of the modules and include functional, environmental, thermal cycles, vibration/drop, and burn-in. To avoid the use of expensive test hardware, extensive use of computer simulation modeling is performed (IBP PT IPT, 1995).

3.3.5 Manufacturing

TRW ASD manufactures very low volume military electronics. Its manufacturing facility coexists with its engineering offices in San Diego, California. The manufacturing area has the feel and appearance of an electronics laboratory, with work benches and electronic test equipment, such as oscilloscopes, arranged in rows (Everett, 1998). A handful of processing equipment is located at one end of the area arranged in order of processing, however the process is not continuous flow. The ASD manufacturing facility can be characterized by the following:

- Very low volume craft-shop production
- Small production area.
- Low capital investment
- Little standardization of products
- Extensive use of manual assembly operations
- Few semi-automated assembly operations
- Highly skilled labor/technicians

Production tests are done on 100% of the modules and include functional, environmental, thermal cycles, vibration/drop, and burn-in.

3.3.6 Business Agreements

3.3.6.1 Contract Regulations

The Federal Acquisition Regulation (FAR) is the basis for government contracting. It was established for publication of uniform policies and procedures for acquisition by all executive agencies. The FAR is the primary document of the Federal Acquisition Regulation System, with agency specific acquisition regulations to supplement the FAR. The DoD specific regulations are within the Defense Federal Acquisition Regulation Supplement (DFARS).

Military procurement contracts include a monumental number of contractual clauses. For example, an analysis of the Apache helicopter Inflatable Body and Head Restraint System (IBAHRS) crash sensor contract showed a total of 183 Contractual and 204 Technical Business Practices and Policy clauses (Kinsella, 1995). Examples of clauses include areas such as socio-economic employment requirements, surrender of cost information, exposure of proprietary technical data, and cost accounting system requirements. Later in this chapter, specific clauses which violate commercial requirements are discussed in detail.

3.3.6.2 Contract Types

There are a number of different types of contracts used for military procurement. The unique features of each are summarized below (DoD, 1998).

Cost Type. Cost type contracts are used to buy products and systems that are the contractors "Best Effort" and are typically used for products that are not well-defined and also present high risk. Payments to the contractor are made as incurred.

- Cost Plus Fixed Fee (CPFF)--Fee is same regardless of actual cost.
- Cost Plus Incentive Fee (CPIF)--Fee is adjusted based on actual cost through the use of a share ratio, and is limited to a min/max fee.

Fixed Price Type. Fixed price type contracts are used to buy well defined products and systems that are "Delivery Promised" with defined deliverables and low risk. Cash flows to the contractor are made based on the delivery of goods or in "progress payment" form. Up to 80% of the manufacturer's costs can be paid prior to delivery in progress payments, with the remaining paid 30 days after receipt of invoice.

- Firm Fixed Price (FFP)--The price is fixed regardless of actual cost.

- Fixed Price Incentive Fee (FPI)(F)--The price is adjusted based on actual cost and use of a share ratio.

Award Fee. An award fee contract is unilaterally determined by the government based on its subjective evaluation of contract performance.

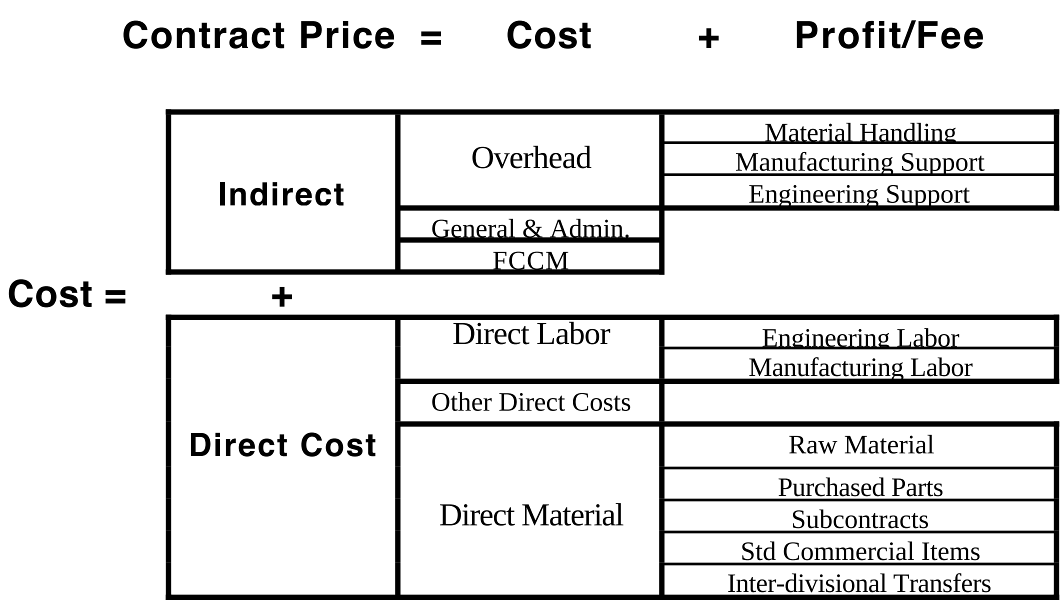
- Cost Plus Award Fee (CPAF)--This is a stand alone contract.
- Combination--in combination with fixed or cost contract types.

The contract let by ASG to AEG for the production of CNI modules is of the Firm Fixed Price Type.

3.3.6.3 Pricing

Pricing of Non-Commercial Items. The pricing of military contracts is unique given the monopsonistic market structure, government control, quasi-competitive market, and the expense of funds from taxpayers wallets.

