Reduction of Front-End Loading of Inventory: Making the Airframe Industry Lean Through Better Inventory Management

by

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or lean production paradigm (as espoused in *The Machine That Changed the World*) and the structure and progress of the LAI thus far. Focus is on the Fabrication and Assembly group, and more specifically on some salient results of the Inventory Practices Survey which was conducted by this group over a period of months in 1993. Finally, stemming from some of the results of this comprehensive survey, the thesis investigates the tendency within the aerospace industry to "front-end load" inventory. Front-end loading refers to maintaining excess inventory in receiving and storage. This thesis attempts to identify some solutions to the front-end loading problem and some economies to be realized with the accompanying reduction of inventory. This is done by investigating in depth one sponsor company whose inventory profile is typical of the industry as a whole. Following this analysis, recommendations for future work in the inventory practices area are made.

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List of Acronyms Used

ABC	Activity Based Costing
AFAM	Air Force Acquisition Model
ASC	Aeronautical Systems Center (U.S. Air Force)
BOM	Bill of Material
CAS	Cost Accounting Standards
C/SCSC	Cost/Schedule Control Systems Criteria
CPI	Continuous Process Improvement
CPM	Critical Path Method
CPS	Consolidated Purchasing System
DCAA	Defense Contracts Auditing Agency
DFARS	Defense Federal Acquisition Regulations Supplement
DOD	Department of Defense
DPM	Defects Per Million
DPRO	Defense Plant Representative Office
ECO	Engineering Change Order
EOQ	Economic Order Quantity
FAR	Federal Acquisition Regulations System
FC&I	Fixed Cost and Incentive (Contract)
FIFO	First In First Out
GFE	Government Furnished Equipment
GM	General Motors
IMS	Inventory Management System
IMVP	International Motor Vehicle Program

JIT	just-in-time
LAI	Lean Aircraft Initiative
LIFO	Last In First Out
LRIP	Long Range Initial Production
M.I.T.	Massachusetts Institute of Technology
MAF	Material Allowance Factor
MIL-STD-1520	Corrective Action and Disposition for Nonconforming Material
MIL-STD -1535	Supplier Quality Assurance Program Requirements
MIL-STD- 1567A	Work Measurement Standard
MIL-Q-9858A	Design for Quality Standard
MMAS	Material Management and Accounting System
MRP II	Manufacturing Resource Planning
NPA	Normal Production Allowance
NTU	National Technological University
PERT	Program Evaluation and Review Technique
R&D	Research and Development
ROI	Return on Investment
SBU	Small Business Unit
SPC	Statistical Process Control
SPO	System Program Office
SRR	Scrap, Rework and Repair
WIP	Work In Process

Chapter 1: Introduction and the Government and Aerospace Industry Relationship

Over time, manufacturing has evolved from "craft" production techniques, where each item is fashioned individually and in many instances by the same highly-skilled person or group of persons, to a system of "mass" production typified by assembly lines and low-skilled labor performing largely repetitious and single tasks. Recently, a new paradigm, "lean manufacturing," has been documented in Womack, Jones and Roos' *The Machine that Changed the World* as a result of the Massachusetts Institute of Technology (M.I.T.) International Motor Vehicle Program (IMVP). This new model has as its goals perfect first time quality, waste minimization, and continuous improvement. Desired outcomes under this system include lower production costs, improved product quality, higher productivity, increased efficiency at a lower scale of production, more rapid product development cycles, and higher product mix diversity. Lean manufacturing is typified by the Toyota Production System.

Unlike the automobile manufacturing industry, the United States' military airframe industry has had a short although turbulent history, characterized by large peaks and valleys in demand and manpower. Although materials, manufacturing processes, and other technologies have improved and evolved significantly since World War I, the manufacturing of military aircraft has remained largely a craft industry due to relatively low production volumes (compared with other products such as the automobile), antiquated management and organizational arrangements, and the unique relationship that this industry has with its virtual sole customer -- the United States government. The Armed Forces are now entering the post-Cold War era with reduced military budgets and decreased production schedules of virtually all weapons systems. Reductions in the military industrial complex (including manpower and other resources) are both demanded and guaranteed in this new environment.

The United States Air Force and over twenty military aerospace contractors, both at the primary and supplier levels, have entered into a consortium agreement to fund the M.I.T. in investigating the application of lean manufacturing techniques to the military aircraft industry. The basic goal of the Lean Aircraft Initiative (LAI) is to infuse lean practices into the industry so as to assure that, given the fiscally restrained environment both government and industry will most certainly face, "more can be done with less." The study concentrates on the areas of human resources, fabrication and assembly, supplier relations, product development, and policy and the external environment. Under the "Fabrication and Assembly Focus Group", a pilot project was started which surveyed participants on their inventory practices.

This thesis will, as a backdrop, briefly outline the unique relationship that has developed between the United States' airframe and aerospace manufacturing industry and the government itself. It will also review in more detail the foundations of the lean manufacturing or lean production paradigm (as described in *The Machine That Changed the World*) and the structure and progress of the LAI thus far (Chapter 2). Focus will be on the Fabrication and Assembly Focus Group, and more specifically on some salient results of the Inventory Practices Survey which was conducted by this group over a period of nine months in 1993 (Chapter 3). Finally, stemming from some of the results of this comprehensive survey, the thesis will investigate the tendency within the aerospace industry to "front-end load" inventory (Chapter 4).

In the airframe industry, inventory is typically purchased much in advance of its actual need-date due to several factors. Military fiscal year buy quantities, Economic Order

Quantity (EOQ) decisions and progress payments are but three of these reasons. One consequence of these activities is the existence of excess inventory in receiving and storage. At a deeper and more insidious level are the build-up of unnecessary excess or obsolete inventory due to change orders or engineering changes, and higher overhead rates due to increased inventory carrying costs, etc. (See Chapter 4). This thesis will attempt to identify some of the solutions to this front-end loading problem and some of the economies to be realized with the accompanying reduction of inventory. This will be done by investigating in depth one sponsor company whose inventory profile is typical of the industry as a whole (Chapter 5). Following this analysis, recommendations will be made for future work in the inventory practices and fabrication and assembly areas (Chapter 6).

