Managing the Defense Industry Transition to Performance-Based Practices and Supply Chain Integration

by

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B.S., Mechanical Engineering
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Abstract

With the end of the Cold-War, the U.S. defense aerospace industry has been going through a historic process of change and adaptation in the 1990s due to a number of significant structural shifts, including changes in national security threats and sharp reductions in defense spending. Cutbacks in defense spending have been particularly deep in the area of weapon systems procurement, which most directly affects the defense aerospace industrial base. Meanwhile, technological developments in the commercial sector have outpaced those in the defense sector in a number of key areas, such as in microelectronics. These changes have resulted in two major outcomes: policy reforms to promote integration of the defense and commercial industrial bases, and defense industry consolidation. Policy reforms to promote military-commercial integration have stressed, among other things, the introduction of performance-based practices into the defense sector. This has been a necessary step to enable military-commercial integration. One of the beneficial outcomes of this policy thrust has been to engage the commercial sector more fully in defense acquisition. Typically in the past, commercial firms had been unwilling to deviate from commercial practices in doing defense business. Consolidation of firms in the industry has been largely a response to achieve greater efficiency gains, as well as to strengthen their market position and competitiveness. In the wake of these drastic structural changes, and in an effort to achieve greater affordability of weapon systems, the DoD has implemented a number of initiatives, including industrial base pilot programs to develop and test new technologies and business practices, such as the Military Products from Commercial Lines (MPCL) Industrial Base Pilot (IBP) program. This thesis focuses on the MPCL IBP experience, which has successfully demonstrated the ability of a military contractor to produce military electronics hardware through a commercial product line, with a “win-win” outcome for all participants. This thesis documents the “Lessons Learned” from the MPCL IBP case study to shed light on the broader set of challenges and opportunities in managing the transition of the defense aerospace industry to performance-based non-governmental or commercial practices, with particular emphasis on supply chain integration.

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<td>AEG</td>
<td>Automotive Electronics Group</td>
</tr>
<tr>
<td>ASC</td>
<td>Aeronautical Systems Command</td>
</tr>
<tr>
<td>ASD</td>
<td>Avionics System Division</td>
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<tr>
<td>ASICS</td>
<td>Application Specific Integrated Circuits</td>
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<tr>
<td>BAA</td>
<td>Broad Area Announcement</td>
</tr>
<tr>
<td>BGA</td>
<td>Ball Grid Array</td>
</tr>
<tr>
<td>BP</td>
<td>Business Processes &amp; Practices IPT</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CAIV</td>
<td>Cost as an Independent Variable</td>
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<tr>
<td>CAS</td>
<td>Cost Accounting Standards</td>
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<tr>
<td>CEE</td>
<td>Concurrent Engineering Environment</td>
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<td>CICA</td>
<td>Competition in Contracting Act, 1984</td>
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<td>CIM</td>
<td>Computer Aided Manufacturing</td>
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<tr>
<td>CNI</td>
<td>Communication Navigation &amp; Identification</td>
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<tr>
<td>COSSI</td>
<td>Commercial Operations and Support Savings Initiatives</td>
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<tr>
<td>DFARS</td>
<td>Defense Federal Acquisition Regulation Supplement</td>
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<td>DFM</td>
<td>Design for Manufacturing</td>
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<td>DoD</td>
<td>Department of Defense</td>
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<td>DSB</td>
<td>Defense Science Board</td>
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<td>DUAP</td>
<td>Dual-Use Applications Program</td>
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<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
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<td>EEO</td>
<td>Equal Employment Opportunity</td>
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<tr>
<td>EMD</td>
<td>Engineering Manufacturing &amp; Development</td>
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<td>EW</td>
<td>Electronic Warfare</td>
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<tr>
<td>FAR</td>
<td>Federal Acquisition Regulation</td>
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<tr>
<td>FARAD</td>
<td>Federal Acquisition Reform Act, 1996</td>
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<tr>
<td>FASA</td>
<td>Federal Acquisition Streamlining Act, 1994</td>
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<tr>
<td>IBP</td>
<td>Industrial Base Pilot</td>
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<tr>
<td>IPPD</td>
<td>Integrated Product and Process Development</td>
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<td>IPT</td>
<td>Integrated Product Team</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>LLSP</td>
<td>Low Latency Signal Processor</td>
</tr>
<tr>
<td>MANTECH</td>
<td>Manufacturing Technology Division, Materials and Manufacturing Technology Directorate, U.S. Air Force Laboratory</td>
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<tr>
<td>MCM</td>
<td>Multi-Chip Module</td>
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<tr>
<td>MI</td>
<td>Manufacturing Infrastructure IPT</td>
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<tr>
<td>MILSPECS</td>
<td>Military Specifications</td>
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<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
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<td>MPCL</td>
<td>Military Products from Commercial Lines</td>
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<td>MRP</td>
<td>Material Resource Planning</td>
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<td>MT</td>
<td>Manufacturing Technology IPT</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<td>NPR</td>
<td>National Performance Review</td>
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<td>NPV</td>
<td>Net Present Value</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>OFPP</td>
<td>Office of Federal Procurement Policy</td>
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<td>PAT</td>
<td>Process Action Team</td>
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<td>PDM</td>
<td>Product Data Management</td>
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<td>PEM</td>
<td>Plastic Encapsulated Microcircuit</td>
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<td>PNP</td>
<td>Pulse Narrowband Processor</td>
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<tr>
<td>PPAP</td>
<td>Production Part Approval Process</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<tr>
<td>PMO</td>
<td>Program Management Office</td>
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<tr>
<td>PPM</td>
<td>Parts per Million</td>
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<tr>
<td>RAH</td>
<td>Reconnaissance Attack Helicopter</td>
</tr>
<tr>
<td>RDT&amp;E</td>
<td>Research Development Test &amp; Evaluation</td>
</tr>
<tr>
<td>RF/FEC</td>
<td>Radio Frequency/Front-End Controller</td>
</tr>
<tr>
<td>ROAE</td>
<td>Return on Assets Employed</td>
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<tr>
<td>SEG</td>
<td>Space &amp; Electronics Group</td>
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<tr>
<td>SPC</td>
<td>Statistical Process Control</td>
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<tr>
<td>SPI</td>
<td>Single Process Initiative</td>
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<tr>
<td>SPO</td>
<td>System Program Office</td>
</tr>
<tr>
<td>TINA</td>
<td>Truth in Negotiations Act</td>
</tr>
<tr>
<td>WACC</td>
<td>Weighted Average Cost of Capital</td>
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<tr>
<td>WIP</td>
<td>Work in Process</td>
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<tr>
<td>WL/MT</td>
<td>Manufacturing Technology Division, Materials and Manufacturing Technology Directorate, U.S. Air Force Laboratory</td>
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CHAPTER 1: INTRODUCTION

AN INDUSTRY IN TURBULENT TRANSITION

1.1 Motivation for Research

The United States defense aerospace industry has gone through drastic evolutionary changes in the last decade due to a number of significant structural shifts. These shifts include a change in national security threats, reduced defense budgets, and an increasing pace of commercial technology. With the Cold War over, the priorities of our national defense policy have shifted and the arms race has reached an end. Congressional budgetary pressures have reduced the Department of Defense (DoD) funding significantly over the past two decades particularly in the area of systems procurement, which most directly affects the defense industry prime contractors. High technology and its development for commercial applications has out-paced defense system technology in a number of key areas--such as micro-electronics, and technology in flexible manufacturing systems has enabled high volume production facilities to economically produce low volume products.

These industry shifts have lead to two major outcomes: policy reform intended to promote integration of the supply chain, and defense industry contractor consolidation. Integration of the supply chain is being pursued both as "supply chain integration" and "military-commercial integration." Policy reforms to promote supply chain integration have focused on introducing performance-based practices into the defense contractor and acquisition system. This is a necessary transition to enable military-commercial integration, since commercial firms are unwilling to deviate from commercial practices when doing business with the defense community. Industry consolidation and firm exit are an outcome of a shrinking marketplace, defined primarily by its monopsonist buyer, the DoD, through the

---

1 "Supply Chain Integration" refers to the integration of the participants in a products supply chain through close links, open communication, trust, and teamwork.

2 "Military-Commercial Integration" refers to the integration of the commercial business sector and the defense business sector into a single industrial base through the removal of the barriers between them.
defense budget. High cost structures created by production overcapacity and the high fixed costs of management and engineering staffs, pushed firms toward merger or divestiture of defense businesses to concentrate on commercial sector products.

The following sections will discuss in more detail these evolutionary influences on the defense industry: the changing threats to our national security, reduced defense budgets and their effect on this unique market environment, and the implications of an increasing pace of commercial technology.

1.1.1 Changing National Security Threat

With the 1989 crumbling of the Berlin Wall and 1991 collapse of the Soviet Union came the end of the Cold War. Thirty years of anti-Communist defense strategy and arms build-up were now obsolete and open for new political debate. Many questions were raised by the American people, their congressional representatives, and politicians alike. Without the Soviet threat, do we need to continue the arms build-up of the Reagan years? Don’t we have more pressing issues on which to spend our tax dollars?

Images of outrageously priced DoD toilet seats and $400 hammers were still seared in the minds of taxpayers from the FBI ethics probes into defense contractor practices during 1987-88. Public and political sentiment has shifted towards social programs, infrastructure, jobs, and the economy.

1.1.2 Decreasing Defense Budgets

The defense budget, with its powerful impact on the defense industry, in effect both dominates and defines the size of the market. Congressional budgetary pressures have reduced DoD funding significantly over the past two decades, particularly in the area of systems procurement, which most directly affects the industry prime contractors. To gain a thorough understanding of how this has effected the defense industry, it is necessary to begin with analysis of the economics behind its structure and to review the budgetary historical trends and the political and social influences which act upon its size.

1.1.2.1 Market Economics and Structure

Prime contractors Perspective of the Market. The defense industry in the United States is a market controlled by a monopsonist--a single buyer--which is the DoD. This is due to the specialized nature of defense products and issues of national security and weapons control, which limit the number of potential buyers. The fact is that there are other buyers, more
specifically foreign governments, which purchase a small percentage of US military production. The case of only a few buyers is considered an oligopsony, however, since foreign sales are such a small percentage of the total market demand for US defense contractors, it can be said that the market is essentially a monopsony. The aerospace segment of the US defense industry is shown in Figure 1.1 below, where it can be seen that the export sales from 1981 - 1995 ranged from $6-8 billion dollars (constant 1995 dollars), which accounted for 8-16% of total military aerospace sales.

**Figure 1.1 Total Military Aerospace Sales by U.S. Defense Contractors**

(\textit{Source: Aerospace Industries Association Fact Book})

Defense markets differ from purely competitive commercial markets in a number of ways. Unlike a buyer in a purely competitive market, a monopsonist pays a price that is dependent on the quantity it chooses to purchase. The monopsonist's problem in theory is to choose a quantity which maximizes its net benefit from the purchase. This net benefit is essentially the value derived from the purchase of goods and services, less the cost of development and production. Since there is only one or a very few buyers, economic theory says that the price paid is less than what they would pay in a competitive market, and that this price
advantage over competitive markets is monopsony power (Pindyck, 1995). The extent to which the DoD holds monopsony power is debatable however, given a more complete picture of the market dynamics, particularly since the necessity of arms proliferation and control policy preclude the existence of a competitive weapon systems market in the United States.

The following quote by F.M. Scherer (1964) describes his view of this very unique market:

"the attributes of weapons systems acquisition preclude reliance on anything like a conventional market system for the procurement of advanced weapons, evoking instead what is best described as a "non-market, quasi-administrative buyer-seller relationship." In this nonmarket environment the automatic guides and restraints provided by the market: "invisible hand" are absent. To replace them the government must deliberately structure its relations with contractors in such a way as to assure successful weapons program execution."

Kovacic (1991) relates this "quasi-administrative buyer-seller relationship" as described by Scherer, to the control and structures common to public utility regulation in the United States.

*Sub-Tier Suppliers Perspective of the Market.* The prime contractors, as a set of buyers of military subsystems and components, constitute an oligopoly market structure, very similar to the Big Three U.S. automobile manufactures. Recently, industry consolidation has raised concerns about potential negative consequences of increased vertical integration in the industry (Defense Science Board, 1997).