Figure 3.2 Components of Defense Contracting Cost



(DoD, 1998)

This is one of the areas where the combination of government regulations and monopsony power are exerted. Since a truly competitive market is non-existent, leading to the potential of excess rents, the buyer uses its power to expose the cost structure of the defense contractor and to impose a fixed profit or fee rate. In other words, the government relies on cost data to negotiate a fair and reasonable price in its mission to protect the public trust. The pricing equation and the components of cost are shown in Figure 3.2.

Pricing of "Commercial Items". The pricing of what are defined as "commercial items" is done differently than non-commercial items (see Appendix A for a detailed definition of Commercial Items). Changes brought about by FASA and FARA allow the DoD to purchase commercial items as a commercial firm would. The determination of the price of a commercial item entails: 1) determining if the item does in fact meet the definition of a commercial item, 2) determination of a fair and reasonable price for the item through market research.

3.3.6.4 Cost Accounting Standards

Given the emphasis on cost as a method of pricing control and oversight, the DoD requires that contractors meet specific Cost Accounting Standards (CAS). Specifically, the CAS were developed to ensure proper cost allocation and as a standard method for cost comparisons between contractors. A CAS-compliant accounting system is required by the DoD for compliance with this standard. The CAS accounting system is established to track labor hours and materials during manufacture, so that "progress payments" can be made at specific milestones in the program. Contracts are written such that the buyer owns the labor and materials throughout the process. The "progress payment" method of program financing requires a CAS-compliant system (DoD, 1998).

The CAS require that costs be broken down by individual contract. For example, an engineer or scientist working on multiple projects, associated with multiple contracts, is required to account for individual labor hours by contract number for all work performed.

3.3.6.5 Supplier Selection

ASD selects suppliers based on two fundamentals of the defense business. First, whether the supplier has proven the capability of delivering components approved to military specifications and secondly, whether the supplier operates according to military standards and practices. The selection process places nearly complete reliance on the military specifications and standards system. Past performance is just beginning to play a role in the selection process, however minor, particularly when a lack of competition for a given key component exists.

3.4 Commercial Industry Practices at TRW AEG

This section discusses commercial industry practices at TRW AEG, based on a site visit and tour (Groth, 1998) of the production facility in Marshall, Illinois, and based on seven years experience as an engineer and project manager at an automotive OEM.

3.4.1 Culture

The culture at AEG is typical of a commercial enterprise operating in a highly competitive market and can be characterized by the following:

- A focus on understanding customer needs
- A focus on best value; minimizing cost while achieving performance targets.
- A culture where successful risk taking is rewarded.
- A culture with focus on manufacturing efficiency and optimization.
- A focus on profit maximization for the firm.

3.4.2 Sources of New Business Opportunities

How does a "commercial" supplier find business? In the automotive industry, a few methods are used. One method is essentially a request for proposals (RFP) bidding process, where OEM buyers of automotive components or sub-systems send a packet of information to known sources capable of producing the assembly. The list of known sources comes from lists of current suppliers, industry supplier listings, and sales literature sent to the OEM from suppliers. The packet of information usually includes all the material necessary to make a per unit price bid for a stated delivery schedule. Bid packets typically include disguised drawings, specification documents, and delivery schedule requirements. This method is used for purchasing commodity products and for beginning long-term relationships as described next.

A second method is limited to the suppliers with the most direct interaction with the OEM and who have had successful long-term relationships. In this case, the supplier would work with the OEM to develop a new or improved product, incorporating the supplier's knowledge of process capability and technology advances. The close relationships can potentially yield a superior design in a shorter design cycle.

A third method is for a supplier to develop a new product or technology and “shop around” for an OEM application. An example in the context of TRW AEG might be a new safety system sensor technology that was developed in-house, without a specific customer in mind but with an understanding of market needs.

3.4.3 Business Practices

3.4.3.1 Quality Systems

The quality systems in place at TRW AEG are automotive industry accepted practices, and are internally referred to as the TRW Quality System. This quality system meets the intent of the international quality system known as ISO 9000. The International Organization for Standards (ISO) quality system ISO 9000 is a methodology for an organization to operate within, leading towards the improvement of or sustainment of high quality products. The framework of ISO 9000 is truly a system. It includes all aspects of the product value chain, from management philosophy to continuous process improvement (IBP BP IPT, 1995).

The elements of ISO 9000 include the following areas:

- Management Responsibility
- Quality System
- Contract Management
- Design Control
- Document and Data Control
- Purchasing
- Control of Customer-Supplier Product
- Product Identification and Traceablity
- Process Control
- Inspection and Testing
- Control of Inspection, Measuring, and Test Equipment
- Inspection and Testing
- Control of Non-conforming Product
- Corrective and Preventive Action
- Handling, Storage, Packaging, Preservation and Delivery
- Control of Quality Records
- Training

3.4.3.2 Parts Control, Selection, and Workmanship Standards

In the high volume world of the automotive industry, parts inspection, rework, and scrap become very costly to not only the supplier but also the customer. To combat these costs and to continuously improve the quality of production, statistical methods have been developed, commonly referred to as statistical process control, and are described below.

Statistical Process Control (SPC). In general, a process in statistical control can be described by a predictable distribution, from which the proportion of in-specification parts can be estimated. As long as the process remains in statistical control and does not undergo a change in location, spread, or shape, it will continue to produce the same distribution of in-specification parts. Process capability is determined by the variation that comes from common causes. Common causes are defined as the many sources of variation that have stable and repeatable distribution over time. In fact, if only common causes were present and did not change, the output of the process would be predictable. If the process capability for a given operation falls within the specified upper and lower bounds of the requirements, then the process is same to be capable. (AIAG, 1991)

Production Part Approval Process. The purpose of the Production Part Approval Process (PPAP) is to determine if all customer engineering design and specification requirements are correctly understood by the supplier and that the production process has the potential to produce product which meets these requirements during an actual production at the quoted production rate. Production parts are manufactured at the production site using the production tooling, gauging, process, materials, operators, environment, and process settings.