1.1 The Monopsony in Aerospace

In order to completely understand the current state of the aerospace industry and to hope to effect some positive change in this business, one must not only comprehend the *internal* and individual corporate histories of the industry and its manufacturing and design advances. One must also understand the *external* environment under which these evolutionary changes were and are occurring. This chapter will briefly trace the development of the government and the aerospace industry's economic and business relationship. The text will cover the important period in United States' aviation and governmental history up to and including World War II. The country's social and political agendas throughout these several decades were very important in shaping what was to become the extremely complicated, highly legislated, and highly regulated relationship between the government and its military aerospace contractors. Subsequently, the period following World War II and through the end of the Cold War will be discussed in an attempt to shed some more light on why and how the government and the military industrial complex have developed such a unique economic and business relationship. Finally, the last part of this chapter will highlight the progress and changes which have arisen in the procurement process following the end of hostilities between the United States and the former Soviet Union, and following the fall of communism. Again, due to the primary focus of the Lean Aircraft Initiative and this thesis, the emphasis of this chapter will be on the United States Air Force, its primary airframe manufacturers, and their related subcontractors. Where appropriate, other industries and military services will be mentioned.

1.2 Development of the Military Industrial Complex Through World War II

In the early part of this century, airframe manufacturing was obviously still in its infancy. The industry itself was small and was characterized by small workshop-like production facilities. From the time when sustained and meaningful flight first became possible to the end of World War I, the only real recognized use (as indicated by funding) for man's new-found mobility was for war fighting purposes. Because of this the government, and specifically the military services, played an enormous and dominating role in shaping the foundations of the growing airframe and aerospace industry. Additionally, subsequent historical analysis of this industry has demonstrated that the political and social agendas of governmental and to some extent of corporate representatives during this time also were of significant importance in shaping the landscape of how the government and this high profile industry were to interact, and indeed still do interact even today.

Leading up to and through World War I, the U.S. airframe industry and government by necessity had to have a symbiotic relationship. Obviously, government depended on industry for the technical ability to develop and manufacture state-of-the-art aircraft, and industry depended on the government as its virtually sole customer for decades. The opportunity existed to develop the industry and its associated governmental relationship with a "clean slate" -- separate and independent from previous government/industry associations. Instead, the industry grew up under the use of the *existing* rules for military contracting which had been used in military procurement for centuries before. Consequently, a portion of the baseline for the aerospace and government professional relationship was rooted in history.

Stemming from this emphasis on history and the "American way" the government interacts with business, it was also important to government officials that the airframe industry develop in a "free market" environment, encouraging the "small firm" and the "independent inventor." It was also essential to these people that the new and burgeoning industry serve as a showcase for American ingenuity and industrial advances by implementing and utilizing "Fordism," or mass production techniques, immediately in its manufacturing of aircraft. On the government contracting side, it was important that the process be based on "price competition," "equal access by all potential competitors," and the minimal involvement required from a limited "state" or governmental presence. Seemingly contradicting all of this dogma and rhetoric, however, were the actual *actions* of the government which included federal regulation of patents and imposed mandated industry associations.

On the contractor or industry side, the early government involvement in the business was met with some hostility to say the least. Innovators and business men who were attracted to this new industry were almost necessarily risk-takers, competitive, and resentful of intervention of any kind. They opposed the government's imposition early on of patent regulations and a trade associations. At the same time, however, many of these same industrialists favored a different form of government involvement which would mean limiting the number of competitors in the field, allowing the ability to help one another in competition, and basing that competition on product performance rather than on price.[1]

The result of all of this confusion was a non-optimal, insupportable and non-sustainable system for the industry and for government. Due largely to the failed application of mass production techniques to aircraft manufacturing, the industry was not able to meet demand during the War and suffered enormous losses. Government was suspicious that failure on the part of industry was a result of poor management and not because the industry was not mature enough to support such demand with manufacturing techniques such as mass production.

In short through the first World War, the young airframe industry was being used as a model for the American capitalist economic way -- not necessarily an appropriate arrangement given the initial mission of the industry, the nature of the manufacturing task at hand, and the sheer infancy of the manufacturing technologies and processes.

In the decade between 1930 and 1940 (and the beginning of hostilities in World War II), the airframe industry and the government continued to have a rather strained and artificial relationship driven largely by legislation and a now commonly accepted history of disrespect and suspicion between the two parties. Government continued to mold the industry based on the perception that it should model the accepted "antistate" and "antitrust" culture which was prevalent in society at the time. Concurrently, entry and exit from the industry was becoming increasingly difficult due to the enormous fixed costs associated with the business itself and the high costs of design. This meant that financial constraints were to become a large issue and that the same group of players (industry and government alike) were to be locked in battle over such procurement issues for some time to come.

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1 Vander Muellen, Jacob, *The Politics of Aircraft*, University Press of Kansas, 1991, pp. 2-41.

Contracts were continuing to be awarded largely on the basis of cost and price competition, which meant that industry naturally felt encouraged to compete for contracts on the basis of volume and product specialization. Counter to this, however, was the fact that the government was unable to respond with large enough orders to merit these large production runs and their accompanying mass production techniques. Additionally, the procurement system was not designed to favor product specialization due to its emphasis on "fair" competition; in theory anyone could bid and compete for any contract. As a result, the industry found itself a "mass production industry, with no mass production product or market."[2] In fact, approaching World War II, the industry actually was operating at only 50 percent capacity, even with a fairly significant export market.[3]

Some reasonably significant attempts were made at reform during this period. Issues such as the limiting of profits, the airframers' rights to their own designs, and an end to or modification of price competition all were surfaced, and all met with demise. The status quo in terms of procurement policy and the relationship between industry and government was successfully maintained.

As the entry of the United Stated into World War II became imminent, President Franklin D. Roosevelt began to demand that the manufacture of aircraft be rapidly ramped up. At one point, he even required that 10,000 new planes be manufactured. He later scaled this number down to 3,000. These numbers did not necessarily reflect any assessment of what was needed to win the war; instead they seemed to be associated more with the unspoken for capacity of the airframers and the emphasis the United States was beginning to place on air power and air superiority.

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[2] *The Politics of Aircraft*, p. 187.
[3] *The Politics of Aircraft*, p. 188.