Through years of defense spending reductions and market exit by sub-tier level suppliers, the firms that remain are potentially well positioned as suppliers of components and technologies in areas with little competition. Given this market environment, market entry might seem appealing. However, the appeal is determined by the extent of entry barriers (i.e. specific skills, contractual guarantees, long-term relationships, technology) and excess rents (abnormal returns through market power).
1.1.2.2 Defense Budget Trends and Market Boundaries

The Defense Budget. The size of the U.S. weapons systems market, given the monopsonistic market structure, is a function of the defense budget. The defense budget has a history of being cyclical due to the nature of a number of factors that impact its size and composition. These influences include:

- Size and form of perceived national security threat
- Health of the U.S. economy
- Short-term, annual defense budget approval, linked to terms in political office
- Congressional support of military jobs in own constituency

Some historical trends have emerged due to the impact of these influences. During the 1970s, the defense budget began to decrease as a result of post-Vietnam War public sentiment—a trend similar to the post-war years following WWII and Korean War. It was during these times that public and political sentiment turned away from defense and inward toward social programs and infrastructure.

In the later 1970s during the Carter presidency, while the U.S. economy was struggling with high levels of inflation, the DoD budget was so reduced that it was coined the "hollow military." The defense prime contractor base failed to react to this downturn and did not contract during this time period, setting the stage for the overcapacity problems of the 1980s-90s. Many sub-tier suppliers exited the market while the prime contractors maintained shares of the shrinking defense budget (Lundquist, 1992).

The Reagan years brought a boom in defense spending to replenish neglected systems, improve technology, and "star wars" R&D. Competition for new procurement programs was fierce, given the long draught of spending and the lack of industry consolidation. It was also realized that increased technology meant high unit costs. For example, in 1951 the DoD purchased 6300 aircraft for a total of $7 billion (1983 dollars), while in 1983 the DoD purchased just 322 aircraft for a total of $11 billion—that's 95% fewer planes (Fox, 1984). Figure 1.1 illustrates DoD spending on new weapons procurement since the Reagan years.
Post-Cold War threat shifts and sentiment have continued to place a strong downward pressure on the defense budget. In real terms, defense spending on procurement has fallen 70% since 1985 when it peaked during the second term of the Reagan presidency. This year though, the Clinton administration is trying to reverse that slide by asking Congress for the first real increase in defense procurement spending in 13 years. It is estimated that modernizing the many 1960s and 1970s era weapons systems used by the military, primarily electronics and material upgrades, will cost nearly $140 billion alone over the next five years (Smart, 1998). This looks to be an excellent market opportunity for firms able to provide the necessary materials for upgrading currently fielded weapons systems—which is particularly true for electronics suppliers.

**Foreign Arms Sales.** The foreign policy of the U.S. Government and statutory laws such as the Export Control Act, control the ability of the defense contractors to expand the market beyond the geographic boundaries of the U.S. and its military installations around the world. Policy has historically extended defense contractors the ability to sell weapons systems to allied countries (i.e. UK, France, Germany, Israel, Saudi Arabia, Taiwan, etc.). Figure 1.3 shows the U.S. trade balance in military aerospace products.

Since the sale of weapon systems impact our national security and arms proliferation, it is obvious that they would be controlled. As Jeremy Sacks (1994) explains, "The main theoretical stumbling blocks relate to the free traders' notions of trade’s relationship to
national security. Free traders fail to recognize that what may be in the nation’s economic interest—i.e. a certain policy that would theoretically increase GNP—may not be in its national security interest." From the prime contractors perspective, foreign sales means profits. A 1974 Coopers & Lybrand study showed that foreign sales were 2.5x more profitable than DoD sales (Gansler, 1977).

**Figure 1.3 U.S. Import-Export Trade Balance in Military Aerospace Products**

![Graph showing U.S. import-export trade balance in military aerospace products.](source)

(Source: Aerospace Industries Association Fact Book)

Outside of these policy controls, the market for weapons is essentially a global market with competition from international weapons producers increasing, particularly from Europe. It should also be noted that the DoD engages in some international sourcing of systems, such as the Harrier aircraft from the U.K., which in this case fills a mission need which U.S. contractors were unable to fulfill.

### 1.1.3 Increasing Pace of Commercial Technology

Military R&D spending has developed many of today’s largest and most prolific technologies and industries. For example, the commercial airline industry was launched by
production subsidies from the U.S. Navy and market subsidies by the U.S. Post Office for air mail. Similarly, the development of long-distance radio transmission prior to WWII was funded through the government's creation of the Radio Corporation of America. Even our interstate highways, originally called the Defense Interstate Highway System, were justified in part for its military importance, and was designed to allow the transport of military vehicles. The DoD's role in the development of the computer is another area of considerable influence. The fledgling computer and semiconductor industries were supported through government R&D support to research institutions like MIT and Princeton, while the business-oriented computer market was kick-started in the 1950's through DoD procurement commitments for the purchase of large numbers of IBM computers--the predecessor to the world's first mass-produced computer, the IBM 650.

But times have changed during the last 20 years. The commercial utilization of computer and semiconductor technologies has proliferated to such an extent that competition in the commercial marketplace for the latest technologies has increased the rate of technological evolution. No longer is DoD funding the core R&D for this industry; instead hundreds of independent firms have taken over this role. Through lean entrepreneurial organizations with flexible designs and manufacturing infrastructure, the latest technologies are introduced at an accelerated pace.

This poses a difficult situation for the DoD's procurement system, historically driven by a bureaucratic and slow process. Given the long design cycle of new weapons system programs, combined with the increasing electronic, computer, and semiconductor content, by the time a system is ready for production, the electronic systems designed into the system many years earlier will quickly become obsolete. This raises concerns over the ability to procure not only the production material and engineering support, but also the fielded system support and spare parts supply to ensure the supportability and sustainment of the system during the entire life-cycle.

1.1.4 Defense Contractors Fighting for Survival

1.1.4.1 Weathering the Storm

Given a market as turbulent as this, how has the defense industry weathered the storm? The defense industry is accustomed to the cyclical swings of a boom-bust defense market. During the post-war market downturns following WWII, Korea, and Vietnam, contractors
turned to commercialization, globalization, and diversification, as strategies to reduce earnings volatility and dependance on defense industry income.

Commercialization. Commercialization has been a very limited avenue for defense firms to expand beyond the boundaries of the defense marketplace. The Jeep vehicle is a good example of post-WWII commercialization, as is McDonnell Douglas' commercial sale of military transport aircraft. More recently, commercialized products include FAA air-traffic systems by Harris and the use of aircraft sensors developed by Westinghouse Defense Electronics for use in mail-sorters. Today, two recent examples include Lockheed-Martin's application of its 3-D graphics technology, developed in conjunction with its flight simulator, which is not being used in Intel personal computer motherboards, and the new E-Z Pass toll collection system in New York, utilizing technology developed to differentiate friendly and enemy tanks.

Globalization. The foreign sale of defense products has long been a primary means for defense contractors to expand their markets for products originally developed for the DoD. However, governmental control over the export of military systems due to national security and arms proliferation, means that Congress defines this portion of the potential market as well. The rise in U.S. exports of military products has been accompanied by an increase in foreign military offsets. Examples of foreign military offsets include the production of F-16 aircraft in Turkey and South Korea, and M1 tank production in Egypt.

Diversification. A mainstay of conglomerate corporations during the 1970s, diversification as a means of spreading earnings volatility over a number of diverse markets has also been popular with defense contractors. The most notable example is Rockwell International, which during the 1970s was almost completely dependent on DoD and NASA contracts for programs such as the B-1 Bomber and the space shuttle airframe and main engines. It later began diversifying into transportation products and electronics during the 1980s and is now almost entirely a commercial firm, especially after the recent sale of its military businesses to Boeing.
1.1.4.2 Consolidation, Diversification, and Market Exit

The pressures for consolidation in the defense industry on prime contractors have been strong over the last decade for a number of reasons:

- A sharp decline in the number of major new weapon systems acquisition programs.
- Substantial production and engineering overcapacity
- Changes in defense acquisition rules in the late 1980s forcing contractors to bear additional risks and costs in developing new high technology systems, through a shift toward fixed price contracting, led to high corporate debt structures.
- Growing international competition for foreign arms sales.

**Figure 1.4 Military Contractors are Shrinking and Diversifying**

<table>
<thead>
<tr>
<th>1992 Fiscal Year</th>
<th>Military Sales (billions)</th>
<th>Share of Companies Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B) McDonnell Douglas</td>
<td>$9.1</td>
<td>52%</td>
</tr>
<tr>
<td>General Electric</td>
<td>8.0</td>
<td>13</td>
</tr>
<tr>
<td>Lockheed</td>
<td>7.5</td>
<td>74</td>
</tr>
<tr>
<td>Boeing</td>
<td>5.4</td>
<td>18</td>
</tr>
<tr>
<td>(R) Hughes Electronics*</td>
<td>5.4</td>
<td>44</td>
</tr>
<tr>
<td>(L) Northrop</td>
<td>5.0</td>
<td>89</td>
</tr>
<tr>
<td>Raytheon</td>
<td>4.7</td>
<td>52</td>
</tr>
<tr>
<td>United Technologies</td>
<td>4.5</td>
<td>20</td>
</tr>
<tr>
<td>(L) Martin Marietta</td>
<td>3.9</td>
<td>66</td>
</tr>
<tr>
<td>(L) Loral</td>
<td>3.3</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total Sales for Top 10</strong></td>
<td><strong>$56.80</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1996 Fiscal Year (latest available)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lockheed Martin</td>
<td>$21.0</td>
</tr>
<tr>
<td>Boeing</td>
<td>15.9</td>
</tr>
<tr>
<td>Raytheon</td>
<td>12.1</td>
</tr>
<tr>
<td>United Technologies</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Total Sales for Top 4</strong></td>
<td><strong>$52.40</strong></td>
</tr>
</tbody>
</table>

Companies acquired by: (B) Boeing, (R) Raytheon, (L) Lockheed.
* A division of General Motors. 1996 figures include Boeing’s acquisition of McDonnell Douglas and Lockheed’s pending acquisition of Northrop. (Source: NYT, 2/27/98.)

**Prime Contractor Consolidations.** Large-scale consolidation of prime contractors may have come to an end. After years of encouraging such measures, the Justice Department surprised the industry with a negative stance on the proposed merger between Lockheed-Martin and Northrop-Grumman. It is unclear whether the opposition comes as an
indication of too much overlap in the tactical aircraft systems market segment or whether the aggressive stance is simply part of the Justice Department’s recent get-tough stance in a variety of industries, including personal computer software (Rapoport, 1998). The effects of industry consolidation and diversification can be seen in Figure 1.3.

1.1.4.3 Negative Effects of Industry Consolidation

Although industry consolidation helps to stabilize the financial well-being of the corporate balance sheet, it does introduce some possible negative side effects. These side effects could include reduced choice for the buyer leading to reduced competition, labor market restructuring, and a reduced industry-generated threat deterrent.

Less Choice. The potential reduction of choice due to industry consolidation can be seen from the perspective of the buyer of a weapons system as well as from the perspective of a supplier of components for the weapons system. From the buyer’s perspective, a reduced choice of producers could mean reduced competition for contracts, leading to potentially increased prices, less innovation in design, and higher risk of dependence on fewer sources. From the supplier’s perspective, industry consolidation could mean a reduction in the number of potential buyers, leading to a dependence on fewer relationships. Additionally, since industry consolidation has resulted in the vertical integration of many prime contractors, suppliers might face the added challenge of overcoming potential internal sourcing biases at these firms, although a recent Defense Science Board (1997) study found that this has not yet been a problem.

Labor Market Restructuring. Operational overhead rationalization in post-merger firms has caused a massive loss of industry employment. The displacement of these well-paid jobs has been a difficult situation, particularly in southern California. The loss of highly skilled engineers, scientists, assembly technicians, and contract administrators to other industries leads to not only a weakening of our industry capabilities, but also a reduced job market for students considering careers in science and engineering.
Figure 1.5 U.S. Defense Industry Consolidation & Vertical Integration
Height Shows Relative Comparison of DoD Sales Dollars

Lockheed

General Dynamics
Dynamics
Tactical
Aircraft

Space Launch Sys

Martin Marietta

GE Aerospace

Loral

Northrop

Grumman

Voight Aircraft

Westinghouse Defense Electronics

McDonnell Douglas

Boeing
Space & Defense
Group

Hughes

Rockwell Space & Defense

Telecom & Space

GM/Hughes


(Rockwell
Hughes (GM)

General Dynamics
Missile Systems

TI Defense
Electronics

Raytheon

Chrysler
Technologies

(Source: Aviation Week & Space Technology, and the Annual Reports of Boeing, Raytheon, Lockheed-Martin, Northrop-Grumman, and General Motors)
Industry Generated Threat Deterrent. The so-called “military-industrial complex” of the U.S. is unique in the world. It provides us with a threat deterrent in itself, due to our ability to mobilize its production capacity and labor skills in times of national security need, as was seen during WWII. Industry consolidation potentially effects this threat through the labor restructuring and production capacity rationalization. With reduced industry capacity, the ability to reconstitute the industrial base in times of need is potentially reduced or a least becomes more difficult.