Parts submitted for PPAP must be taken from a “significant” production run. A “significant” production run would typically be from one hour to one shift’s production, with the production quantity for submission to total 300 consecutive parts minimum, unless some other quantity has been agreed upon (i.e.; very low volume part or process produces many more than 300 in one hour or shift). Parts for each position of a multiple cavity mold, die, tool or pattern are to be measured and representative parts tested (AIAG, 1995).

Once the 300 part PPAP samples are produced, all customer dimensional, material, and performance requirements are tested or measured to demonstrate initial process capability. These requirements are evaluated on various sub-sets of the sample submission parts, usually on a 25-50 piece sample from at least 10 subgroups.

3.4.4 Product Design and Development

3.4.4.1 Product Design

The components and processes used in the design of automotive electronics follow the philosophy of low cost with best value performance. The typical use of components include a few ASICS of low complexity, low to high PCB component density, extensive use of analog circuitry, some RF circuitry, and very little digital. ASICS are "packaged" in plastic, which is inexpensive and meets the environmental conditions required for automobiles. A focus on efficient manufacturing is an important method for reducing product cost. DFM analysis is given a great deal of attention. If a manufacturing problem arises due to product design, the burden of change usually falls on the side of a design change, since efficient manufacturing is so essential (IBP PT IPT, 1995).

The standard method for attaching electrical components to the PCB assemblies at TRW AEG, is with through-hole mounting. This method is common and has been used for many years. The process begins with a PCB that is etched with the circuits and with holes through the board in the locations of component leads. Components are placed on the PCB with automated assembly equipment, such that the leads of the chip are placed through the PCB holes (an chip may have 20+ leads per side). The assembly is then processes through a soldering process called "wave flow" soldering, where the PCB and components are passed over a wave of molten solder such that the wave only contacts the component leads protruding through the PCB. The solder is wicked up the leads and affixes the components to the PCB.

Surface mount designs, as used extensively in the defense industry and described in the last section, are also employed in commercial industry but to a lesser extent in automotive applications.

3.4.4.2 Design Specifications

Design specifications for commercial products are stated in any of a number of ways. Industry organizations such as SAE, ANSI, and ISO are just a few. SAE specifications are known to many consumers, particularly the engine oil specifications like 10W50 or 5W30. The commercial firm can also create its own test specifications for custom designed products. These specifications are typically performance driven or "must meet this" in nature.

3.4.4.3 Design Validation and Testing

Design validation and testing are taken very seriously at AEG, especially since many of the products, such as restraint system electronic controls, are safety related and involve product liability risk. Since per unit costs are relatively small, many components and assemblies are tested to validate not only the design, but also the design as produced by the manufacturing process. With very high production volumes, the number of defective products produced at a given probability are increased, driving the necessity for a very robust design and manufacturing process. This high production volume leads to the necessity of large test sample lot sizes to prove statistical confidence in the design and process (Murphy, 1996). Testing is done for functionality, environmental conditions, thermal shock/vibration, dust and humidity. The limited use of computer simulation modeling to test designs is being increased, however no thermal simulations are performed.

3.4.5 Manufacturing

TRW AEG manufactures electronic assemblies for 14 customers from a single facility in Marshall, Illinois. This facility contains 6 production lines that are designed for the flexible manufacture of PCB assemblies. Five of these lines are for the very high volume products, while the sixth line, known as Flex Line 3, is designed for lower volume products. Although the five high volume lines are similar, each has some unique equipment for the production of specific assemblies, such as airbag sensor assemblies. The manufacturing environment at AEG and can be characterized by the following (Groth, 1998):

- High volume/high mix
- Central facility for scale economies in labor and overhead
- Highly automated
- Continuous flow production
- Automated production line material replenishment
- Product change-over is done infrequently, striving for a high utilization rate.
- Striving for maximum utilization of capital equipment
- Capital intensive operation

Production testing includes 100% checking for defects and burn-in, and a statistical sampling for environmental and functional tests.

3.4.6 Business Agreements

3.4.6.1 Contract Regulations

Typical commercial business contracts vary from industry to industry and are tailored to the specific set of circumstances and issues involved in the particular business arrangement. In general, commercial contracts stick to the basics of price, delivery, quality, and service expectations. The length of contracts vary, however long-term contracts with proven suppliers are beneficial to both parties, particularly with regard to resource planning and development of good relationships.

3.4.6.2 Pricing

The pricing of commercial products varies based on whether it is a commodity item, an off the shelf item, or a designed to specification item. Also considered in pricing is the level of service being provide with the purchase in the way of engineering support, delivery, and warranties.

Competitive Market

Commodity and homogenous products. These types of products have prices established through competitive markets (Pindyck, 1995). Market prices are easily obtained from sales literature, catalogs and price lists. If large quantities are being procured, reduced prices can usually be negotiated through the requesting of quotes from a number of sources.

Design to specification product. In a market where a number of competitive suppliers are capable of producing a product, the buyer can “shop around” the specifications of a new product and a target price until a supplier is willing to meet the requirements.

Uncompetitive Market

Monopoly supplier of a product or technology. In this situation the supplier holds market power and can set the price where it deems appropriate (Pindyck, 1995). The buyer must determine whether the price is reasonable based on the need for the specific product or technology.

Current successful long-term relationship. A successful long-term relationship is one where the expectations of the OEM are met and a mutually beneficial environment of trust and sharing is present. Open relationships such as this ensure a high level of commitment on the part of both parties in all areas of the business, from leadership to engineering and manufacturing. This does not mean that quality or production problems do not arise on occasion. However when they do, the supplier acts quickly to announce the problem and the supplier-buyer "team" work together to solve the problem quickly and to make adjustments accordingly.