During World War II, funding for aircraft manufacturing was abundant. The government finally began to take on some of the financial risk of the airframe manufacturers by providing very liberal advanced payments. Negotiating powers on the part of both the government and industry were enhanced somewhat. Industry began to take on the responsibility for the management of new weapons systems, a job which had previously been performed by government personnel.[4] In short, during the War itself, age-old tensions between the government and the manufacturers were somewhat assuaged due to the war-time environment which stressed production over all else. These tensions, however, were to resurface somewhat in the post World War II environment where production volumes were necessarily reduced.[5]

1.3 The Cold War, the Airframers, and the Government

The years following the second World War and including the Cold War were marked by strong fluctuations in demand as the United States passed through the periods of the Berlin blockade, the Korean Conflict, the Cuban Missile Crisis, the Vietnam War, the Iranian hostage situation, and the Soviet involvement in Afghanistan, among others. In addition, the country was faced with the almost constant and pervasive threat on the part of the Soviet Union that they were surpassing American defense capabilities in terms of both sheer numbers and performance. Although the U.S. demand for aircraft fluctuated, there was still on average a higher level of spending on defense procurement than had been experienced during any other time period.[6]

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4 Sapolsky, Harvey M., "Is Aerospace an American Industrial Policy Success?", internal M.I.T. document prepared for *Audacity Magazine*, August 1993, p. 6.

5 For a more in depth discussion of the post WW I environment see *The Politics of Aircraft* pp. 182-219.

6 Gansler, Jacques S., *The Defense Industry*, M.I.T. Press, 1982, p. 13.

It is hard to adequately generalize what is a roughly fifty year period in our nation's history, but it is fair to say that the emphasis of the procurement system as a whole shifted. Performance rather than price became of tantamount importance; the technical superiority of a weapon system was emphasized almost at all cost. As an example of this trend, during the Korean conflict, aircraft were being procured at the rate of 3,000 per year. This number decreased to roughly 1,000 per year during the 1960's and by the 1980's became only 300 per year.[7] The declining numbers of aircraft being procured reflected the increasing sophistication (and accompanying increased unit cost) of each aircraft as well as the increasing emphasis and importance being placed on these new performance capabilities. The period became characterized by astoundingly complex and technical systems, accompanied by enormous cost overruns, low volume production, and excess capacity.

As a consequence of all of this, affordability became a major issue to the government. The question raised on the part of government was whether these increased prices were an inevitable trade for performance, or were they due somehow to mismanagement and the way in which the procurement business had always been done. As in the past, the government continued to be heavily involved in the day-to-day activities of the airframe and aerospace industry and heavily suspicious of industry. At a national level, a number of government commissions and panels set out over the years to make recommendations for the comprehensive reform of the system.[8] On a more local level, government negotiators attacked what they thought to be the major problem -- the overall profits of industry.[9] They did this by wielding their strong influence and leverage at the *beginning* of each contract negotiation and award process.

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[7] Gansler, Jacques S., *Affording Defense*, M.I.T. Press, 1989, p. 171.
[8] See McKinney, Ethan, "An Analysis of Acquisition Reform Reports" (prepared by the Policy Focus Group of the Lean Aircraft Initiative) for more information on these specific reforms.
[9] *The Defense Industry*, p. 86.

For their part, contractors also continued to approach the government/industry relationship with mistrust. They protected their interests in a number of ways. Heading into the 1980s, they began to "team" with a number of other major contractors to compete for the increasingly limited number of contracts (but of large dollar value) to be awarded. Contractors also began to horizontally integrate with other defense contractors. They began to diversify and to rely more heavily on commercial and foreign sales. Lastly, and perhaps most importantly in terms of the implications to the procurement process, they began to use the leverage they had *after* a contract was awarded (as a virtual sole-source supplier of a weapon system) to raise a contract's price with modifications and adjustments all made with the "best interests of the government" in mind. It was estimated in 1980 that the average government contract would grow in cost by 45 percent from contract award to actual delivery of the product.[10]

With the recent close of the Cold War, it is becoming increasingly evident to all parties that the acquisition and procurement environment which all sides have simply grown accustomed to over the past seven decades cannot support the major changes needed to ensure the survival of the industry and the viability of our national defense without some major modifications.

1.4 Post Cold War and Beyond

Although the relationship between the Department of Defense and the country's major airframe manufacturers has remained largely unchanged in the few years since the end of the Cold War and the apparent death of the fifty year tension between the United States and

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[10] *The Defense Industry*, p. 93.

the Soviet Union, there has still been *some* movement towards progressive and necessary change.

On the government side, there has been the expected reduction in defense budgets, and more specifically large reductions in procurement budgets, or "downsizing." In addition to reducing spending, the government has also been working on efforts to address the inevitable implications and ramifications of reduced budgets to the hundreds of contractors which have grown to rely upon the government for a significant portion of their business. Defense conversion is one of these efforts. This is the attempt to adapt defense manufacturing and development capacities and capabilities to civilian or commercial needs. This includes the retooling of factories as well as the retraining of technicians to utilize new skill-bases. Also included in the defense conversion effort is the necessity to assure that the capabilities needed to build and maintain a strong defense still remain at least latent within the industrial base. This also means that the subcontractor level, which might be discouraged from continuing to maintain government contracts in a downsized environment, must be incentivized by the government to do so. These defense conversion efforts, although largely spearheaded by Congress and congressional committees, are also contributed to by industry and the affected local communities.

In addition to conducting studies and providing funding for defense conversion efforts, the government and more specifically the armed forces have also been modifying their approach to the remaining government/contractor relationships. In an attempt to maintain the historical balance between supporting this critical industry and keeping it independent from the government, at a top-level the decision has been made to reduce procurement programs and to stretch out the schedules for those programs already in the pipeline. There will be tougher criteria for new program starts now that there is a perceived reduced threat. Programs will inevitably have to be thoroughly tested and proven technologies before they are given the "go-ahead" for further development and production. There will be an increased emphasis on the part of the government on research and development (R&D) and prototyping, and an accompanying attempt to make this R&D profitable to industry. Lastly, there will possibly be an effort made to take some of the business away from industry in the area of logistics, maintenance, and in some cases R&D.[11]

On the industry side, there has clearly been the recognition and accompanying action that the military industrial complex cannot sustain itself at current manning levels with the inevitable decrease in business which will be associated with decreasing defense procurement budgets and downsized armed forces. Mirroring the military's downsizing attempts and the termination and postponement of major acquisition programs, industry has also been employing large lay-offs and numerous plant closings. Additionally, industry has been in the process of consolidating through a combination of mergers and acquisitions and other sales of assets. Indeed it has been predicted that as soon as 1995, there will be as few as 5 major airframe manufacturers left in this country -- that is those manufacturers capable of producing "full service" aircraft.[12] In the mid 1960s there were as many as 35 of these major airframe manufacturers.