1.1.5 Commercial and Military Integration

For years the notion of integrating the military industrial sector with the commercial industrial sector into a single national industrial base has been discussed as a solution to some of the defense industry’s biggest problems. As early as in 1977, Jacque Gansler, now Under Secretary of Defense for Acquisition and Technology, in his clairvoyant Harvard Business Review article entitled, Let's Change the Way the Pentagon Does Business,” wrote of “...the need to encourage contractors to integrate their defense-oriented and civil-oriented production lines....” as a means to reduce product costs and improve the capability to increase production capacity in times of security needs. Gansler mentioned two of the many potential benefits of integration. These potential benefits included:
- *Increased Competition*—through an increased number of potential sources.
- *Affordability*—reduced system procurement and sustainment costs through scale economies of production.
- *Technology transfer*—particularly in electronics and semiconductors.
- *Improved National Security*—through an improved ability to mobilize military production capacity in times of need or changing threats.

With all these benefits, the question can be raised as to why commercial and military integration as not already occurred. The answer is not a simple one, nor is there a simple solution. Many barriers exist to integration. As Gansler (1977) wrote, “... the DoD would have to change its policies and practices considerably. Present auditing and accounting requirements make it difficult to take such actions as buying according to a commercial specification rather than military specifications, or buying from the commercial division of a company.” It is exactly these and many other barriers, including deeply rooted cultural barriers, which have prevented commercial and military integration from taking place.

Since 1994 a number of major Government reform initiatives, DoD directives, and statutory laws have been implemented and enacted to overcome these very barriers. The need exists to better understand how well these reforms have worked, through studies and pilot programs.

### 1.1.6 Supply Chain Integration

A major recent thrust in the defense industry has been performance-based source selection and supply chain integration. Supply chain integration refers to the integration of firms in a supply chain through closely linked relationships and partnering, regardless of whether the participants in the supply chain are from the commercial sector or defense sector. The potential benefits of supply chain integration are many, and 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 implementation of supply chain integration requires that participants make an organizational commitment to encouraging an atmosphere of trust and teamwork. Enabling mechanisms include integrated product/process development teams (IPPD) and the use of information technology for the fast, accurate, and efficient sharing of communications, product design information, material scheduling, and product order information.

### 1.2 Research Goals and Methodology

This thesis is primarily focused not only on military-commercial integration, but also on supply chain integration, with emphasis on the enabling benefits they provide toward developing an integrated industrial base. A key objective is to develop an improved understanding of the major barriers, enablers and incentives for attracting commercial firms to defense business as part of a larger strategy for building an integrated U.S. industrial base. A related objective is to document the lessons learned in managing the transition of defense firms and their supplier bases to a performance-based business environment, and the implications for future DoD reform initiatives.

The foundation of this thesis is a case study of the Military Products from Commercial Lines (MPCL) Industrial Base Pilot (IBP) program. Funded by the DoD through MANTECH at WPAFB, this program seeks to produce F-22/RAH-66 Communication, Navigation, and Information (CNI) suite electronics modules on a commercial supplier’s manufacturing line. TRW Avionics Systems Division (ASD) is the CNI system supplier, while a sister division, TRW Automotive Electronics Group (AEG) is the commercial electronics supplier contracted to produce two of the electronics module assemblies on their commercial assembly line.

This research seeks to gain a better understanding of the enabling effects of the reform initiatives of the past five years, toward supply chain integration and military-commercial integration, as demonstrated by the MPCL program. Identification of the barriers that still remain will be an output of this analysis. Additionally, through strategic analysis of the defense industry, this thesis seeks to illustrate the appeal or lack of appeal, that defense
work offers the commercial supplier, to better understand the barriers to military-commercial integration.

1.2.1 Research approach

The approach to this research has been threefold. First, a literature search was conducted as background development for understanding the changes taking place in the defense marketplace and the acquisition reform initiatives of the past decade. Secondly, on site discussions, as well as facility tours, were held with MPCL IBP personnel at TRW ASD in San Diego, California, TRW AEG in Marshall, Illinois, and MANTECH in Dayton, Ohio. These meetings were the starting point for developing an understanding of the MPCL program. The major outcome of these meetings was the collection of the publicly released and industry released reports, briefs, and articles produced by the MPCL Industrial Base Pilot team as part of its mission to document and disseminate the lessons learned throughout the acquisition community. Third, a thorough review of these documents was conducted to develop a detailed understanding of the MPCL program. Information contained in these documents constitute the vast majority of the reference material for the MPCL case study presented in chapter 3. Additional background information on the commercial perspective is provided by automotive industry reference materials and my personnel knowledge of product design and development in the automotive industry, obtained during my seven years of work experience in that industry prior to attending graduate school.

1.2.2 Outline of Chapters

This thesis has been arranged to progress from a broad industry view down to the focused details of the case study, followed by analysis. Chapter 2 begins with a review of the history of acquisition reform as it has transpired over the last decade, working towards implementation of performance-based practices and supply chain integration. Chapter 3 analyzes the operational details of the Military Products from Commercial Lines (MPCL) program and examines the enablers, roadblocks, and lessons learned during the Industrial Base Pilot (IBP) program. Chapter 4 analyzes the MPCL program for the impacts on performance-based practices and supply chain integration and critiques the appeal of the defense industry business opportunity from the commercial supplier perspective. Finally, chapter 5 provides a summary of findings, lessons learned, and recommended actions, followed by recommendations for areas of further study.
CHAPTER 2: ACQUISITION REFORM

"For many years, our military's strategy has been based on battlefield dominance through our leadership in technology, especially information technology. During the '50s, '60s and '70s, the Defense Department was the principal supporter of research and development for the computer, communications and semiconductor industries. Some of the most significant advances were developed first for military systems. In effect, our nation's commercial industry was riding on the shoulders of the Defense Department.

But the Defense Department's role in developing technology has changed. Today, that situation has been reversed. The technological explosion has led to a set of amazing new products for industry, businesses, schools and the home. Commercial applications of computers are leading military applications in all of these fields and, for computer companies, commercial revenues dwarf Defense Department revenues. Today, the Defense Department must ride on the shoulders of our commercial industry.

Defense can no longer support a unique defense industry but must increasingly rely on commercial companies and commercial products. To attract and retain those companies as suppliers, the Defense Department must give up its unique buying practices and employ best commercial practices. ...Reform is off to a good start, but we must eliminate unnecessary barriers to commercial companies and their technology..."

Dr. William J. Perry (1998)
Former Secretary of Defense
2.1 Introduction

Defense acquisition reform\(^3\) initiatives have been going on for years. The reforms in the 1990s however, have been some of the most dramatic and powerful to date. What is new is the immediacy of change and the high-level leadership support for these sweeping changes. As Dr. William Perry states in the chapter opening, the reforms are taking hold but much work is still needed.

The discussion of these reforms is organized using an organizational change model developed by Beck, Brokaw, and Kelmar (BBK) in their 1997 Military Research Fellows Report. This framework looks at change in the defense industry in four phases, as shown in Figure 2.1.

![Figure 2.1 BBK Change Process Framework](image)

(Source: Beck, 1997)

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\(^3\) The term “reform” has been used quite often in recent years. Here is the Webster’s Dictionary definition: reform \(\text{Re}^\star\text{form}\) To put into a new and improved form or condition; to restore to a former good state, or bring from bad to good; to change from worse to better; to amend; to correct; as, to reform a profligate man; to reform corrupt manners or morals. Syn: To amend; correct; emend; rectify; mend; repair; better; improve; restore; reclaim.
2.2 Assessment Phase
The assessment phase of change is during the period of current state assessment and reporting. Due to the public and political oversight of government, there is an affinity for reporting and analysis of its function, through government appointed task forces, non-profit organizations supported by industry and political groups, and consulting firms. The DoD is no different. Many studies assessing the status of DoD functioning, particularly the acquisition process, have taken place over the last half a decade. Table 2.2 summarizes these studies.

Figure 2.2 Studies Identifying Acquisition Process Improvements

<table>
<thead>
<tr>
<th>Year</th>
<th>Common Name</th>
<th>Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949 &amp; 1955</td>
<td>The Hoover Commission</td>
<td>Commission on Organization of the Executive Branch of the Government</td>
</tr>
<tr>
<td>1970</td>
<td>The Fitzhugh Commission</td>
<td>President’s Blue Ribbon Defense Panel</td>
</tr>
<tr>
<td>1972</td>
<td>The 1972 Commission on</td>
<td>The 1972 Commission on Government Procurement</td>
</tr>
<tr>
<td></td>
<td>Government Procurement</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>The Carlucci Initiatives</td>
<td>Acquisition Improvement Task Force</td>
</tr>
<tr>
<td>1983</td>
<td>The Grace Commission</td>
<td>President’s Private Sector Survey on Cost Control</td>
</tr>
<tr>
<td>1983</td>
<td>Defense Science Board I</td>
<td>“Transition for Development of Production”</td>
</tr>
<tr>
<td>1986</td>
<td>The Packard Commission</td>
<td>President’s Blue Ribbon Commission on Defense Management</td>
</tr>
<tr>
<td>1986</td>
<td>Defense Science Board II</td>
<td>“Functional Performance Requirements”</td>
</tr>
<tr>
<td>1987</td>
<td>Defense Science Board IV</td>
<td>“Technology Based Management”</td>
</tr>
<tr>
<td></td>
<td>Report)</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>Defense Science Board</td>
<td>“Acquisition Streamlining Task Force”</td>
</tr>
<tr>
<td>1991</td>
<td>Center for Strategic</td>
<td>“Integrating Commercial and Military Technology</td>
</tr>
<tr>
<td>1993</td>
<td>The Section 800 Panel</td>
<td>Department of Defense Acquisition Law Advisory Panel</td>
</tr>
<tr>
<td>1994</td>
<td>1994 Coopers &amp; Lybrand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Report</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>1997 Coopers &amp; Lybrand</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Defense Science Board</td>
<td>Task Force on Vertical Integration and Supplier Decisions</td>
</tr>
</tbody>
</table>

(Source: Beck, 1997)
2.1 Preparation Phase

The preparation phase is the most critical for planting the seeds of change. High-level leadership vision and support of the change is necessary for it to take root and grow. The government or any other bureaucratic organization is a gauntlet of various political agendas, opinions, and opposing forces. Energy and support must be aligned in order for change to survive these counter forces. During the 1990’s, this took place, both at the Executive branch with the National Performance Review and at the DoD with a new leadership team.

2.3.1 National Performance Review and Reinventing Government

In March of 1993, President Clinton announced an initiative to “reinvent government” called the National Performance Review (NPR) and appointed Vice President Al Gore as its leader. The goal of NPR is to create a government that “works better and costs less.” The core leadership of NPR included two directors and four deputies that included: Billy Hamilton, who lead a team examining the 24 largest agencies—including the DoD, and John Kamensky, who led lead a series of teams examining government-wide systems—including procurement (NPR, 1997). The first of three phase reports was issued in September of 1993 and by December President Clinton had signed 16 directives implement implementing specific recommendations.

This initiative is particularly significant because it placed much high level attention and energy behind government reform activities—something that previous iterations of defense reform initiatives had lacked.

2.3.2 DoD Leadership

A driving force behind the DoD reforms during the last decade has been a strong leadership team at the DoD. This team was not in place by chance. The Clinton Administrations vision of re-inventing government and NPR opened the door for then Secretary of Defense Les Aspen, to assemble a team of leadership at the DoD who were aligned and supportive of a vision of reform defense acquisition. This new leadership team included the appointment of Dr. William Perry as Deputy Under Secretary of Defense—soon to take Aspens place, Paul Kaminski as Under Secretary of Defense for Acquisition and Technology, Colleen Preston as Deputy Under Secretary of Defense for Acquisition Reform, and new acquisition leadership at each of the services.
Figure 2.3 Major DoD Acquisition Reform Initiatives of the 1990s
and the Relationships Between Them

2.4 Implementation Phase
The implementation phase of the BBK change framework includes both the actions used to initiate the change and the actions needed to implement and nurture the change. In the case of acquisition reform, change initiation actions come in the form of law, policy, and
initiatives. The implementation of change is often considered the most challenging, and in the case of the defense acquisition system, the challenge is significant.

2.4.1 Congressional Reform of Statutory and Regulatory Law

Law is the foundation upon which our government operates and is therefore a good place to begin a discussion of specific reforms. This is particularly true for contracting officers. A large portion of their role in procurement contracting is to ensure that statutory and regulatory laws are obeyed—the same laws which deter supply chain integration.