In this case, the supplier holds market power due to the beneficial relationship between it and the buyer. This relationship has been developed over many years and both parties are happy. In this case pricing of designed-to-specification products are negotiated in an open environment of trust and mutual respect for the relationship. The price may or may not be higher than is available elsewhere, however the value of the relationship and the switching costs are difficult to determine and are risky.

3.4.6.3 Accounting

Commercial firms account for product costs as they see fit within the guidelines of Generally Accepted Accounting Principles (GAAP) and tax laws. The components of cost, such as labor and materials, are held closely so that information about the firms competitive position and profit margins are not exposed to competitors. All costs of goods sold (COGS), including capital depreciation, are owned by the firm until the finished product is sold.

3.4.6.3 Supplier Selection

Commercial firms select suppliers based on many attributes. In sum, the favorable attributes are those that support the buyer's needs (cost, quality, deliver, technology, performance, engineering support, etc.) and indicate a good chance of a long-term mutually beneficial relationship. Figure 3.3 lists the comprehensive supplier selection evaluation categories for an automotive OEM. Each category is evaluated by the supplier selection team and given a numerical rating. The category scores are then multiplied by a weighting factor for relative importance and then tallied for comparison versus other potential sources.

Figure 3.3 Sourcing Evaluation Categories at an Automotive OEM

Business Factors: • Experience • Proven Performance • Cost Competitiveness • Present Customers • Proprietary Products	• Training Programs • Location: U.S. vs. Int'l • Continuous Improvement • Stability • Openness	• Team Concept • Housekeeping • Innovativeness • Financial Strength • Risk/Reward
Engineering Issues: • Flexibility/responsiveness • Research and Development • Quality Control System • Sub-supplier Relationships	• Just-in-Time Systems • Test & Validation Capability • Technology • Design (DFM/DFA)	• Process Certification • Capability • Reliability History • Capacity
Management Philosophies: • Attitude • Style • Customer Orientation	• People Orientation • Labor Relations History	• Cooperativeness • Suggestion Plan • Empowerment

(Source: OEM Supplier Selection Manual)

3.5 Integration of Defense and Commercial Business

Given the very different environments in each of the business sectors that the TRW divisions operate, the challenge was to integrate them in a manor that was functionally acceptable to AEG and legally acceptable to the military customer. Since one focus of military-commercial integration is on bringing performance-based business practices into the defense sector, the foundation of the IBP was to not force changes onto the commercial AEG organization, but instead to infuse commercial practices into the ASG organization. The challenges facing military-commercial integration are many. This section will review the challenges and barriers which the MPCL program encountered, and the solutions they found for overcoming them.

3.5.1 Comparison of Defense and Commercial Industry Practices

Let us begin by comparing side-by-side the TRW ASD "defense" and TRW AEG "commercial" practices. Figure 3.4 summarizes the discussion of the last two sections on the industry practices of the defense and commercial business sectors.

Figure 3.4 Summary Comparison of Defense and Commercial Practices

	Defense Industry at TRW ASG	**Commercial Industry at TRW AEG**
Culture	• Bureaucratic and process driven • Risk averse • “How to” • Performance over cost	• Common sense practices • Adaptive and flexible • “Meet this” • Best value
Sources of New Business Opportunities	• Buyer announcement • Commerce Business Daily advertisement	• RFP from OEM • Continuation of current relationship • “Shop around” new technology
Business Practices		
Quality Systems	• Mil-Q-9858A (recently obsoleted for ISO)	• ISO 9000 equivalent
Parts Control & Workmanship Standards	• Mil-Std-965 • Mil-Std-2000A	• Use of SPC • PPAP
Product Design		
Material Specifications	• Military spec’s and stds. (recently replaced)	• Industry spec’s and stds.
Components	• Design and materials for operation at extreme temperatures • Ceramic ASIC packages that are vacuum sealed.	• Design and materials for operation in less extreme temperatures • Plastic ASIC packages
Testing & Validation	• Tests are minimized, using as few components and assemblies as feasible	• Numerous test using many components and assemblies
Manufacturing	• Low volume/high mix • Low capital investment • Manual assembly	• High volume/low mix • Capital intensive • Highly automated assembly
Business Agreements		
Contracting	• Numerous BP&P requirements and contractual clauses	• Common sense practices • Incentives for cost reduction and quality improvements
Pricing	• Cost driven with fixed profit/fee rate	• Competitive market driven
Cost Accounting	• CAS compliant accounting system is required • Customer requirement to track costs in particular manor	• Must meet GAAP/Tax rules for reporting purposes • Not a customer requirement
Supplier Selection	• Based on ability to meet military specifications and standards	• Based on past performance, good relationships, support and cost.

3.5.2 Cultural Integration

Given the extreme cultural differences between the defense and commercial industries, it should be expected that integration will be difficult. The IBP program confronted this challenge through implementing a training plan. The training plan goals were to establish a strong team environment for the creation of the three program IPTs, develop a common understanding of current engineering and infrastructure improvements, and to familiarize participants with the tools used in the concurrent engineering environment. Through team training and team building, participants in the IBP from both ASD and AEG were aligned with a common understanding of program goals and were able to bring the unique skills of each industry to the table.

3.5.3 Sources of New Business Opportunities

It is apparent from the comparison of defense and commercial industry sources of new business opportunities that each looks to different sources. For military-commercial integration to take place, these sources must be aligned. The MPCL program did not, however, encounter a barrier in this area since the program was created on the basis of selecting AEG for production of the CNI modules. Essentially the source of new business for AEG was the relationship with ASD through the parent TRW corporation. This relationship is similar to the non-competitive selection of a supplier with good long-term relations.