For those companies which do remain into the twenty-first century, there is a need to generate new business strategies to address remaining government contracts and to balance this work with commercial aviation contracts and other commercial business. Those companies which remain have in general approached their government business in similar manners. Some companies which intend to remain "full service" airplane manufacturers have decided to place an increased emphasis on research and development. They plan to concentrate on prototyping aircraft and hope to do some limited production. These primary

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11 Morocco, John D., "Balanced Defense Acquisition Strategy Key to Retaining Healthy Industrial Base," *Aviation Week and Space Technology*, May 25, 1992, pp. 58-62.
12 Smith, Bruce D., "Airframe Building Capability Loss Looms for Full-Service Defense Contractors," *Aviation Week and Space Technology*, March 16, 1992, p. 41.

contractors intend to keep some of the production work in-house which might have been out-sourced or sub-contracted in better days. Additionally, there has been a counter-attempt by major contractors to acquire some of the work which has traditionally been done by the government itself in logistics depots. Other companies have made the strategic decision to leave the defense business entirely or to step down in the "food chain" to the position of subcontractor as opposed to integrator.[13]

1.5 Implications and Summary

There is an enormous amount of history and tradition which forms the basis of the relationship which has developed between the airframe/aerospace industry and the United States government. Much of this history has resulted from an attempt to maintain an artificial or imposed sense of "competition" and the "free market" in an economic relationship which by its very nature is a monopsony. Some of this tradition arises from the need for our government to demonstrate to its constituency the fairness and openness of the contracting process, sometimes at the expense of efficiency and cost-effectiveness. To a lesser extent, the relationship has evolved in the manner in which it has from the experience of the many players in the process. Many policies and regulatory actions have arisen to address a specific situation or problem. These standards and practices are then applied, perhaps wrongly, to all similar situations in an attempt to prevent the issue from arising again. Lastly, a portion of the government and aerospace industry's relationship can be attributed purely to historical events such as the abrupt end of World War II or of the Cold War.

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13 Smith, Bruce A., "Aircraft Manufacturers Use Innovative Deals to Counter Competition, Financial Squeeze," *Aviation Week and Space Technology*, December 24, 1990, pp. 59-60.

What has resulted from this more than two hundred year-long relationship is a system of hundreds of regulations, rules, and standards which attempt to assure a "fair, efficient, and stable" relationship between government and contractors. It can be argued, however, that what has really resulted is a procurement system which is so complex and convoluted that it cannot even be easily described.

It seems clear that given the external acquisition environment of the future, with reduced procurement budgets and accompanying reduced resource implications, that there is a real need for reform both within the government and within the aerospace industry itself. This need has been recognized in many of the ways outlined previously such as defense conversion efforts and new acquisition strategies both on the part of government and industry. Another such corrective effort which has been undertaken in the past year is the Lean Aircraft Initiative (LAI). An off-shoot of the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology, LAI is a consortium of academic, government and industry representatives who have joined together to study how the defense acquisition community can learn to do "more with less." Chapter 2 will go into greater detail about the Initiative, as well as give some pertinent background concerning the IMVP program and its findings and history.

Chapter 2: Background of The Lean Aircraft Initiative[1]

The foundations of the Lean Aircraft Initiative (LAI) lie in the lean manufacturing methods first identified in the Japanese automobile industry. The principles behind this revolutionary approach to business are beginning to be implemented in many other industries as well. This chapter outlines the basic premise of lean manufacturing and discusses its use as related to the domestic military aircraft industry through LAI.

2.1 What is Lean?

The term "lean manufacturing"[2] was coined during the early phase of the M.I.T. International Motor Vehicle Program (IMVP) as a way to indicate the marked difference between the revolutionary approach to manufacturing observed in the study and the mass production tradition. The concept encompasses many of the current "hot topics" of management practice, such as total quality, process improvement, integrated product development, and just-in-time (JIT). The key difference between these various single-focus topics and the lean philosophy is the way lean manufacturing works to combine these disparate concepts into one direct focus for improved operation. Numerous surveys of and site visits to the Japanese automobile factories and their American and European counterparts formed the basis of the IMVP work between 1985 and 1990. M.I.T. began its second major study of lean manufacturing with LAI. A brief description of the relationship between the two studies and a discussion of the foundation of lean manufacturing principles follows.

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1 This chapter was co-authored by Renata Pomponi, LAI Research Assistant.

2 Note: the terms "lean manufacturing" and "lean production" will be used interchangeably throughout the text to refer to the concepts described in the IMVP study.

2.1.1 IMVP Beginnings

The original study of lean manufacturing (IMVP) was a five-year, five million dollar project conducted by a world-wide team of researchers based at the M.I.T. Center for Technology, Policy, and Industrial Development. IMVP consisted of a comprehensive study of the auto industry with emphasis on the Japanese development and implementation of lean manufacturing. Major results of the program are documented in *The Machine That Changed the World*.[3] The program was highly successful in earning major visibility among an international competitive manufacturing community largely unaware of the huge disparity of cost and schedule metrics between Japanese and Western car manufacturers. As *The Machine That Changed the World* became a national bestseller, its popularity and influence spread throughout the manufacturing world, eventually bringing lean production ideas to the attention of top officials at the United States Air Force Aeronautical Systems Center (ASC) in 1992. As mentioned in Chapter 1, following the collapse of the Soviet Union, the defense aircraft industry was faced with a crisis in dealing with a decreasing and uncertain threat accompanied by shrinking procurement budgets. In short, the government and industry were challenged to do more with less. Searching for ways to apply lean manufacturing principles to these problematic aspects of the defense aerospace industry, ASC looked to M.I.T. to extend its research into this area. Continuity between IMVP and LAI is provided by former IMVP Director Daniel Roos, who was appointed LAI Co-Principal Investigator.

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3 Womack, James P., Daniel T. Jones, and Daniel Roos, *The Machine That Changed the World*; Rawson Associates, 1990.

2.1.2 Lean Principles

Lean production is fundamentally different from mass production, having a different operational framework, corporate culture, and organizational structure.[4] The term "lean" manufacturing was selected because the associated techniques require significantly fewer resources than previous methods. For instance, compared to mass production, lean manufacturing uses less human effort in the factory, less manufacturing space, a smaller investment in tools, fewer engineering hours to develop new products, and less inventory on-site.[5] In addition, lean production results in many fewer defects while producing a greater variety of products. From a philosophical perspective, practitioners of mass production set limited goals for "good enough" performance, while lean producers set their sights on perfection.[6] This attitude is evidenced by the major goals of lean production, namely, perfect first-time quality, waste minimization, and continuous improvement. The corresponding desired outcome is lower production cost, improved product quality, higher productivity, efficiency at a lower scale of production, rapid product development cycle, and product mix diversity.[7]

To accomplish these lofty goals, lean manufacturing amalgamates the best features of craft production (high quality, custom-made products) with those of mass production (large quantities to satisfy broad customer needs at lower price).[8] Here is where many of the management concepts that have emerged from Japanese business come into play in the lean arena. One of the most notable distinctions of lean production is the ability of any worker to stop the line to fix problems, unlike the rigid structure found in mass

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4 Weiss, Prof. Stanley I., "Lean Aircraft Initiative," National Technological University (NTU) presentation, Washington DC, July 26, 1993, p. 15.