2.4.1.1 Federal Acquisition Streamlining Act of 1994 (Public Law 103-355)

On October 13, 1994, President Clinton signed the Federal Acquisition Streamlining Act (FASA) of 1994 which introduced sweeping changes in the ability of the DoD to pursue the purchase of commercial items and in various other procurement policies. The recommended changes and reforms that were ultimately enacted as FASA were the result of recommendations made by an Under Secretary of Defense for Acquisition appointed Acquisition Law Advisory Panel—commonly known as the “Section 800 Panel.”

In January of 1993, the so called “Section 800 Panel” submitted its final report titled “Acquisition Reform” to Congress. This panel of government and industry appointed experts was charted by Congress under statutory provision in the DoD Authorization Act for FY1991 to review all DoD-related acquisition laws. The panel made its recommendations in an 1,800 page final report to the legislature calling for many significant changes in the policies, structure, and substance of current acquisition laws as related to the DoD procurement system.

The major changes included the following (DoD, 1996):

- The definition of what qualifies as a commercial product is expanded.
- Purchases of commercial items are exempt from over 30 statutes unique to government.
- Contracts for commercial items are exempt from the requirement to provide cost and pricing data.
- The threshold under the Truth in Negotiations Act (TINA) is raised to $500,000.
- The simplified acquisition threshold is raised to $50,000 and will go up to $100,000 when certain conditions are met. Purchases made under the threshold are exempted from 15 statutes.
• More extensive debriefings are required upon award of contract to reduce the number of protests.

• The use of Past Performance as a selection criteria added as a requirement to assist in best source selection and to motivate contractors to perform better.

• Requires contracting officers to take advantage of commercial warranties.

2.4.1.2 Federal Acquisition Reform Act of 1996

The Federal Acquisition Reform Act (FARA) was introduced as part of the National Defense Authorization Act for Fiscal Year 1996. FARA expanded FASA and made additional changes to increase the use of commercial products and processes. These additions simplified government purchase of commercial items in several ways (DoD, 1996):

• Added flexibility for the contracting officer to determine price reasonableness of the contract, subcontract, or modification.

• Authorization for the use of simplified acquisition procedures for commercial items valued at less than $5 million, when the contracting officers expects only responses by commercially available items.

• Requirement of the FAR to be modified to include a list of procurement provisions that are inappropriate for COTS contracts.

• Expansion of commercial item definition to include those items which the price is based upon established market prices sold to the general public.

• Elimination of certain Cost Accounting Standards

2.4.2 DoD Procurement Policy Reform

Once statutory and regulatory law reforms have established the new legal boundaries of government procurement, DoD policy must be reformed to establish guidelines and principles for operation with them. These DoD policies are defined through Secretary of Defense policy memorandum, directives, and initiatives.

The focus of acquisition reform initiatives are on three basic objectives:

• Reduction of overall DoD program costs

• Improvement of program performance

• Increased quality of delivered products
2.4.2.1 Perry Memo of 1994, "A Mandate for Change"

In March of 1994, following the wave of support for government reform generated by the NPR, the secretary of defense, Dr. William J. Perry, issued a memo titled "A Mandate for Change." This comprehensive policy memo drastically changed the way that requirements would be written for military products in Request for Proposals (RFPs). The policy directed the use of commercial and performance specifications, while discouraging the use of military unique standards and specifications. This was to be implemented through the use of a contract waiver. This drastic policy change was the first step in the move from a "how to" military specification and standard environment, to a "meet this spec" environment. The rationale was to encourage commercial suppliers to compete for military contracts based on innovative designs, high quality standard, and past performance.

2.4.2.2 Specifications and Standards Reform

In June of 1994 Secretary of Defense William Perry issued a memo titled "Specifications and Standards--A New Way of Doing Business." The goal of this memo was to better enable the DoD acquisition community to integrate commercial and military development and manufacturing through the removal of government-unique requirements and to ensure that the DoD has access to state-of-the-art commercial technology.

The memorandum was a result of the recommendations set forward by a process action team (PAT) assembled to study the recommendations of a 1991 Center for Strategic International Studies (CSIS) report. The CSIS report concluded that military unique specifications resulted in higher prices for the DoD than the same purchases with commercially available specifications. Elimination of military unique specifications would also enable dual use technology applications.

*Non-Government Standards IPT.* The joint industry/government Non-Government Standards (NGS IPT) was formed in 1995 to address the environment of specifications and standards reform. The NGS IPT was chartered to "...define a business environment which takes advantage of the efficiencies of commercial practices to improve our military acquisition environment..." and to "...allow suppliers to compete and be selected based upon innovative designs and process excellence, and not government dictated practices, within the limits of public law" (NGS IPT, 1996).

The NGS IPT's focus was on the identification of opportunities, options, issues, and concepts for reducing the requirement to use government unique specifications and
standards. The teams February 1996 final report offers a set of options and processes for implementation of the specifications and standards reform policy identified in the June of 1994 Perry memo.

2.4.2.3 DoD 5000 Series Directives of 1996

The DoD 5000 series directives have been one of the key policy documents and a foundation of the defense acquisition process for over 20 years (Ferrara 1996). Since its original edition in 1971, there have been nine different updates and revisions.

This directive, which evolved from a 1994 Under Secretary of Defense policy directing the use of open systems in defense electronics, broadened the use of open systems to all weapon systems. The technical and business strategy for the use of open systems is to promote the use of commercial standard interfaces that have been adopted by recognized standard bodies. This could include everything from light bulbs to fasteners, however electronics systems for computing, telecommunications, sensing, and signal processing are where open standards appear most prevalent and numerous.

Four principle objectives form the underpinnings of this revision:

1. Separation of mandatory policies and procedures from discretionary practices.
2. The incorporation of new laws and regulations since the 1991 revision, including FASA and DoD policy memoranda implementing acquisition reform recommendations.
3. Consolidation, for the first time, of acquisition policy guidance for weapon systems and automated information systems.

The new documents institute several major changes:

1. Decentralization of acquisition practices as much as possible to give acquisition executives more say in managing the programs for which they are accountable.
2. Several new guiding principles which articulate the changing global security environment, including the importance of “nontraditional acquisition” and Cost as an Independent Variable (CAIV).
3. The encouragement of integrated solutions through the removal of report-based interaction, instead relying on IPTs to breakdown inter-organisational barriers.
2.4.2.4 Cost as an Independent Variable

Cost as an Independent Variable (CAIV) is a new guiding principle of DoD strategy, as December 1995, stemming from the 1996 revision of the 5000 Directives. CAIV makes total life-cycle costs a key driver of system requirements, performance characteristics, and schedules. (Rush, 1997)

The Defense Acquisition Deskbook defines CAIV in the following broad context: "CAIV is a strategy the entails setting aggressive yet realistic cost objectives when defining operational requirements, acquiring defense systems, and managing achievement of these objectives. Cost objectives must balance mission needs with projected year-out resources, taking into account existing technologies, maturation of new technologies, and anticipated process improvements in both DoD and industry" (DoD, 1996(a)).

There are many implications of cost as a key driver on the supply chain. These implications include:

- **Trade-off**---Requirements/cost/performance
- **Competition**---An acquisition strategy to maintain competition as far into the process as possible.
- **IPPD**---Concurrent engineering and integrated product and process development teams to cooperate meet aggressive cost targets.
- **Lean Enterprise**---A lean enterprise philosophy within the contractor community to do more with less.
- **Commercial Practices**---Use of reform initiative enabled commercial specifications, practices, and components, where feasible, to reduce cost.

CAIV is not simply a cost reduction process but is a guiding principle for program managers and IPTs throughout the development process. It has the most impact when implemented at the earliest beginnings of a program. In programs that are mid-stream, such as the Grissly vehicle program, the CAIV principles provided only minimal cost savings in areas such as process quality (Bley, 1997).

2.4.2.5 Dual-Use Technologies

Dual-Use Technology Program was a strategy of the DoD implemented in 1995 to leverage the commercial sector to reduce costs, shorten acquisition cycle-times, and to obtain high technology defense systems, with an end goal of integrating the military and commercial
industrial bases into one national industrial base (DoD, 1995). The Dual-Use Technology strategy is based upon three “pillars” with acquisition reform as a foundation. These three “pillars” are:

1. Investment in R&D on Dual Use Technologies
2. “Dual Produce:” Integration of Military into Commercial Production
3. Insertion of Commercial Capabilities into Military Systems

The original Dual-Use Technologies program has lead to the formation of the Dual-Use Applications Program (DUAP) to find suitable applications for these technologies.

2.4.2.6 Single Process Initiative

The Single Process Initiative (SPI) is an initiative designed to accelerate the shift from separate government and commercial manufacturing facility processes, to common facility-wide processes. The three most frequently proposed processes are in the areas of quality programs, manufacturing processes such as plating, and business practices such as certification requirements (Drewes, 1997). Since its announcement in December of 1995 by Secretary of Defense Dr. William Perry, a total of 741\(^4\) process changes have been approved of the 1239 proposals submitted (Rebentisch, 1998). Early during the initiative, concern was raised by both industry and government regarding implementing block changes at major sub-contractors. As a result, a memo was issued by Kaminski in September 1996 providing guidance for dealing with specification or process changes at sub-contractors.

2.4.2.7 Commercial Operations and Support savings Initiatives

In fiscal year 1997 Congress appropriated funding for a new effort under the DUAP which was designated Commercial Operations and Support Savings Initiatives (COSSI). The goal of this initiative is to develop and test a method for reducing DoD operation and support costs by inserting commercial products and processes into fielded military systems. The intended outcome of this program is reduced operational and support costs through reduction in the costs of parts, maintenance labor, reduced need for specialized equipment, and increased reliability.

\[^4\] Totals as of December 1997 and reflect actual total rather than total of service reports to avoid redundancies.
2.4.2.8 Integrated Process/Product Teams (IPT)

The IPT concept was first formally introduced to the DoD for program management in a June 1995 Perry memorandum. Although this was the formal introduction, all three services had already introduced IPTs within their organizations and had published guidelines for implementation. The introduction of IPTs was one of the ways for the DoD to implement change through improved communication and process improvements.

2.6 Institutionalize and Re-Evaluate

The final phase of change is the process of institutionalizing the changes within the culture of the organization and the continuous process of re-evaluation.

2.6.1 Institutionalize Reforms

Leadership, communication and training are crucial for the successful implementation of change initiatives and the institutionalization of the reforms. The defense acquisition process, with its conservative and risk averse culture, is very much grounded in the old and comfortable processes that have served the system for years. Change is uncomfortable and disturbing—which is why it is so difficult.

2.6.2 Re-evaluation with Pilot Programs

The continuous process of re-evaluation and reassessment of the current condition of change implementation is essential to understanding the effectiveness of the change process. Re-evaluation can take place through a number of means, including studies and test programs.

2.6.2.1 Re-assessment Studies

Re-assessment studies, like the original assessment studies described earlier in the chapter, are desired and inherent in the closely observed arena of government. This thesis falls into this area, as does much of the activity performed by the Lean Aerospace Initiative (LAI). LAI is a joint research effort between the aerospace industry, the DoD, and MIT, to study the aerospace industry implementation of lean enterprise processes.

2.6.2.1 Pilot Programs

Testing the effectiveness of changes to any system is prudent. The DoD has initiated a number of pilot programs to test the effectiveness of defense acquisition reform initiatives over the years. The Military Products from Commercial Lines (MPCL) Industrial Base Pilot (IBP) program discussed as a detailed case study in chapter 3 is just one example.
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 initiated 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 engineers, 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](image)

\[
\text{Contract Price} = \text{Cost} + \text{Profit/Fee}
\]

\[
\text{Indirect} \quad \text{Overhead} \quad \text{Material Handling} \\
\quad \text{Manufacturing Support} \\
\quad \text{Engineering Support} \\
\quad \text{General & Admin.} \\
\quad \text{ECCM} \\
\]

\[
\text{Cost} = \text{Direct Cost} + \text{Other Direct Costs}
\]

- Direct Labor
- Engineering Labor
- Manufacturing Labor
- Raw Material
- Purchased Parts
- Subcontracts
- Std Commercial Items
- Inter-divisional Transfers

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

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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.