3.5.4 Business Practice Integration

3.5.4.1 Quality Systems

The BP&P IPT made a detailed comparison of the TRW Quality System against ISO 9001 standards, which are in agreement with Mil-Q-9858A. The comparison found the Quality System to be in agreement with exceptions in these areas:

Costs Related to Quality (Mil-Q-9858A, Par. 3.6) There is no ISO series equivalent clause for this item. TRW AEG tracks cost related operational metrics such as scrap, rework, first pass success rate, and loss of production, for daily management information purposes. It is common industry practice for customers to request a review of this data, however no formal reporting is provided which would increase the costs of the QA system.

Use of Contractor's Inspection Equipment by Government Personnel *(Mil-Q-9858A, Par. 4.4)* There is no ISO series or TRW QS equivalent clause for this item. Given the statistical quality control at the AEG facility, no special equipment needs are foreseen.

Government Inspection at Subcontractors *(Mil-Q-9858A, Par. 7.1)* There is no ISO series or TRW QS equivalent clause for this item. The government reserves the right to make quality inspection of production items at the source, which is disruptive to the manufacturing process. The most similar ISO 9001 statement (Par. 4.6.4) affords "the right to verify at the subcontractors premises." It is common in the automotive industry for customer representatives to visit the production facilities and discuss quality, design, and cost reduction programs, and to offer assistance in approval of such programs. It is not, however, acceptable for the customer to disrupt production at the source for quality inspections, unless there have been specific qualify problems with delivered goods which have affected the customers business. Even in this case, the customer and supplier would closely together and are in acceptance of the situation as a necessary means to a solution.

The cost of quality at the military and commercial businesses of TRW are compared in Figure 3.5 versus a typical small business. These costs of quality include internal failure costs, appraisal costs, and prevention costs. External failure costs do not appear to be included in this comparison. It can be seen that the cost of quality at AEG is 40% below that of ASD, and well below the 1-2% that the BP IPT perceives to be standard for a small business. This difference in appraisal costs is a function of the high volume sales of AEG with low personnel for quality control, along with the use of statistical process control methods.

Figure 3.5 Cost of Quality Comparison

	Cost of Quality as Percentage of Sales
Small Business	1-2.%
TRW "Military" ASD	0.57%
TRW "Commercial" AEG	0.32%

(Source: IBP BP IPT, 1995)

3.5.4.2 Parts Control and Selection

The BP&P IPT made a cost comparison of the military standard versus the internal commercial parts control and selection processes of TRW AEG. This comparison showed that a significant reduction (>30%) in parts approval cycle-time can be achieved using the commercial practices. Figure 3.6 shows the comparison data.

3.5.4.3 Workmanship Standards Integration

The military standard Mil-Std-2000A is not acceptable to TRW AEG due to its requirements for in-process inspections by personnel. An analysis of alternative workmanship standards was performed and generated the commercial alternatives of ANSI/J-003 and IPC-610. Both of these standards are similar to Mil-Std-2000 in technical requirements for component mounting, soldering, and defect tables, however they differ with respect to inspection methodology (100% inspection versus SPC), customer audits, and training programs.

Figure 3.6 Parts Approval Time Comparison in Days

	ASD “Military”	**AEG “Commercial”**
Part/Process Approval (PPAP)	0	42
Evaluate Existing Part Data	14	3
Generate NSPAR	14	0
Contract or Part Approval	30	0
Parts Control Board Approval	120	0
Supplier Survey	14	90
Total	192 days	135 days

(Source: IBP BP IPT, 1995)

A test was performed to compare the costs incurred through each of these standards. The test subject was an AEG produced engine controller for Caterpillar, which was subjected to the military inspection process and a cost comparison was made between it and the commercial process costs. It was determined that the military inspection costs are at least four times those incurred by commercial practices. It was also determined that the additional inspection steps required of the military standard do not add value to the product, and therefore should be eliminated. As a result, a recommendation to flow down the ANSI/J-003 class III commercial workmanship standards was made.

3.5.5 Product Design and Development Integration

3.5.5.1 Product Design

A summary of design and process characteristics is shown below in Figure 3.7. In the area of product design, the MPCL program sought to reduce costs and improve quality through the use of IPTs, commercial components, and commercial processes. To achieve these goals a number of actions were taken, including the implementation of a Concurrent Engineering Environment and the evaluation of commercial electronics components versus a rationalized military system performance envelope.

Concurrent Engineering Environment (CEE). The starting point for developing a CEE for the IBP was to evaluate the current CEE at both ASD and AEG. A comparison of the product design and process characteristics of each division is given below in Figure 3.6. According to the CEE Definition document, the implemented environment must provide the following to meet IBP program objectives:

- Provide a development environment which allows the use of concurrent engineering principles for a seamless product transition to manufacturing resulting in minimum design modifications.
- Allow cost effective geographic distribution of product development and manufacturing data through the use of EDI.
- Implement a manufacturing infrastructure using agile or flexible lines for the manufacture of small quantities of military electronic modules.
- Allow transition of the IBP CEE architecture and methodologies to industry through the use of standards, open systems, and metrics.

Figure 3.7 Detailed Comparison of Product Design Characteristics

	ASD--Defense	AEG--Commercial
Design Elements	Significant digital logic with some analog and RF devices	Mostly analog and RF devices with growing portion of digital circuitry
Design Complexity	PCB: High Density ASICS: Highly Complex	PCB: Low to High Density ASICS: Low Complexity
CAD Tools	Standardized on Mentor Graphics, also use third party integrated tools	In transition from PCAD to Viewlogic/Recal-Redac
Design Validation	Extensive use of simulation modeling DoD releases liability from ASG for field failures	Small but growing use of simulation modeling Liable for product field failures.
Development Process	Production units modified with design modifications (cuts and jumpers).	Multiple cycles of pre-production prototypes
Production Volume	Low Volume, 50 - 500 units total per product	High Volume, >50,000 units/yr.
Production Process	High level of manual labor, not continuous flow, no CIM	Continuous flow, High levels of automation
Functional and Environmental Testing	All manufactured modules	Statistical sampling of manufactured modules