5 *The Machine*, p. 13.

6 *The Machine*, p. 14.

7 Ling, Dr. James, "Lean Production," LAI Internal Memorandum, October 1993.

8 Weiss, NTU presentation, p. 17.

production factories where the continuity of the line is maintained to the detriment of the amount of re-work to be corrected in the finished product. The Japanese kaizen principle (continuous incremental quality improvement), which has come into vogue in Western plants as of late, demands this flexibility and empowerment of the line workers to reduce defects by catching problems where they occur instead of later in the process when the value-added is much higher and errors are buried beneath complex layers of later-installed parts. The effect of errors is therefore reduced, while the probability of correcting the source malfunction is significantly improved. The concept of design for manufacture complements this error-reduction strategy by aiming at designs with fewer parts that fit together better.

The kanban/just-in-time (JIT) method is also incorporated into lean manufacturing principles. By coordinating the flow of parts within their supply system, lean producers are able to reduce inventories and speed manufacturing cycle times. They generally have a much better understanding of their process flow through the use of "value engineering" to break down the costs of each stage of production so as to identify factors that could lower part cost.

The IMVP researchers found the Toyota Production System typified lean production principles. The most graphic testimony to the effectiveness of lean production in improving plant operational efficiency is evidenced by a comparison of various operational statistics for the General Motors (GM) Framingham Assembly Plant (now closed) and the Toyota Takaoka Assembly Plant (see Table 2.1). The data refer to the production of a "standard car" defined by IMVP to allow comparisons between disparate plant sizes and product configurations.

Table 2.1: Comparison of General Motors (GM) Framingham Assembly Plant and the Toyota Takaoka Assembly Plant (1986 figures).

Source: IMVP World Assembly Plant Survey[9]

	GM	Toyota
Gross Assembly Hours per Car:	40.7	18.0
Assembly Defects per 100 Cars:	130	45
Assembly Space per Car (sq. ft.):	8.1	4.8
Inventories of Parts (average):	2 weeks	2 hours

As these figures demonstrate, the Toyota plant was more than twice as productive and almost three times as accurate as the GM plant. In general, the IMVP study found that Western auto companies misunderstood the reasons for the Japanese business advantage and were unwilling and unable to diagnose their own problems. The first precise definition and evaluation of lean production helped to clarify the competitive situation and identify key areas for improvement.

2.2 What Is LAI?

The often-quoted statistics from *The Machine That Changed the World* GM/Toyota survey brought the benefits of lean production to light for many American businesses and aided in creating the impetus for LAI. This section contains a discussion of the LAI mission and its organizational structure. A description of the inventory pilot project is also included.

9 *The Machine*, IMVP World Assembly Plant Survey, p. 81.

2.2.1 Mission

The formal mission of the Lean Aircraft Initiative is "to spearhead an organized process of research and action leading to a fundamental transition of the defense aircraft industry over the next decade by instituting substantial improvements in both industry and government practices."[10] Major goals are to identify "roadmaps for change" to lead to better, faster, and cheaper manufacturing, searching for best practices to use as models for comparison along the way. The program is designed to build upon the IMVP work but treats the aerospace industry as its own entity, lending special consideration to the unique customer relationship between defense manufacturers and the government. As in the auto industry, lean manufacturing appears to be a good fit with the traditional aerospace environment of high-tech craft managed as mass production.[11]

The approach to LAI differs from the usual mode of industry research in that the focus is on implementation of real-world concepts and strategies rather than academic theorization. Researchers work closely with industry and government representatives to insure the selection of near-term implementable goals and plans. The final main objective is to identify and validate areas of the government acquisition process (i.e., regulations and procedures) that impair efficiency for industry producers.

2.2.2 Sponsors

LAI is under the joint sponsorship of the United States Air Force and 21 aerospace industry corporations whose membership includes all sectors of the industry -- airframe, avionics/electronics, engines, subsystems, and others. A financial contribution of $50,000 per year from each industry participant is matched by one-third government

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10 Bozdogan, Kirkor, "Lean Aircraft Initiative Mission," LAI Internal Memorandum, March 26, 1993.
11 Weiss, NTU presentation, p. 23.

funding through ASC. Commitment to the program is demonstrated by the high-level of support and participation at ASC (general officer level) and the companies (corporate level). Total program funding is $1.8M per year for three years, with a possibility for follow-on work. Current sponsors are shown in Table 2.2.

Table 2.2: LAI Sponsors

Air Force Aeronautical Systems Center (ASC)

AIL Systems	Lockheed-Ft Worth	Rockwell-NAA
Allied-Signal	Loral Defense Systems	Sundstrand
Boeing Defense and Space Co.	Martin Marietta	Texas Instruments
GE Aircraft Engines	McDonnell Douglas Aircraft Co.	Textron Defense Systems
Grumman	Northrop	TRW
Hughes Radar Systems	Pratt & Whitney	Vought Aircraft
IBM Federal Systems	Lockheed Aeronautical	Westinghouse Electronic Sys.

2.2.3 Program Structure

LAI is structured with M.I.T. serving as the "honest broker," allowing tight interaction with sponsors to guarantee a useful path of research and a reliable supply of unbiased data. Sponsor interaction occurs at many levels, and industry participants are expected to expend approximately six person-months of effort annually for meetings, site visits, and data collection support. The upper-most level of direction is provided by an Advisory Board comprised of roughly 20 president-level industry representatives and high-ranking government military and civilian personnel. Industry Board membership is chosen from among the sponsor companies on a rotating basis. The Advisory Board meets three times per year at M.I.T. and is responsible for guiding the overarching direction of research and for setting program policies. A Working Group made up of subordinate staff from the same organizations is tasked to set agendas for Board action items and to carry out any subsequent mandates. M.I.T. has its own Internal Advisory Board to handle Institute-specific issues.