<table>
<thead>
<tr>
<th></th>
<th>Cost of Quality as Percentage of Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Business</td>
<td>1-2.%</td>
</tr>
<tr>
<td>TRW &quot;Military&quot; ASD</td>
<td>0.57%</td>
</tr>
<tr>
<td>TRW &quot;Commercial&quot; AEG</td>
<td>0.32%</td>
</tr>
</tbody>
</table>

(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**

<table>
<thead>
<tr>
<th>Part/Process Approval (PPAP)</th>
<th>ASD &quot;Military&quot;</th>
<th>AEG &quot;Commercial&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate Existing Part Data</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Generate NSPAR</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Contract or Part Approval</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Parts Control Board Approval</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>Supplier Survey</td>
<td>14</td>
<td>90</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>192 days</strong></td>
<td><strong>135 days</strong></td>
</tr>
</tbody>
</table>

*(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

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

(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.
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

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

(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.

<table>
<thead>
<tr>
<th>Benchmark/Source</th>
<th>Total Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive Industry QS9000</td>
<td>244</td>
</tr>
<tr>
<td>F-22 EMD</td>
<td>204</td>
</tr>
<tr>
<td>ANSI Q9001</td>
<td>137</td>
</tr>
<tr>
<td><strong>MPCL IBP</strong></td>
<td></td>
</tr>
<tr>
<td>Q9001 Basic Requirements</td>
<td>20</td>
</tr>
<tr>
<td>Q9001 Clarified for Defense</td>
<td>24</td>
</tr>
<tr>
<td>National Standards</td>
<td>16</td>
</tr>
<tr>
<td>Military Standards</td>
<td>6</td>
</tr>
<tr>
<td>Best Practices</td>
<td>12</td>
</tr>
<tr>
<td><strong>IBP Total</strong></td>
<td><strong>78</strong></td>
</tr>
</tbody>
</table>

(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

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 fared 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**

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

(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**

<table>
<thead>
<tr>
<th></th>
<th>MPCL IBP</th>
<th>Military Baseline</th>
<th>IBP Goal</th>
<th>Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Average Cost</td>
<td>$10.9K*</td>
<td>$40K*</td>
<td>50%</td>
<td>73%</td>
</tr>
<tr>
<td>of First 30 Units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Pricing from</td>
<td>$12.7K</td>
<td>$40K*</td>
<td>50%</td>
<td>68%</td>
</tr>
<tr>
<td>Validation Participants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.
CHAPTER 4: ANALYSIS

4.1 Introduction
An assessment of the current state of defense industry appeal to the commercial business sector is essential for evaluation of how current reforms are taking effect and for consideration of further action. This chapter will analyze the defense industry from multiple levels to aid in this assessment. First, a strategic analysis of the defense industry competitive environment will give a high-level view of the forces influencing it, both before and after the reforms and consolidation of the last five years. Second, an operational level analysis is presented of the barriers and enablers to military-commercial integration, incorporating the lessons learned from the IBP program. Finally, the last section presents a focused discussion of the major enablers that still must be addressed.

4.2 Strategic Analysis of Defense Industry Appeal
A good starting point for developing an understanding of an industry is through economic analysis of the industry structure and through analysis of the industry competitive environment. In Chapter 1, the economic structure of the defense industry was discussed in detail, so I will not repeat it here. Analysis of an industries competitive environment can be structured using a Porter 5-Forces framework (Porter, 1990). The following section will use this framework to analyze the defense industry from two perspectives; a prime contractors analysis of the industry and a sub-tier suppliers analysis. The analysis will compare the state of the defense industry today versus the state before the reforms and industry consolidation of the last five years.
4.2.1 Prime Contractor Analysis of the Defense Industry

The prime contractor is the 1st-tier interface with the monopsonist buyer of defense products in the U.S. market. Figure 4.1 summarizes the prime contractor level analysis of the defense industry as described below.

*Government Intervention.* The effects of government intervention in the defense industry, for numerous reasons that were discussed in Chapter 1 are very high, and are as influential as can be found in any industry. The previously regulated industries of telecommunications and power are examples of industries nearly as controlled, however even in these industries the market was only geographically constrained, never sales constrained. Intervention has been reduced slightly through reform initiatives and through reduced oversight, however anti-trust intervention regarding industry consolidation has demonstrated one of the strongest means the government has for controlling competition. Government also intervention remains high in its control of international markets.

*Barriers to Entry.* The barriers to entry for prime contractors were high before consolidation and reform, and are about the same today. There are numerous barriers to entry in the defense industry for a prime contractor. These include specific fixed assets in capital equipment, skills and knowledge in dealing with government and DoD policies and procedures, political connections, and R&D technologies. Consolidation has increased the entry barriers through increased scale in R&D, complex project management, and production. Reforms may have slightly reduced barriers through the removal of government unique standards and practices, however the barriers that remain are so large that this reduction is small in comparison. Barriers due to fixed assets in specific equipment have been reduced through the use of flexible manufacturing and CIM technology.

*Barriers to Exit.* Many of the conditions that pose barriers to entry also act as barriers to exit for industry participants. These exit barriers, which are very high for prime contractors include:

- Product/industry specific fixed assets
- Industry specific workforce (skills, culture, geographic location)
- Intangible assets (intellectual assets, R&D, people, organization)
- Leadership commitment to the industry
- Political influence
## Figure 4.1 Prime Contractor Level Analysis of the Defense Industry

<table>
<thead>
<tr>
<th></th>
<th>Before Consolidation &amp; Reform (late-80's / early-90's)</th>
<th>After Consolidation &amp; Reform (1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Government Intervention</strong></td>
<td>Very High</td>
<td>Very High but Reduced Slightly</td>
</tr>
<tr>
<td></td>
<td>• Controls size of market through Congressional approval of procurement budget and policy on export sales</td>
<td>• Controls size of market through Congressional approval of procurement budget and policy on export sales</td>
</tr>
<tr>
<td></td>
<td>• Defines legal contracting and business interface requirements of the acquisition process</td>
<td>• Defines legal contracting and business interface requirements of the acquisition process</td>
</tr>
<tr>
<td></td>
<td>• High degree of oversight</td>
<td>• Reform has reduced degree of oversight</td>
</tr>
<tr>
<td><strong>Barriers to Entry</strong></td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>• Knowledge is required to deal with government process</td>
<td>• Technology advances have increased barriers</td>
</tr>
<tr>
<td></td>
<td>• Capability to manage large complex projects</td>
<td>• Increase scale in R&amp;D through consolidation</td>
</tr>
<tr>
<td></td>
<td>• High investment in industry specific plant, equipment, and personnel</td>
<td>• Increased scale in production and engineering, due to larger competitors</td>
</tr>
<tr>
<td></td>
<td>• High debt structure</td>
<td>• Reform has reduced slightly through less government specific knowledge required</td>
</tr>
<tr>
<td></td>
<td>• Political connection asset</td>
<td>• Reduced fixed asset barriers through flexible manufacturing technology.</td>
</tr>
<tr>
<td></td>
<td>• Scale in R&amp;D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Learning curve effects</td>
<td></td>
</tr>
<tr>
<td><strong>Buyer Bargaining Power</strong></td>
<td>Very High Power</td>
<td>High</td>
</tr>
<tr>
<td>(DoD)</td>
<td>• One main buyer, DoD/US Government</td>
<td>• Prime contractors less reliant on defense sales for corporate health.</td>
</tr>
<tr>
<td></td>
<td>• DoD has high power since Monopsony buyer and many suppliers</td>
<td>• Reduced % of sales to DoD has reduced power of the DoD as a customer</td>
</tr>
<tr>
<td></td>
<td>• DoD has full &amp; complete information</td>
<td>• Reduced through less direct control on “how to”</td>
</tr>
<tr>
<td></td>
<td>• Little threat of backward integration</td>
<td></td>
</tr>
<tr>
<td><strong>Supplier Bargaining Power</strong></td>
<td>Low Power</td>
<td>Low-to-Medium Power</td>
</tr>
<tr>
<td>(2nd/3rd-Tier)</td>
<td>• Many suppliers to many contractors</td>
<td>• Increased through fewer suppliers due to reduced defense spending and consolidation</td>
</tr>
<tr>
<td></td>
<td>• Supply base has been reduced over years of defense spending reductions</td>
<td>• Fewer suppliers reduced competition for some sole-source technology firms</td>
</tr>
<tr>
<td></td>
<td>• Suppliers with monopoly positions for some sole-source technologies hold high power</td>
<td>• Vertical integration of prime contractors has increased power of internal sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reform for military-commercial integration is trying to reduce power through increased competition.</td>
</tr>
<tr>
<td><strong>Threat of Substitutes</strong></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>• Mission requirements tend to limit opportunity for substitutes</td>
<td>• Mission requirements tend to limit opportunity for substitutes</td>
</tr>
<tr>
<td><strong>Rivalry among existing firms</strong></td>
<td>High</td>
<td>High but Reduced Slightly</td>
</tr>
<tr>
<td></td>
<td>• Many firms fighting for contracts</td>
<td>• Increased through few new programs.</td>
</tr>
<tr>
<td></td>
<td>• High fixed costs due to over-capacity and engineering staffs</td>
<td>• Increased exit barriers from consolidation</td>
</tr>
<tr>
<td></td>
<td>• Fierce competition for international exports with US and international firms</td>
<td>• Decreased due to less competitors</td>
</tr>
<tr>
<td></td>
<td>• High exit barriers</td>
<td>• Reduced through web of teaming relationships between prime contractors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Easier to coordinate with fewer firms</td>
</tr>
</tbody>
</table>

*Porter 5-forces analysis framework (1980)*
Buyer (DoD) Bargaining Power. The power of the DoD as a monopsonist buyer in the defense industry and as a partner with Congress in developing the defense budget, provide a very high level of power for the DoD over the industry. Reductions in the level of power have come from reduced oversight due to reform initiatives and more importantly, through the diversification of prime contractors into other industries, leading to a reduced reliance on DoD spending for financial health.

Supplier (Sub-Tier) Bargaining Power. The power held by sub-tier suppliers varies tremendously, from the low power of a commodity product like PC’s to the high power of a sole-source supplier of a custom technology. On average, the power seams to be relatively low. The consolidation and vertical integration of prime contractors has reduced power through incentives to source internally. Reforms encouraging military-commercial integration have also reduced power through increased competition, however this may have been balanced through exit of existing suppliers.

Threat of Substitute Productions. For the prime contractor, little threat is posed by substitute products. Technology and our confidence in its use has the greatest impact on this threat. A B-2 bomber could potentially be replaced by guided cruise missiles, just as a manned F-22 fighter could be replaced with unmanned aircraft or lasers from satellites for that matter.

Rivalry Among Existing Firms (Prime-Contractors). Rivalry among existing prime-contracts was high before consolidation and today is reduced only slightly. Before consolidation, the drivers of rivalry were high fixed costs, high debt, and excessive capacity in production and engineering. Today, consolidation has begun to rationalize the financial structure and capacity driven competition, however fewer firms competing for a smaller market and fewer new programs has balanced these forces. Fewer firms also increases the ability for coordination and tacit collusive behaviors, particularly with the use of teaming arrangements on major new programs.

4.2.2 Sub-Tier Supplier Analysis of the Defense Industry

The Sub-Tier suppliers in the defense product supply chain provide goods and services to the prime contractors. Consolidation has reduced the number of prime contractors which compete in the industry to between one and three in any given market segment. The effect
has been a more powerful set of buyers, similar in economic structure to the oligopsony of the U.S. automotive industry. Figure 4.2 summarizes the sub-tier supplier level analysis of the defense industry as described below.