(Source: IBP MI IPT,1995)

Commercial Component Evaluation. In order to utilize commercial electronic components and the advantages of them (reduced costs, current AEG supplier network, etc.) their performance must be evaluated relative to the operating requirements of the CNI modules. This was done in a number of steps. First, numerous commercial PCB and plastic packaged chips were tested to confirm the operating limits as specified by the manufacturer. Secondly, the CNI module operating environment limits were rationalized for the modules themselves, versus for the F-22 aircraft as a whole (Myers, 1998). The rationalized operating limits were then compared against the component test results, demonstrating that commercially available components and plastic packaging were viable for the military application. Finally, the custom military ASICS were redesigned with commercial plastic packages to reduce costs. This evaluation process lead to the decision to utilize plastic packages (IBP PT IPT, 1995).

3.5.5.2 Specifications

Component specifications for design such as materials, were stated in the industry standard practices of AEG. Since the AEG suppliers of commercial electronic components were the sources to be utilized for the program, they are accustomed to the use of these standards. Additionally, specifications and standards reform policy direct the use of non-military standard whenever possible.

The only “military” specified components were the interfacing components, such as connectors, which connect the electronics modules with the aircraft and were system specified by the prime contractor. In this case, the supplier was not a current supplier to AEG, but was a supplier to ASG for the same components as used in other modules not included in the MPCL program. As a result, ASG supplied the connectors to AEG, leading to the avoidance of complexity in specifications flowdown.

3.5.5.3 Product Validation and Testing

The integration of product validation and testing was straightforward. Since the assemblies are low volume and costly, testing resembled the defense industry methods of small test sample sizes and extensive use of computer simulation modeling. The exception was the testing of the commercial components to the operating limits, where large samples could be evaluated cost effectively.

3.5.6 Manufacturing Integration

The manufacture of the low volume military electronics modules on the high volume commercial manufacturing line at AEG requires that the manufacturing facility be capable of producing the design in the volumes required. The design for manufacturing concerns now have a concurrent engineering environment for evaluation and redesign as discussed in the last section, which identified the need for additional processing capabilities. The question of volume capability rests on the state of the manufacturing infrastructure and the use of computer integrated manufacturing.

3.5.6.1 Processing Capabilities.

The processing capabilities at the AEG facility required a few improvements and additions for the manufacture of the CNI modules. These modifications included:

- Screen Printer--the existing screen printer at AEG was not capable of screening the high density and fine pitch leads required by the complex military ASICS. As a result, this equipment was replaced with a new screen printer capable of this requirement.

- Manual Assembly Area--An area with work stations was installed for the assembly of components to the modules which require manual operations. Core bonding is one process which will be done in this area as is the placement of components which exceed the physical size constraints of the placement equipment.
- BGA Removal/Repair--Equipment was installed in the manual assembly area for the removal of BGA components to repair connections that process tests had shown as non-performing.

Modifications to the AEG assembly line totaled $392,000 in capital equipment, which represents less than 5% of the $8,552,000 total capital invested in the production line (IBP BP IPT, 1997).

3.5.6.2 Computer Integrated Manufacturing

The purpose of the Computer Integrated Manufacturing (CIM) system is to facilitate the flexible manufacture of low volume/high mix military electronics modules with the high volume/low mix AEG production environment in Marshall, Illinois. The current design to manufacture systems in place at AEG require a large effort and are therefore very costly when introducing new products. This high cost makes it even more difficult to introduce low volume products such as the military CNI electronic modules. Automation of the design to production system will reduce the cost and effort required to introduce new products, from design to initial production. Design to production processes can be modified by CIM in the areas of product data management, program development, automated database configuration, user interface development, and data entry into the MRP system.

The CIM system will offer many outputs which will dramatically improve the ability to manage the manufacturing process and for implementing continuous improvements. Figure 3.8 lists the many CIM system outputs. The testing of production assemblies is planned to resemble the automotive methods of statistical sampling versus the 100% testing of the defense industry. However, given the small production runs, there will be difficulty in developing high statistical confidence .

Figure 3.8 Computer Integrated Manufacturing System Outputs

Product Performance and History Functions	
• Material and Process Traceability	• Automatic Reporting of Scrap
• Electronic Scheduling	• Operator Reporting of Scrap
• Warnings for Schedule Problems	• Setup and Cycle Time Feedback
• Work In Process (WIP) Tracking	• Setup Verification-Material
• Module History Review	• Maintenance Management System Interface
• Controlled Replenishment of Line Side Storage	
Mistake Proofing	
• Process mistake proofing	• Real time feedback
• Prior step mistake proofing	• Supplier Feedback
Problem Solving Tools	
• Graphs and reports	• On-line quality assurance manual
• Symptoms and solutions history	• Queries

(Source:IBP MI IPT, 1995)

3.5.7 Business Arrangement Integration

3.5.7.1 Contracting Integration

TRW AEG was adamantly opposed to any contractual obligations which are outside of the realm of standard commercial practices before the MPCL IBP, and remains opposed today. This position is grounded on the basis of:

- Cost--associated with compliance.
- Disruption--of normal business and production.
- Risk--exposure of proprietary information and potential leaks to competitors.

Removal of clauses from the subcontract would be challenging, if not impossible, prior to the determination of Commercial Item status for the IBP modules. Prior to Commercial Item determination 30 clauses were applicable to the AEG subcontract, while only 3 clauses were applicable after Commercial Item status was determined. Figure 3.9 list the clauses before and after Commercial Item determination.