Representatives from all the sponsors gather four times a year at M.I.T. for Workshops whose purpose is to report on LAI progress, disseminate current research results, present case studies of lean practices, and identify issues for further consideration. At this time, Focus Groups are convened in each of the five major areas of research: fabrication and assembly; product development; supplier relations; human resource management; and policy and external environment. A cross-section of participants from industry, government, and academia attend each Focus session to discuss specific research progress and goals. The Focus Groups are also a vehicle for direct sponsor interactions with the M.I.T. team which often result in individual company case studies and site visits. The Workshop also hosts Sector Group meetings, where company representatives from each industry sector -- airframe, avionics/electronics, engines, or subsystems -- confer to discuss issues relevant to their particular specialties. The most comprehensive level of sponsor/researcher interaction takes place during intensive mini-workshops throughout the year, during which industry and government specialists meet to discuss detailed research methodology and results.

2.2.4 Pilot Project - The Inventory Survey

The five Focus Groups mentioned above indicate the main organizational categories for LAI research. Each topic is under the direction of M.I.T. faculty and research staff, with a complement of graduate research assistants. Plans call for a series of M.I.T.-conducted surveys, to be completed by the industry sponsors, which examine specific practices relating to each topic. The goal is to look at industry and government attitudes and practices relating to the focus area and then to identify best practices and opportunities for improvement. The first LAI focus team concentrated on aerospace inventory practices, a subcategory of the Fabrication and Assembly group. The pilot project is described below.

2.2.4.1 Origins

Fabrication and Assembly was singled out from the start of the LAI program as a major area of current difficulty with good possibilities for successful implementation of change. In particular, inventory control processes were cited by the industry participants as having a significant impact on company viability and also needing improvement. Key questions to be answered included:

- How much capital is tied up in inventory?
- How much does it cost to carry inventory?
- How fast does inventory turn over?
- What factors drive inventory levels and turns?
- How do inventory levels affect ability to meet production schedules?
- What do inventory practices reveal about the company's control over process flow?
- What improvements can be made?

2.2.4.2 Research Plan of Attack

The pilot project process flow is detailed in Figure 2.1. Once the inventory topic was selected, the first step in examining industry practices was a series of seven site visits to LAI member companies during the spring of 1993. Researchers prepared a list of

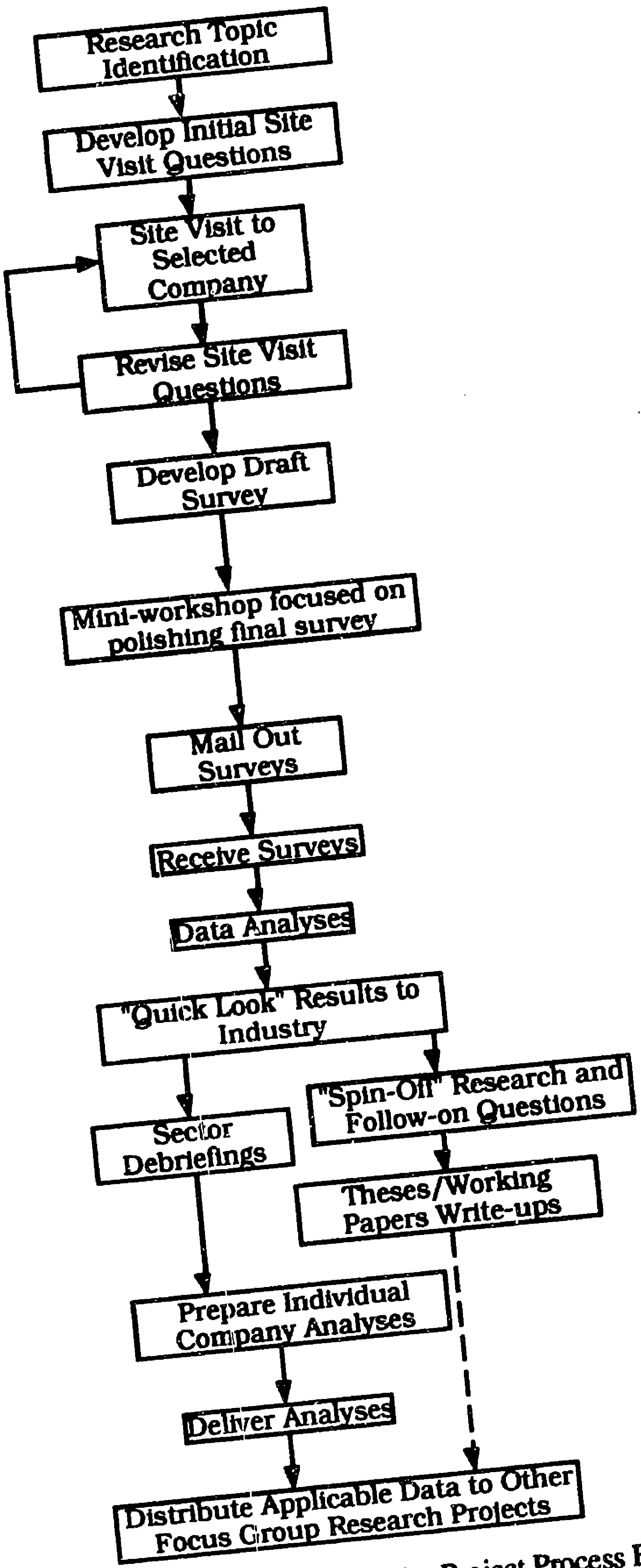

Figure 2.1: Inventory Pilot Project Process Flow

approximately 60 inventory-related questions, derived from initial research, to serve as a basis for discussion at the visits. Site hosts typically provided two days of presentations by inventory control management personnel and a factory tour, followed by a question and answer session. One can conclude from general impressions from site visits that many opportunities for the introduction of lean practices exist in aircraft manufacturing, especially in fabrication, scheduling, and parts distribution. There is a clear recognition among top management of the need for leanness, as well as an existing visible movement toward teaming and integrated product development. Researchers also saw variability of government oversight coupled with a gradual change in government approach, shifting towards process verification. In the specific area of inventory control, a wide range of practices were found -- from 1940's approaches to 1990's world-class. Excess inventory was found to cause problems in four ways: up front capital investment, carrying costs, scrap and rework costs, and masking of production problems. On the government side, progress payments and fiscal year buys seemed to encourage excess inventory. All in all, the evidence pointed out that companies are trying to reduce inventory, but the process is slow at current production rates.