### Figure 4.2 Sub-Tier Supplier Level Analysis* of the Defense Industry

<table>
<thead>
<tr>
<th></th>
<th>Before Consolidation &amp; Reform (late-80's / early-90's)</th>
<th>After Consolidation &amp; Reform (1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Government Intervention</strong></td>
<td>High • Controls size of market through Congressional approval of procurement budget and policy controls on export sales • Defines legal contracting and business interface requirements of the acquisition process • High degree of oversight</td>
<td>High but Reduced Slightly • Controls size of market through Congressional approval of procurement budget and policy controls on export sales • Defines legal contracting and business interface requirements of the acquisition process ↓ Reform initiatives have reduced, particularly with commercial items</td>
</tr>
<tr>
<td><strong>Barriers to Entry</strong></td>
<td>High • Knowledge is required to deal with government process • Personnel, skills, CAS accounting, contracting knowledge, all required</td>
<td>Medium ↓ Reform has lowered through less government specific knowledge required ↓ Technology advances in flexible manufacturing have reduced barriers</td>
</tr>
<tr>
<td><strong>Buyer Bargaining Power</strong> (Prime-Contractors)</td>
<td>Medium • At least a few competitors in each market segment • Prime becomes monopsonist buyer once contracted for program since only one producer • Multiple programs with similar technology offer competition</td>
<td>Medium-to-High ↑ Increase through threat of backward integration ↑ Few new procurement programs limit opportunities for new business ↓ Consolidation of prime contractors has reduced the number of buyers in this oligopoly market</td>
</tr>
<tr>
<td><strong>Supplier Bargaining Power</strong></td>
<td>Low • Many suppliers to many contractors • High Defense spending • Technology based monopoly positions for some suppliers offer isolated power</td>
<td>Low-to-Medium Power ↑ Increased through fewer suppliers due to reduced defense spending and consolidation ↑ Fewer suppliers reduced competition for some sole-source technology firms ↓ Vertical integration of prime contractors has increased power of internal sources ↓ Reform for military-commercial integration is trying to reduce power through increased competition</td>
</tr>
<tr>
<td><strong>Threat of Substitutes</strong></td>
<td>Low • Mission requirements tend to limit opportunity for substitutes</td>
<td>Low • Mission requirements tend to limit opportunity for substitutes</td>
</tr>
<tr>
<td><strong>Rivalry among existing firms</strong></td>
<td>Medium • Many firms fighting for contracts</td>
<td>Medium but Reduced Slightly ↑ Potential to increase with more commercial sector competition ↓ Decreased due to less competitors ↓ Reduced through less dependence on DoD sales</td>
</tr>
</tbody>
</table>

*Porter 5-forces analysis framework (1980).
**Government Intervention.** Intervention at the sub-tier level of the supply chain is nearly as strong as at the prime contractor level, but is slightly lower due to reduced direct control and oversight. Reform initiatives are working towards more oversight reduction. This is particularly true for sub-tier suppliers of commercial item status components as seen in the MPCL case study.

**Barriers to Entry.** The barriers to entry for sub-tier suppliers are nearly the same for sub-tiers as for prime contractors. Reform initiatives encouraging supply chain integration are working to reduce the barriers to entry, however many remain including the need for specific assets in contracting personnel.

**Barriers to Exit.** The barriers to exit for defense industry suppliers is very dependent on the level of the industry specific fixed assets in the firm. Flexible manufacturing assets and a workforce with transferable skills act to minimize barriers.

**Buyer (Prime-Contractor) Bargaining Power.** The power of the prime contractors as oligopsonist buyers in the defense industry is of medium strength, and was increased through consolidation. Consolidation and vertical integration have also potentially increased power through the threat of continued backward integration. Buyer power held over commercial firms is even lower, since purchases tend to be very small in quantity and more often than not require some administrative disruption.

**Supplier (Lower-Tier) Bargaining Power.** The power held by sub-tier suppliers varies tremendously, from the low power of a commodity product like PC's to the high power of a sole-source supplier of a custom technology, as is the case for the 2nd-Tier suppliers to the prime contractors. On average, the power seems to be relatively low. Reforms encouraging military-commercial integration have also reduced power through increased competition, however this may have been balanced through exit of existing suppliers.

**Threat of Substitute Productions.** For sub-tier suppliers, the threat of substitute products is greater than for the prime contractors, although it varies depending on the product. In general, the threat of substitutes for highly engineered products tailored to narrow specifications is very low. Again, technology poses the greatest potential threat for substitute creation. Examples include integrated circuits replacing vacuum tubes and
graphical displays replacing analog gages. Military-commercial integration may increase the rate of substitute creation through the increased pace and innovation of the commercial market.

*Rivalry Among Existing Firms (Sub-Tier Suppliers).* Rivalry among existing sub-tier suppliers varies widely by product and technology depending on the number of competing firms. The dwindling number of suppliers in any given market segment has placed many firms in monopoly or near monopoly positions with little rivalry.

**4.2.3 Summary of Defense Industry Analysis**

This analysis has shed some light on trends in the competitive landscape of the defense industry. The following trends can be seen through this analysis:

- Government intervention exerts a higher level of power over the prime contractors than the suppliers.
- Barriers to entry have been reduced in the supplier ranks by reform initiatives.
- The buyer power of the DoD has been reduced, whereas the buyer power of the prime contractors has increased--the one opposing trend seen.
- Supplier power has increased at both levels of the supply chain.
- The threat of substitutes remains low in both levels of the supply chain.
- Rivalry has been reduced slightly at both levels of the supply chain.
4.3 Operational Level Analysis of Military-Commercial Integration

Now that the high-level strategic analysis has developed a picture of the competitive landscape in the defense industry, the analysis must focus in on the operational issues surrounding implementation of supply chain integration. This section presents an analysis of the barriers and enablers to integration and concludes with a summary table.

4.3.1 Cultural

4.3.1.1 Barriers

*Focus.* The culture of the defense industry is a barrier to integration because its product performance focus so very much opposed to the value based focus of commercial industry.

*Incentive Alignment.* The motivating forces behind the cultural focus miss-match are incentives. Currently the incentives acting on both defense contractors and government personnel are not aligned with the objectives of commercial industry, causing a barrier for integration. Government acquisition personnel are incensed to follow official process and to obey the laws governing acquisition—leading to a risk averse culture. The rewards are job security, a career, and a “feel-good” knowing that they are protecting American taxpayer dollars. Contractors have the same incentive misalignment, even though they are part of a firm trying to maximize shareholder value, since profit/fee rates are controlled by the DoD and since contracts are not written to encourage cost cutting.

The MPCL program experienced these same cultural difficulties, particularly regarding focus. This misalignment was mitigated through training and IPT experience. Incentive misalignment was not as pronounced since the financial rewards of the program were all directed at the same parent company.

4.3.1.2 Enablers

*Training.* Education of the defense acquisition community on the benefits to a performance-based focus is required. Training programs and materials have been made available to DoD personnel and contractors. The internet has been exploited extensively by the DoD for information dissemination throughout the acquisition community. The
Program Managers Deskbook is a good example of consolidated and widely distributed internet based training and reference material.

**Rewards.** Every incentive is based on some kind of reward--personal, career, or financial. Commercial businesses reward personnel through all of these means. Financial rewards come in a number of forms, including cash payments, stock options, stock savings plan matching funds, and gifts. Defense contractors offer stock based rewards and corporate performance-based compensation fund pools, like other commercial firms. The government side of the acquisition community has a problem with financial rewards--going back to the issue of protecting the public trust and being a non-profit end user of procured goods.

### 4.3.2 Sources of New Business Opportunities

#### 4.3.2.1 Barriers

*Communication with Commercial Industry.* Communication is necessary to inform the commercial marketplace of business opportunities in the defense industry. This is a barrier for two reasons, 1) because defense contractors and the DoD do not have a thorough understanding of the commercial industry products, suppliers, and communication mechanisms, and 2) because the defense contractors and the DoD have not had to market their business opportunities beyond the Commerce Business Daily.

*Lack of Relationships with Commercial Suppliers.* Defense contractors have been developing relationships with defense industry suppliers for years. There has not been a reason for building relations with commercial firms until now, due to reform initiatives. This is a barrier since a lack of relationships means that new relationships must be formed and trust developed. This also means that the most direct and efficient communication path does not exist.

In the MPCL program, TRW ASD did not encounter these barriers when selecting AEG as a supplier. Since AEG is a division of the same parent corporation, communication and relationships were established, however a working relationship still needed to be developed and fostered.
4.3.2.2 Enablers

*Marketing*. Communication programs to inform commercial suppliers of defense industry business opportunities can be used to develop awareness of the benefits to participating in defense business and to inform commercial industry of the reforms that have been implemented in recent years.

*Training*. The development of commercial industry knowledge on the part of contracting officers, program managers, and engineers will enable defense contractors to target commercial suppliers and technology which best suits program needs. Eventually relationships will develop to a point of mutual trust and high performance.

4.3.3 Business Practices

4.3.3.1 Barriers

*Knowledge and Understanding of commercial practices*. The barriers to military-commercial integration in the areas of quality, parts selection and workmanship standards, are 1) the military unique specifications and standards themselves, and 2) acquisition personnel knowledge and understanding of commercial best practices with which to replace them following reform.

4.3.3.2 Enablers

*Specifications and Standards Reform*. DoD directives pursuing the use of commercial industry specifications and standards wherever possible have enabled supply chain integration through the elimination military unique requirements.

*MPCL IBP Program*. The MPCL program has been an enabler in this area through their thorough analysis of industry specifications and standards to determine MILSPEC equivalents, and the subsequent sharing of lessons learned throughout the defense community.

*Training*. Training in the business practices of commercial industry is an important enabler of military-commercial integration. This is particularly applicable to specifications and standards reform, since this initiative was implemented as an immediate mandate with no role-out period.
4.3.4 Product Design and Development

4.3.4.1 Barriers

*Culture.* The defense industry culture and focus on performance rather than best value and cost, is a barrier to integration in product design and development. Integral with the cultural barriers is the lack of focus on design for manufacturing (DFM), which is central for utilization of automated assembly processes.

*"How to" specifications.* The reliance on military specifications and standards which tell a supplier "how to" design a product are a barrier to integration--again, integral with the cultural barriers. The barriers presented by specifications and standards are more than cultural, but also include the additional costs of compliance with these unique requirements.

*Long Product Development Cycle.* The long product development cycle for defense products can be a barrier to integration. Long development cycles mean that engineering resources are utilized on the program for many years, lending to employee turnover during the course of the program, and difficulty maintaining project team momentum and energy. Long development cycles also mean partially utilized overhead for an extended time, resulting in administrative and management inefficiencies.

4.3.4.2 Enablers

*Integrated Product/Process Teams.* Reform initiatives promoting the use of IPTs have enabled the culture to begin a transformation to better communication and understanding of the needs of each constituent involved in product design and development--including manufacturing. TRW utilized IPTs extensively during the MPCL program to effectively open communication.

*Information Technology (IT).* The use of IT to share information and improve the open flow of communication, particularly among a distributed IPT, is an enabler for product design integration. IT enables improved communication, sharing of drawings and other technical data through EDI. TRW invested in developing a solid IT foundation for its distributed IPT for the MPCL program.

*Specifications and Standards Reform.* Reform initiatives removing the use of military-unique specifications and standards wherever possible has enabled military-commercial
integration through the use of common practices. These reforms, along with commercial item status, has allowed the use of commercial components. The MPCL program worked very hard to integrate commercial product technologies, such as plastic ASIC packages, into the electronics assemblies.

*Training.* Training is an important enabler in product design and development. Training of defense industry personnel in commercial practices, like DFM and IPT participation, is crucial for integration. Just as important is training for the commercial industry participants in IPT activities regarding defense product design aspects, such as product technology and simulation modeling techniques, to reduced physical testing requirements. Training in these areas was an important and integral part of the MPCL program.

### 4.3.5 Manufacturing

#### 4.3.5.1 Barriers

*Low Volume Production.* The low volume production quantity of military products is a barrier for commercial firms. The competitive commercial markets force firms to be efficient and low cost to maximize profits. Taking advantage of scale economies in business processes and production are a major element of competitiveness. The introduction of low volume products reduces efficiencies in the administration and production processes. Administrative inefficiencies include the management of suppliers and inventories. Production inefficiencies include production scheduling, down-time and set-up. The MPCL program encountered barriers in this area with AEG's production systems. The assembly line was not capable of efficiently producing very low volume products efficiently, like the CNI modules, due to a long set-up time.

*Long Product Life-Cycle.* A long product life-cycle can be a barrier to commercial firms in a few different ways. The long product life can be a slow drain on engineering resources, where the "maintenance mode" of production and engineer support are of very low priority and on the back-burner of work priority. Manufacturing technologies may eclipse the production design of the military product, making it costly to maintain the production line for fewer and fewer products, or for only the low volume military production.

*Military Product Design.* The design of military products is a barrier for the same reasons discussed in the product design barrier section--mainly that they are not designed for efficient assembly by automated processes. Additionally, military product include some
components, processing, and materials that are not commonly used in commercial industry.

4.3.5.2 Enablers

Flexible Manufacturing Technology. Advances in flexible manufacturing technologies have made it possible to produce low volume products efficiently on highly automated production lines. These advances have reduced set-up time in the physical adjustments to the continuous flow mechanisms and surface mount screen, configuration of automated processing equipment, and presentation of material to the line. TRW AEG was in production of numerous electronic products on its six flexible production lines prior to the MPCL program. The IBP was able to take advantage of this capability to proceed with the pilot. This is one of the most fundamental enablers for military-commercial integration.

Computer Integrated Manufacturing (CIM). The use of CIM along with flexible manufacturing systems enables both the low volume manufacture of military products and the efficient transfer of product design and bill of material (BOM) data to the production line. TRW AEG needed to improve the CIM area of its manufacturing infrastructure to enable the flexible manufacturing line to produce the very low volume military products efficiently. AEG sees this advance in its manufacturing capability as one of the major wins from the MPCL program. The investment in the CIM upgrade was a strategic decision for AEG and required a substantial engineering effort from a member of the TRW ASD organization.