Figure 3.9 Contractual Clauses Before and After Commercial Item Status

Date	Clause Title
Before Commercial Item Status:	
1988	Anti-Kickback Procedures
	Defense Priority and Allocation Requirements (DPAS)
1993	Examination of Records by Comptroller General
1993	Audit-Negotiation
1991	Subcontractor Cost or Pricing Data
1989	Termination of Defined Benefits Pension Plan
1991	Revision or Adjustment of Plans for Post Retirement Benefits Other than Pensions
1984	Utilization of Labor Surplus Area Concerns
1984	Labor Surplus Area Subcontracting Program
1984	Notice to the Government of labor Disputes
1984	Walsh-Healey Public Contracts Act
1984	Equal Opportunity Employment
1984	Affirmative Action for Special Disabled and Vietnam Era Veterans
1984	Affirmative Action for Handicapped Workers
1988	Employment Records on Special Disabled Veterans and Veterans of the Vietnam Era
1984	Clean Air and Water Act
1992	Restrictions on Foreign Purchases
1984	Authorization and Consent
1984	Notice and Assistance Regarding Patent and Copyright Infringement
	Changes-Fixed Price
1984	Limitation of Liability
1993	Special Prohibition on Employment
1991	Acquisition form Subcontractors Subject to On-site Inspection Under the Intermediate-range Nuclear Treaty
1991	Duty Free Entry--Qualifying Country End Products and Supplies
1991	Preference for Domestic Specialty Metals
1993	Foreign Source Restrictions
1988	Rights in Technical Data and Computer Software
1988	Restrictive Markings on Technical Data
1988	Identification of Technical Data
1991	Statutory Prohibition on Compensation to Former DoD Employees
After Commercial Item Status:	
1984	Equal Opportunity Employment
1984	Affirmative Action for Special Disabled and Vietnam Era Veterans
1984	Affirmative Action for Handicapped Workers

(Source: IBP BP IPT, 1997)

The culmination of the IBP work in the area of contracting and business practices has been the development of a manual titled "Business Practice Requirements for Defense Suppliers." This reference source presents suggested methods and best practices for implementing supply chain integration. The IBP benchmarked and reviewed commercial industry and defense industry contracting methods. A comparison of the operational requirement totals for each are shown in Figure 3.10 along with a breakdown of the 78 possible IBP requirements.

Figure 3.10 Operational Requirement Comparison

Benchmark/Source	Total Requirements
Automotive Industry QS9000	244
F-22 EMD	204
ANSI Q9001	137
MPCL IBP	
Q9001 Basic Requirements	20
Q9001 Clarified for Defense	24
National Standards	16
Military Standards	6
Best Practices	12
IBP Total	**78**

(Source: IBP BP IPT, 1997)

The justification for Commercial Item determination on the CNI electronics modules were as follows (Dillon, 1997):

- AEG only performed work for non-government customers.
- AEG products are "of a type" used for non-government purposes.
- The CNI modules would be produced using the same processes , equipment, and workforce that are used for commercial products sold to the general public.

3.5.7.2 Pricing

Once Commercial Item status was determined, pricing considerations moved away from the typical defense industry focus on obtaining cost information and towards determining a fair market value for the modules.

Market research and Pricing Analysis. Determination of price reasonableness through market research requires that equivalent or similar products be available for price comparison. This is not the case with custom designed products which are not widely used. The IBP was able to compare the modules against commercially available digital signal processors and the prices for components utilized in them. This analysis showed that the PNP price was approximately 3% below the market price of comparable products, while the RF/FEC price was approximately 10% below the market price (IBP BP IPT, 1997).

AEG Determination of Price. TRW AEG used their proprietary financial analysis model for calculation of a price for the CNI modules. This financial model takes the inputs of volume, limited non-recurring engineering costs, capital requirements, material cost, labor costs, and a fixed target for return on assets employed (ROAE) to determine a per unit price. This price can then be compared against ASG's design-to-cost price target to see if a business case for proceeding with the program is viable. The model assumed a multi-year procurement of modules over several years. (Ebeling, 1996)

The Firm Fixed Price Commercial Item Subcontract between ASD and AEG was written with the prices of $11,800 each for 41 units of FR/FEC modules and $16,525 each for 75 units of PNP modules, for delivery on June 1, 1998 (IBP BP IPT, 1997).

3.5.7.3 Accounting Standards

The determination that the IBP electronic modules were "commercial items" relieved AEG of the need for a CAS-compliant accounting system.

3.5.7.4 Supplier Selection

The selection of suppliers for the IBP program were in concert with minimizing the disruption of the AEG's business practices. Components were sourced differently by type as described below.

- Commercial Components--Current suppliers of commercial components to AEG were used in all possible cases to take advantage of current relationships, scale purchases, and current administrative processes.
- Custom ASIC and MCM Redesigns--The redesign of the custom CNI ASIC's and MCM's were sourced to new suppliers for AEG. This was because no current AEG suppliers were able to supply the components.
- Standard Electronic Module Interfacing--The SEM interfacing components for the CNI electronics suite are common across the F-22 and RAH-66 platforms. Since the components are currently being supplied to ASD to military specification, the easiest solution for the IBP was for ASD to supplier the components to AEG through its own procurement system.

3.6 Supply Chain Integration

Supply chain integration is a major enabler for the success of the MPCL IBP program. The IBP team saw supply chain integration as a necessity for obtaining the greatest possible gains from military-commercial integration. The potential benefits of supply chain integration include:

- Improved product design--through accurate, efficient, and open dialogue in a team environment, throughout the product design and development process.
- Faster design cycle--through efficient communication, open discussion to avoid design delays, and fast team reaction to development roadblocks.
- Higher quality products--improved designs yield high quality products.
- Reduced costs--faster design cycles, higher quality products, and more efficient designs lead to reduced product costs.
- Win-Win outcomes--relationships with open communication and trust provide all participants with a "win."