The results of the site visits were used to fine tune the initial set of questions and to convert them into a draft questionnaire. Attention was paid to developing a consistent survey format so as to increase response accuracy. A mini-workshop was then held at M.I.T. in June to revise the survey. A panel of industry and government inventory specialists, selected as a representative sample of the sponsoring organizations, was invited to the intensive two-day meeting. The goal of the mini-workshop was to address outstanding global issues, including the definition of the scope of analysis, response protocol, and results/output. Small groups examined each section of the survey to modify format and content. To insure consistent terminology within the survey across industry segments, the group prepared standard industry production and planning models and a glossary of terms.

The output of the mini-workshop was a final version of the survey. The 60-page questionnaire contained numerical, yes/no, and essay questions in nine areas:

- Section O: Company Overview and General Statistics
- Section A: Organization and Management Policy
- Section B: Metrics
- Section C: Accounting Practices
- Section D: Inventory Handling and Facility Management
- Section E: Planning and Simulation
- Section F: Inspection and Defects
- Section G: Government Relations
- Section H: Final Comments

The final inventory practices survey was distributed to the member companies in late June. Each company was asked to complete surveys for those internal organizations that in total comprised 80 percent or more of its annual DoD business. Thirty-six valid surveys were returned, representing 20 companies (six companies surveyed multiple plants/divisions).

2.2.4.3 Analysis Methodology

Response data were compiled in a Microsoft Excel spreadsheet database format running on a Macintosh personal computer. Initial analysis included the calculation of averages and statistical information on numerical data and percentages on Boolean responses. Researchers assessed the data as it was entered to verify reasonableness, check for outliers, and correct technical errors. A second more in-depth analysis consisting of data evaluation and manipulation resulted in the creation of graphics describing general results. Quantitative information was combined with written answers to essay questions in order to assemble a snapshot picture of the state of the industry (see Chapter 3). Presentations on initial results were made at the Workshop and Sector Group level, while individual reports were prepared for respondents showing how they measured up to industry norms. Ongoing data interpretation involves the search for internal and external benchmarks related to inventory and production management practices, which will be documented in subsequent student theses and M.I.T. working papers.

Chapter 3: Inventory Pilot Project Survey Results[1]

As was briefly explained in Chapter 2, inventory practices was selected as the first major area of investigation under the Fabrication and Assembly focus group. As is shown in Figure 3.1, inventory is pervasive throughout an organization, masking many problems inherent to that organization and its manufacturing operation. As the diagram shows, the presence of inventory affects and is affected by a great many aspects of a manufacturing operation: facilities management, supplier relations, quality, purchasing, etc. By starting with inventory, a good snapshot of the state of the industry and of individual companies results, along with ideas for a number of areas for future research. This chapter will provide some background on the format of the survey itself, some details on the requirements for "valid" data and the characteristics of the database, and finally some of the more salient and germane results from each of the sections of the survey itself.

3.1 Survey Format and Database Characteristics

As was first outlined in Chapter 3, the survey was grouped into eight major sections as follows:

- General
- Organization and Management Policy
- Metrics
- Inventory Handling and Facility Management

1 This chapter was co-authored by Renata Pomponi, LAI Research Assistant.

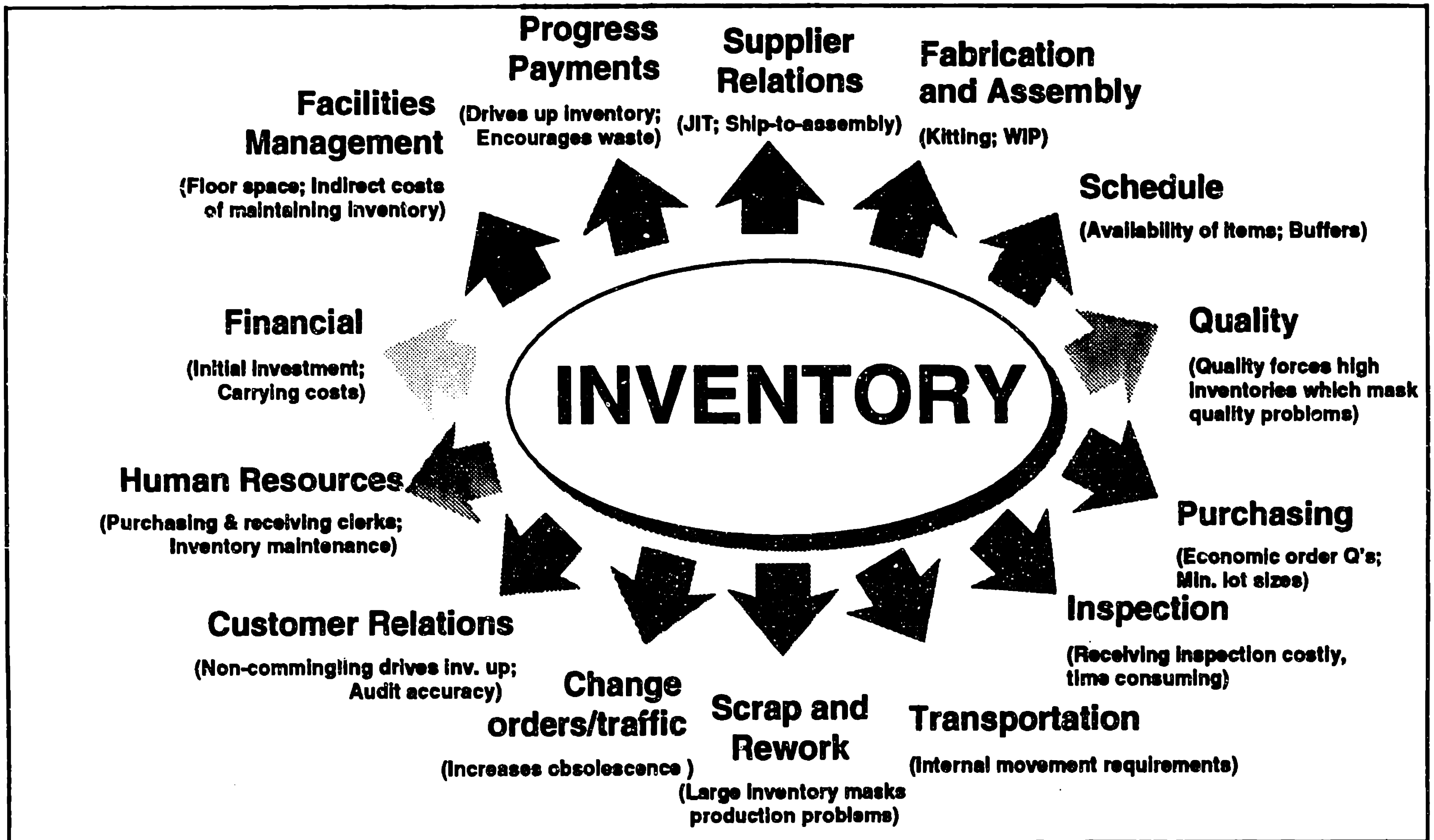

Figure 3.1 Pervasiveness of Inventory Diagram

- Accounting Practices
- Government Relations
- Planning, Inspection and Simulation
- Final Comments