Training. This is intertwined with the training needs for culture and product design. Products designed using commercial practices and standards with DFM techniques will be more easily integrated into the commercial manufacturing environment. Training and experience are needed for this to occur.

4.3.6 Business Agreements

4.3.6.1 Barriers

Contractual Clauses and Requirements. Government imposed contractual clauses and requirements, covering many areas of business conduct with good intentions, create a formidable barrier for military-commercial integration. Figure 4.3 provides a summary of these, along with a brief explanation of the government intent and commercial objection.
Specific Knowledge of Government Contracting. Industry specific skills are required for effectively negotiating the gauntlet of government contracting requirements and mitigating the risks associated with compliance to applicable laws. Down-side risks could entail penalties due to fraudulent claims and losses due to underbidding projects. This specific knowledge can also extend to political relationships with pentagon and congressional leadership.

Short-Term Contracts. The process of annual defense budget appropriation by Congress leads to short-term contracting. This provides a barrier to commercial firms through the risk of future cash flows, causing non-recurring investments to be amortized over a short production cycle. This is also a barrier through the increased opportunity cost of short-term defense work versus potential long-term commercial projects.

Figure 4.3 Government Contracting Requirements Which Deter Commercial Suppliers

<table>
<thead>
<tr>
<th>Government Requirement</th>
<th>Government Intent</th>
<th>Commercial Objection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost and Pricing Data</td>
<td>Ensure a Fair and Reasonable Price</td>
<td>Proprietary--Key to Competitive Advantage</td>
</tr>
<tr>
<td>Cost Accounting Standards (CAS)</td>
<td>Ensure a Fair and Reasonable Price</td>
<td>Not a Commercial Practice--Requires Costly Infrastructure</td>
</tr>
<tr>
<td>Sauce-Economic Provisions</td>
<td>Ensure Equal opportunity</td>
<td>Not a Commercial Practice--Costly and No Value-added</td>
</tr>
<tr>
<td>Technical Data Rights</td>
<td>Allows Reprocurement from Another Source</td>
<td>Proprietary--Key to Competitive Advantage</td>
</tr>
<tr>
<td>Defense Priority and Allocation System (DPAS)</td>
<td>Ensure priority of material in times of national security need</td>
<td>Disruptive to production scheduling, cost, and delivery record</td>
</tr>
<tr>
<td>Civil False Claims Act</td>
<td>Protect government against fraud</td>
<td>High risk--simple mistake could initiate a contract dispute, penalties and damages.</td>
</tr>
<tr>
<td>Certifications</td>
<td>Ensures Compliance with Statutes.</td>
<td>Duplicates Requirements of Existing State and Federal Laws</td>
</tr>
</tbody>
</table>

(Source: Adapted from Kinsella, 1996)
4.3.6.2 Enablers

Statutory Law Reform. FASA and FARA introduced expanded definitions of commercial items which has enabled integration of commercial products and technologies into military products. The MPCL programs ability to proceed with the AEG produced electronics hinged on the reduction of contractual clauses and requirements through the designation of commercial item status for the modules. This is one of the most fundamental enablers for military-commercial integration.

MPCL IBP Program. The MPCL program has been an enabler in this area through their thorough analysis of industry contracting best practices and the subsequent sharing of lessons learned throughout the defense community.

Funding Stability. Elimination of the process of annual budget approval for defense programs would stabilize program funding and enable firms to make longer term investment decisions. A longer time horizon for investment decisions with reduced risk of future cashflows would help to attract commercial firms to the defense sector.

4.3.7 Summary of Operational Level Barriers and Enablers

Figure 4.4 summarizes the operational level barriers and enablers that have been discussed the preceding sections. The figure offers the enablers which have been put in place and the enablers that are still required to overcome the remaining barriers.
<table>
<thead>
<tr>
<th>Cultural</th>
<th>Barrier to Integration</th>
<th>Enablers for Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Focus on performance vs. Best value</td>
<td>Training/Experience</td>
</tr>
<tr>
<td></td>
<td>Misaligned Incentives</td>
<td>Incentives/Rewards</td>
</tr>
<tr>
<td>Sources of New Business Opportunities</td>
<td>Communication</td>
<td>Marketing</td>
</tr>
<tr>
<td></td>
<td>Knowledge</td>
<td>Training/Experience</td>
</tr>
<tr>
<td></td>
<td>Lack of Relationships</td>
<td>Education</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experience</td>
</tr>
<tr>
<td>Business Processes</td>
<td>Knowledge/Skill</td>
<td>Spec’s &amp; Std. Reform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training/Experience</td>
</tr>
<tr>
<td>Product Design &amp; Development</td>
<td>Culture</td>
<td>IPTs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IT &amp; EDI</td>
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<tr>
<td></td>
<td></td>
<td>Training/Experience</td>
</tr>
<tr>
<td></td>
<td>“How To” Spec’s &amp; Std's.</td>
<td>Spec’s &amp; Std. Reform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training/Experience</td>
</tr>
<tr>
<td></td>
<td>Long Product Life-Cycle</td>
<td>Financial reward commensurate with risk taken</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Low Volume Production</td>
<td>Flexible Manufacturing</td>
</tr>
<tr>
<td></td>
<td>Product Design</td>
<td>CIM</td>
</tr>
<tr>
<td></td>
<td>Long Product Life-Cycle</td>
<td>IPTs</td>
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<td>CEE</td>
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<td></td>
<td></td>
<td>Training/Experience</td>
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<td></td>
<td></td>
<td>DFM Training</td>
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<td></td>
<td></td>
<td>Incentives/Rewards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial reward commensurate with risk taken</td>
</tr>
<tr>
<td>Business Agreements</td>
<td>BP&amp;P requirements</td>
<td>FASA &amp; FARA</td>
</tr>
<tr>
<td></td>
<td>Contract Clauses</td>
<td>Commercial Item Status</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPCL Handbook</td>
</tr>
<tr>
<td></td>
<td>Risk</td>
<td>Contract Reform</td>
</tr>
<tr>
<td></td>
<td>Specific Knowledge</td>
<td>Training/Experience</td>
</tr>
<tr>
<td></td>
<td>Short-Term contracts</td>
<td>Financial reward commensurate with risk taken</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reform Initiatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Funding Stability /multi-year funding</td>
</tr>
</tbody>
</table>
4.4 Remaining Enablers for Military-Commercial Integration

The output of the strategic and operational level analysis of the previous two sections are the identification of the barriers and enablers presented in figure 4.5. The enablers presented in this table are not all currently in place. The two key enablers that must be addressed are; first, the communication and marketing of the defense business opportunity to commercial industry, and second, assessment of the financial and non-financial incentives for entry into defense business relative to commercial business opportunities. The following sections discuss these two key enabling areas in detail.

4.4.1 Communication and Marketing of the Defense Business Opportunity

A key enabler for supply chain integration is communication of the opportunities present in the defense business sector to the commercial sector. From the discussions in the previous sections it was very clear that commercial businesses and defense businesses look to different sources for information on new business opportunities. In addition, according to the EMS Survey,5 the commercial business sector is not aware of the recent changes in acquisition laws and policy which have removed or reduced barriers to entry into the defense business (Rebentisch, 1998). Improved communication and education of commercial industry of the unique opportunities in the defense business sector will enable the implementation of supply chain integration.

4.4.1.1 Communication

Alignment of communication channels. The starting point for communication between the defense and commercial business sectors regarding new business opportunities is to decide on a communication channel. Since it is the defense business that is trying to attract commercial business, it seems that the defense sector should adjust its methods to conform to commercial methods. The Commerce Business Daily is the standard communication

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5 “EMS Survey” refers to a 1997 survey of electronics manufacturing services (EMS) and contract assembler firms, performed by a joint team of MIT, TRW ASD, Aneon Corp., and the Institute for Interconnecting and Packaging Electronics (IPC). The goal of the survey was to gain an understanding of the firms willingness to engage in or expand into military business and to assess whether acquisition reforms have diffused into the supplier base. The survey was sent to 1340 IPC member firms which include EMS and printed wiring board (PWB) manufacturers, and received an 11% response rate.
channel for the defense sector, but the EMS Survey showed that it is seldom consulted by commercial industry. The EMS Survey showed that direct sales, trade shows, and advertising are the main channels for commercial business knowledge of new business opportunities.

**Marketing.** The DoD and prime contractors need to market the business opportunities of defense program involvement to the commercial business sector. Placing a compulsory disclosure in the Commerce Business Daily does not constitute marketing. Marketing of the opportunities in the defense business sector means strategically identifying and targeting a communication campaign that is aggressive, thought provoking, and educational for specific areas of the supply chain. Marketing mediums can be advertising in trade journals, industry association magazines, newspapers, or even billboards in targeted areas. Billboards may sound like a strange place to advertise this type of business, but it is very common for example, in the Detroit, Michigan area for automotive suppliers to advertise products or technologies on billboards due to the high concentration of automotive OEM engineers and management in the region.

4.4.1.2 **Education**

**Trade Shows.** In the EMS Survey, 43% of respondents stated trade shows as a source of new business opportunity knowledge. Trade shows are a great forum for interactive discussions with commercial firms, through face-to-face conversations and group lectures. The visual and physical interaction of trade shows, with a very targeted and motivated audience.

**Web-based communication and training.** The Web has introduced a highly efficient and interactive conduit for the disbursement of information. As the Web develops and becomes a more rich source of information, an increasing number of businesses will utilize it for many business functions. The DoD has done a great job of publishing documents and information on the Web. In fact, much of the information referenced in this thesis was located on the Web. The current target customer of the DoD web sites is not commercial business. These informative sites are targeted to defense community participants within the DoD, contractor, and supply base. The DoD should leverage its Web-based information resources to communicate with commercial business and educate them on the business opportunities and recent reforms initiatives that have reduced barriers.
4.4.2 Incentives and Rewards

The next major enablers for supply chain integration that must be pursued are the financial incentives and rewards for the commercial firm. It is very important to understand the full benefit to the commercial firm derived through participation in defense business for a number of reasons. These include:

- **Profit/fee rate determination**—The determination of a fair and reasonable profit/fee rate must be based on an understanding of the full economic benefit and risks associated with participation in defense business.

- **Opportunity cost versus commercial business**—Engaging in defense business with the limited resources of the firm means that a potential opportunity to utilize those resources in commercial business endeavors is forgone.

- **Marketing of the business opportunity**—A full understanding of the benefits from participation in defense work must be thoroughly understood so that these benefits can be marketed to the commercial business sector.

4.4.2.1 Financial Returns

The financial returns of a project in a commercial business must meet the internal hurdle rates of the firm. For example, TRW AEG established a minimum of 12% ROAE for the MPCL program. Any meaningful financial analysis of future cashflows requires a sound understanding of the risk associated with the cashflows (Beta) and the firm's cost of capital (WACC), based on the firm's capital structure and debt rating. One of the biggest sources of risk in the cashflow analysis of defense business are the future cashflows beyond the current term of the annual defense budget approval process. This uncertainty is high, and essentially outside of the firm's influence.

*Option value of future returns.* Once the contracts are awarded for production, the option value of potential future returns becomes high for supply chain participants. A number of potential or inevitable opportunities become available for financial returns. These opportunities include engineering changes, service parts and spares, upgrades and retrofits, and export programs.

- **Engineering changes**—Engineering changes caused by specification and feature modifications occurring during product development are an opportunity for the contractor and suppliers to make some excess returns. Since the program has
committed to a supply chain, the participants hold power over the buyer, to whom
switching costs would be excessively high. The limitation of this power is the reason
behind the contractual clauses concerning data rights. Engineering changes have
traditionally been an area where contractors and suppliers reap excess returns, often to
cover losses taken during early program phases. This portion of financial returns may
not be as stable on future programs as in was in the past, given the more integrated
design and development processes implemented on the current programs.

- **Service parts and spares**--Fielded product sustainment procurements of service parts
and spares provides nice annuity returns for the production supply chain, again due to
the high switching costs for the buyer. The problem for the supplier of these service
parts and spares is that the required quantities are very low, often sporadically ordered,
and extended over a very long life of fielded service. These factors make it difficult to
produce the components on an “as-needed” basis, leading to a one-time up-front
purchase by the DoD for warehousing of the inventory. Additionally, building on an
“as-needed” basis requires that the production tools be kept in working condition and
available for production, which combined with the low volume and extended life yield a
very costly process.