The MPCL IBP program sought to implement supply chain integration through the development of a concurrent engineering environment (CEE) for design activities, and through computer integrated manufacturing (CIM) for manufacturing activities. The extent of supply chain integration for the CNI electronics modules was limited to the integration of activities at ASD as the system supplier and AEG as the module manufacturer. Linkages between component suppliers and AEG appear to be limited to those component suppliers which provide AEG with material for other production programs, while the suppliers of military-unique components do not appear to be linked.

3.6.1 Concurrent Engineering Environment

The distributed integrated product team (IPT) environment of the MPCL IBP program necessitates the extensive use of information technology (IT) for communications and for common access to product design data and tools. ASG team member locations include the San Diego design center and offices in Dayton, Ohio. AEG team member locations include the Farmington Hills, Michigan design center and the Marshall, Illinois manufacturing facility (IBP MI IPT, 1995).

Team Communications. The use of IT for electronic mail communications and electronic data interchange (EDI) is the primary method of team communications beyond telephone discussions and face-to-face meetings.

Product Data Management. The management of product design data for access by all members of the distributed product team was necessary. This was accomplished through a client-server computer network, with the file server located at ASD in San Diego and with client PCs located in Marshall, Dayton, and Farmington Hills. Product design databases such as the IBP Components database and the IBP PCB Design Rules database are located on the file server, which ensure the common and consistent use of IBP design data by both product engineering and manufacturing, and aids in DFM analysis.

Product Design Tools. Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), and design simulation tools are located on the file server in San Diego for access by the all team members.

3.6.2 Computer Integrated Manufacturing

The CIM system installation and upgrade for the IBP program has done more than just enable the flexible manufacture of low volume military assemblies. The CIM system is also a contributor to supply chain integration through enabling electronic links between the manufacturing floor and product design and the material requirements planning (MRP II) system (IBP MI IPT, 1995).

Product Design Data Interface. The automatic download of product design data to the ensures that the product design data held by the manufacturing line is the latest available form the product design team.

Scheduling and Order Tracking. The CIM system helps to integrate the supply chain through the electronic linkage of the Marshall manufacturing line and the MRPII system in Farmington Hills.

3.7 MPCL IBP Program Results

The pioneering efforts of the MPCL IBP program in demonstrating military-commercial integration with the manufacture of military electronics modules has been enlightening. Many lessons have been learned from this program and the results demonstrate its success.

3.7.1 Lessons Learned

- **Military-commercial integration is operationally achievable**

The MPCL IBP program has successfully demonstrated that the operational details of military-commercial integration are achievable, particularly within the electronics manufacturing environment. This has been demonstrated through design modifications to the military CNI electronics modules which enabled the use of commercial components, the use of automated high-volume commercial manufacturing equipment, and through the elimination of business practices and requirement barriers.

- **Commercial Item status is essential for military-commercial integration**

Without commercial item determination for the CNI electronics modules, the IBP program would not have faired as well. Commercial item status brought about the elimination of numerous contractual clauses and requirements which AEG deemed unacceptable.

- **Flexible manufacturing technology is a critical enabler**

The low volume production of military products has precluded access to the capital intensive high-volume production facilities of commercial industry in the past. Today however, flexible manufacturing technologies and CIM systems have reduced the minimum scale and set-up times of high volume commercial manufacturing to a level where the production of defense products is feasible. The MPCL program has demonstrated that this is the case for PCB assemblies, which is of particular importance since electronics technology is one which the commercial development pace exceeds that of the defense industry and where integration is critical.

- **Cost reductions can be achieved through integration of the supply chain and the use of commercial component technologies**

The MPCL program results show that product cost reductions can be achieved through the combination of faster production cycles, commercial component technologies, and supply chain integration.

- **Technology and knowledge transfer to the commercial supplier have been developed as assets for future business opportunities.**

TRW AEG is developing its assets in CIM, engineering skills, improved production flexibility, and knowledge of military product designs, so that they can be leveraged for future business opportunities down the road.

3.7.2 Results Summary

Figure 3.11 summarizes some of the key program metric results.

Figure 3.11 IBP Results to Date

Critical Parameter	IBP Target	IBP Actual
Design to Cost (PNP): 75 units	$17K	$16.5K
Design to Cost (FEC): 41 units	$15.6K	$11.8K
Overall ROAE	18%	19.7%
Minimum Annual ROAE	12%	13%
Number of Processes with Cpk>1.33	14	13
Number of Processes with Set-up Time>15min	11	13
Weight (PNP)	≤ 1.38 lbs.	1.12 lbs.
Weight (FEC)	≤ 1.40 lbs	1.28 lbs

(Source: Ebeling, 1997; IBP BP IPT, 1997)

It is can be seen from this summary that the IBP program has been successful. The targets for design to cost, ROAE, process capability and weight have all been exceeded, while process set-up time targets are only slightly off target.

Since product cost reduction is such a key potential benefit of military-commercial integration, a more in-depth discussion of the cost comparison is necessary.

Figure 3.12 MPCL IBP Cost Comparison

	MPCL IBP	Military Baseline	IBP Goal	Cost Reduction
Cumulative Average Cost of First 30 Units	$10.9K*	$40K*	50%	73%
Average Pricing from Validation Participants	$12.7K	$40K*	50%	68%

* Based on material cost actuals for a quantity of 30 LRM's, in 1996 dollars, AEG profit included, ASD profit and overhead excluded.
(Source: Ebeling, 1997, IBP BP IPT, 1997)

Figure 3.12 presents a cost reduction comparison for the MPCL program using two methods. Based on the cumulative average cost per unit of the labor and materials spent to produce the first 30 units, the resulting cost savings over the military baseline is 73%. The second comparison shown in the figure is against the average validation pricing submitted by the eleven validation participants, which resulted in a 68% cost reduction over the military baseline. It can be seen that both of these comparison methods yield significant cost savings and substantially exceeded the 50% cost reduction target.