- **Upgrade and retro-fit programs**--Product improvement programs for fielded systems in
the form of upgrades and retro-fits offer one more opportunity for the incumbent
component and systems suppliers to exert market power and extract good returns.

- **Export of mature products**--In chapter 1, military product exports were discussed to be
held at a steady $6-8 billion annually. Historically, a high percentage of these export
sales have consisted of mature products without the latest technology upgrades. Export
sales, though controlled by the U.S. government, provide lucrative returns, at around
2.5 times those of DoD sales (Gansler, 1977).

### 4.4.2.2 Non-Financial Returns

Non-financial returns to the firm are returns that have a profound impact on the firms ability
to generate future financial returns, through the development of intangible assets and option
value, but that do not have an immediate effect on the firms balance sheet and income
statement. This analysis frames non-financial returns into five areas (Figure 4.5);
technology, organizational knowledge, supply chain relationships, goodwill, and employee
“feel-good.” Evaluation of these returns by the commercial firm considering defense
business is essential for a full economic comparison between defense and commercial business alternatives.

Figure 4.5 Returns from Defense Business for the Commercial Firm
Technology. The transfer of technology from defense programs to commercial industry has long been a benefit of involvement in defense business. Chapter one briefly discussed a number of influential commercial technologies and industries that have developed from defense products over the last 50 years. The potential of future returns in the commercial marketplace from defense system technologies is a substantial incentive. These future returns do not necessarily need to come from the application of complete defense technologies. The returns can come from the application of product or process enabling technologies which improve the firms competitive position. TRW AEG saw the benefits of technology in the MPCL program, in the form of processing capabilities and CIM technologies, from which they hope to gain future returns in the commercial market.

Organizational Knowledge. The development of a firms intellectual assets is important to the future livelihood of the firm, just like technology. Defense business offers an opportunity to challenge employees and develop skills with new technologies which are not readily available in the commercial marketplace. Development of these defense related skills also increases the option value of pursuing future defense business. TRW AEG sees this benefit as key output of participation in the MPCL program.

Supply Chain Relationships. Participation in defense business will cause the commercial firm to develop some new supply chain relationships. These new relationships will at a minimum be with the prime or sub-contractor and additionally could include new relationships with lower-tier suppliers of military or specialty components that the firm does not currently interact with. Farther removed but still important are the potential relationships with the DoD, government organizations, and politicians. These relationships create value for the firm through the development of trust, contacts, personal relationships, and knowledge of each others capabilities. Returns from these new relationships come in the form of the option value of future business opportunities. The MPCL program is offering TRW AEG an opportunity to strike a strong relationship with ASG, offering the potential of more future involvement.

Goodwill. Defense business can offer returns in the way of building brand equity for the firm. Financially, the value of brand equity is not evaluated as goodwill unless the firm is involved in an agreement to be purchased, in which case the goodwill is the difference between the purchase price and the market value of total assets. However, in non-financial terms, the development of brand equity increases the option value of future business.
opportunities leading to potential future cashflows from both commercial and defence business.

*Employee* "Feel-Good". This non-financial return is derived from the feeding of employee moral and nationalism. One positive return from defense business is the opportunity for employees to work on technically advanced products. This is particularly true with engineers and scientists who enjoy highly engineered and advanced product designs. A second return from defense business can be the positive impact on employee commitment and pride through knowledge that the program output will help defend our great nation. This effect may be particularly strong with veterans and families of veterans. The flip side of this are any negative moral effects for employees who hold strong beliefs against weapons and their use.
CHAPTER 5: CONCLUSIONS

5.1 Summary

5.1.1 External Forces Driving Change
The defense industry has gone through a turbulent transition during the last decade that continues today. The end of the Cold War has brought about shifts in U.S. national security needs and annually reduced Congressional budgets for weapon systems procurement. Coincidental to these changes has been the ever increasing pace of technology in the commercial sector, particularly in electronics, which has been difficult for the defense industry to access due to a numerous and diverse array of barriers.

5.1.2 Response to a Changing Environment
The reaction to these external forces on the defense industry by the DoD and the contractors have been sweeping and dramatic.

5.1.2.1 DoD Response
The DoD response to these external forces has been to search for methods for gaining more value from each dollar of the reduced budget, introduction of a limited number of new programs on extended development time tables, and through finding means to infuse commercial technology into defense programs.

The chosen methods for meeting these needs have been a transition to performance-based practices, military-commercial integration, and supply chain integration. Military-commercial integration will ideally offer the defense industry access to commercial
processes in design and manufacturing which place a priority on low cost and high value, and will offer access to the latest technologies from the commercial sector that are evolving at an increasing pace.

The ideal of military-commercial integration requires changes in the way the DoD and the acquisition community operate. The process of defense acquisition must become more "commercial-like" through the removal military specifications, standards, and practices, and performance-based practices must become the operating norm. Sweeping changes to the acquisition process, in the form of statutory law and policy reforms, were initiated to remove these uniqueness' and to enable the streamlined purchase of commercial items.

5.1.2.2 Defense Industry Contractors' Response

The response of the defense industry contractors to the changing environment has been massive consolidation and diversification into other markets. Annual reductions in the defense budget over the last 13 years and a sparse number of new procurement programs, had left the industry with huge excess capacity in production and engineering resources with few new program opportunities to capture. The consolidation and exit of firms through mergers and asset sales has rationalized capacity to the current market needs and has searched for greater economies of scale in all areas of business function. Additionally, the diversification of defense contractors into commercial businesses, and the application of defense technologies for commercial use, has continued to be a method for stabilizing earnings volatility.

5.1.3 Test Effectiveness of Response

The DoD and industry implemented programs in reaction to the changing external environment that must be tested to determine the effectiveness of these changes.

5.1.3.1 DoD

Pilot Programs. The MPCL IBP program analyzed in Chapter 3 is one program used to check the effectiveness of enabling reform policy to support military-commercial integration. This pioneering and successful pilot program has shown that military-commercial integration is not only achievable, but mutually beneficial to all participants, leading to a "Win-Win" outcome.

Surveys. The EMS Survey discussed in Chapter 4 shed light on some very important enabling mechanisms that are not yet in place. The first is the current misalignment of
communication channels for locating new business opportunities between the commercial and defense business sectors. Secondly, the survey showed that knowledge of the recent acquisition reform initiatives of the DoD are either not known or not understood by the commercial electronics business sector.

Direct Feedback. Commercial industry does not appear to be “beating down the door” of the defense market trying to capture a piece of the business. This direct feedback could indicate that commercial industry is not interested in defense business or that commercial industry is not informed of the changes taking place to improve the appeal of defense business.

5.1.3.2 Defense Industry
A defense industry firm, like any other publicly held corporation, is evaluated each day in the stock market by numerous expert analysts and individual investors. The effectiveness of corporate diversification and consolidation strategies are shown through the strength of the firms financial statements and through the markets determination of the firms stock price.

5.2 Lessons Learned
The analysis presented in this thesis offers a number of lessons learned regarding military-commercial integration, and the enabling effects of supply chain integration. These lessons have come out of the MPCL IBP case study, from the high level strategic analysis of defense industry appeal to commercial firms, and from the operational level analysis of specific barriers and enablers to integration. These lessons learned are presented below.

- 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 so well. Commercial item status brought about the elimination of numerous contractual clauses and requirements which AEG deemed unacceptable. The number of contractual clauses were reduced from 30 down to 3 with commercial item status determination.

• 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. Cost savings can be seen through a comparison of the military program baseline cost and the commercial item price, and is comprised of a number of elements. The elements of cost savings include; reduced material costs through the use of high-volume commercial components (i.e. “plastic” ASIC packages), reduced inspection costs through the use of SPC and commercial quality methods, and reduced non-recurring engineering costs through the use of concurrent engineering methods and EDI.

• Technology and knowledge transfer to the commercial supplier have been developed as assets for future business opportunities.
TRW AEG is developing its technology and knowledge assets in supply chain integration methods, CIM, engineering skills, improved production flexibility, and knowledge of military product designs. These assets provide AEG with the option value of leveraging them for access to future business opportunities which may not have been accessible prior to their development.
• **Benefits from participating in defense business come in many forms**
The DoD and commercial industry must consider all the potential returns that may be
created through participation in defense business when evaluating project alternatives.
Beyond financial returns, non-financial returns may yield a higher NPV through
technology, knowledge, relationships, goodwill, and employee "feel-good." TRW AEG
has focused on a number of these non-financial returns as "wins" from participation in the
MPCL IBP program.

• **Communication channels are not aligned between the commercial and
defense business sectors**
Commercial businesses will not seek defense business opportunities unless they are within
the firms consideration set of business alternatives. Communication of defense industry
business opportunities to the commercial sector must be along the communication channels
that are typically consulted for such information. Currently this is not the case. This
misalignment of communication coincides with a lack of knowledge regarding the
acquisition reform changes of the past decade which have reduced industry entry barriers
and have improved the appeal of defense business.

### 5.3 Recommendations

The lessons learned from this analysis have pointed to areas where reform initiatives are
currently in place, and to some areas where actions to overcome integration barriers are still
required. The recommendations below focus on two areas where further attention must be
given to enable the process of military-commercial integration to continue.

1) **DoD & Prime-Contractors must "market" the defense business
opportunity to commercial industry.**

Alignment of communication channels between the defense and commercial business
sectors is key to military-commercial integration. Defense business opportunities must be
"marketed" to commercial firms. This "selling" of the industry must include educating the
business sector of the changes taking place to remove entry barriers, and must promote the
areas of appeal to the commercial firm. A targeted marketing plan must be developed to
access specific areas of the commercial business sector, based on current and future
program needs.
2) **Analysis of the defense business opportunity must include both financial and non-financial returns, and the risk associated with those returns.**

The areas of defense industry appeal for the commercial firm come in the form of financial and non-financial returns. Both sides in the business transaction must have a complete understanding of the potential benefits which defense business has to offer. Additionally, the various risks associated with these returns must be understood and included in any analysis. The DoD and prime contractors must understand the potential benefits of these returns so that the appeal of military business can be properly marketed to the commercial sector. The DoD must also understand the full returns from participating in defense business when determining a competitive financial return for a new program. The commercial business sector must understand the potential returns from defense industry business opportunities so that a thorough comparison of project alternatives can be performed when making strategic investment decisions.

### 5.4 Areas for Further Research

The two recommendations presented above are areas where further study is needed. In the area of communication and marketing, further study into the various communication channels available for targeted segments of the commercial business sector, and the success rate of those communication channels, would offer a foundation for developing a marketing or outreach plan. In the area of financial and non-financial returns, further research attempting to identify specific non-financial returns, and the actual option value of those returns through case studies, would help demonstrate firm evidence of these benefits for attracting commercial firms to the defense industry.
Appendix A: Commercial Item Definition

The following paraphrases the definition in FAR Part 2 and provides examples (DoD, 1997(b)).

A commercial item is:

1. Any item, customarily used for nongovernmental purposes, that has been sold, leased, or licensed to the general public or that has been offered for sale, lease, or license to the general public. For example, items sold in the commercial market, which includes wholesales and retail distribution centers, catalogs, personal sales -- items offered for sale commercially, but not yet sold, are also included. General examples of commercial items DoD buys range from food, clothing, and computers to trucks and airplanes. The availability of commercial items to meet a specific defense requirement is determined by market research.

2. An item that evolved from a commercial item described in paragraph 1 above. A new model of an existing commercial product, product upgrades, or a new version of a commercial software package are examples.

3. An item that meets the description in paragraph 1 above, but with minor modifications to meet DoD needs or modifications of type normally done for commercial customers. Examples include products that are customized commercially, such as automobiles, computer systems, and products with DoD unique modifications that do not change the basic properties or function of the item. Minor is a technical judgment call.

4. Any combination of items meeting this definition of commercial item, if it is normally combined and sold commercially. Examples include a computer or video system that is a combination of commercial items, even though the system itself may be a unique configuration.

5. A service bought to support commercial items. For example, training, maintenance and service contracts purchased to support items meeting the definition of commercial item are included.

6. A service of a type offered and sold competitively in the commercial market at catalog or market prices. Construction, storage and distribution services, aircraft maintenance, and janitorial services are examples.

7. Any item or service described in 1 through 6 above, even though it is transferred between separate divisions of a contractor. For example, a commercial item transferred from a commercial division to a defense division of a company is still a commercial item.

8. An item developed at private expense and sold in substantial quantities, on a competitive basis, to state and local governments. For example, products sold to state and local governments, not sold commercially, could be bullet proof vests and fire and rescue equipment. Remember this definition was created primarily to trigger the use of FAR Part 12 in solicitations and contracts. In that context, including this subset as a commercial item makes more sense.
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