Respondents were given a month to respond to the sixty page questionnaire. Appended to the survey was a tracking sheet so that companies could note individual company representatives who could be contacted should questions arise on the part of research staff at M.I.T. during analysis. One premise of the survey was that all respondents agreed to the standard industry and standard planning models which were developed at an industry-government-M.I.T. workshop and were provided to them in the survey (Figures 3.2 and 3.3).

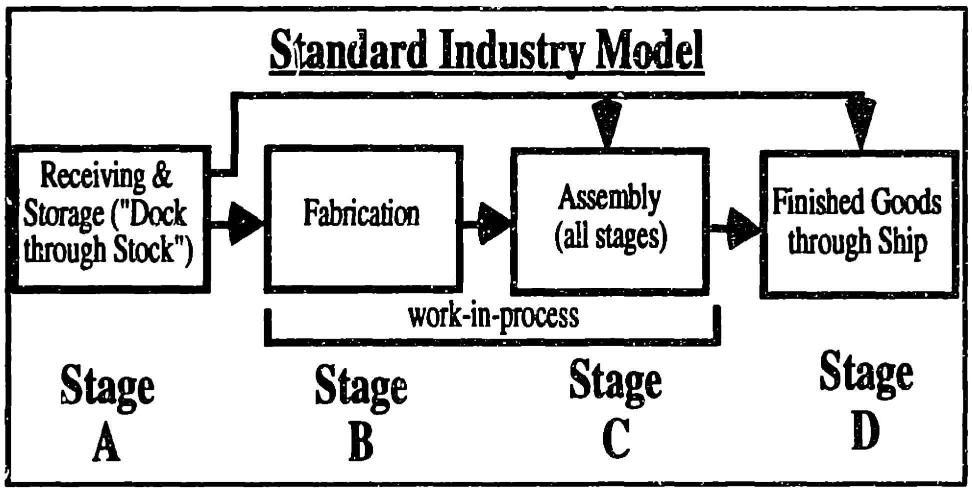

Figure 3.2: Standard Industry Model

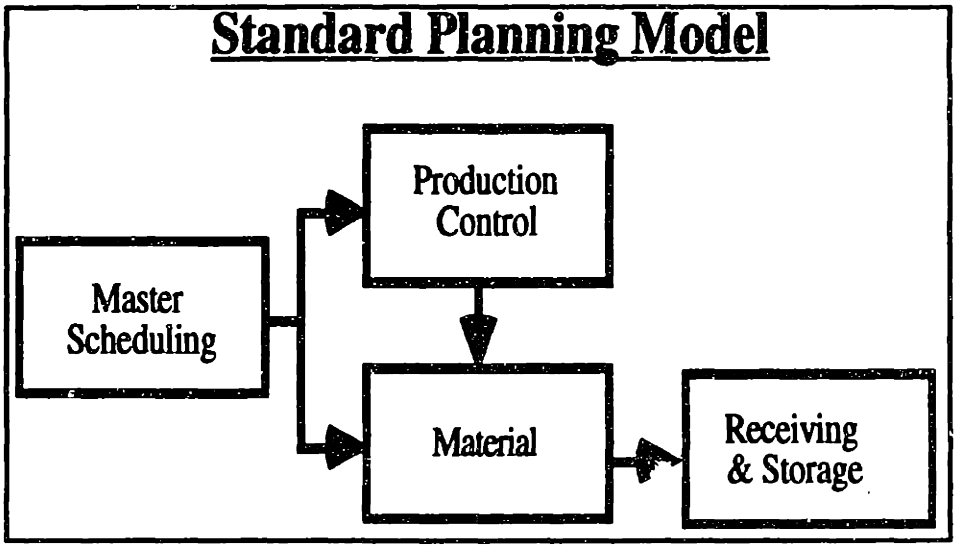

Figure 3.3: Standard Planning Model

Most questions were based on the acceptance of these models as being fairly accurate representations of the responding company's system. The survey also included space for the company to describe its own system if it differed substantially from the standard model. The following are data on surveys which were distributed, received, and later analyzed:

- 21 companies surveyed
- 20 companies responded
- 1 company refused to participate in this survey
- 36 returned responses were determined to be "valid" (companies sent multiple responses representing independent divisions)

In order for a survey to be "valid", it was necessary that the responding company or Single Business Unit (SBU) fit the following requirements:

- Must be an independent business unit

- Must have at least 200 employees
- The collective responses for each company must comprise at least 80 percent of their government business

Respondents were grouped into the following major sectors (the number of surveys within each category is indicated after the colon) :

- Airframe and Major Assemblies (fuselage sections, major structures or skins): 10
- Aircraft Engines (primary power plants): 3
- Electronics and Avionics (flight computers, guidance equipment, etc.): 13
- Aircraft Subsystems (electro-mechanical systems and components): 4
- Others (missiles, satellites, communications, etc.): 6

Data were analyzed for the industry as a whole, as well as for individual sectors.

3.2 Results and Relationship to Lean Principles

The remainder of this chapter will highlight some of the more notable results of the survey's analysis. Where appropriate, this analysis will be on the industry as a whole. As well, this review will include some of the sector data which were analyzed. Where applicable, results will be accompanied by an explanation of how they relate or do not relate to lean tenets or principles. The results which will be presented do not in any way represent the totality of data or findings which resulted from this lengthy and extensive survey. They do, however, represent data and results which are available as of the writing of this thesis. Charts and graphs have been culled from the numerous presentations which have been given over the past few months to a variety of interested groups.[2] Analysis is still ongoing as of this time.

3.2.1 Organization and Management Policy

This section of the survey asked a number of questions related to the organizational structure of the responding company. Questions were also asked to gauge attitudinal characteristics of the workforce, both of management and of labor.

Perhaps most fundamental to the subject of inventory management and inventory practices is an understanding of the sheer number of people required to support inventory related functions within the company. Respondents were given a list of possible responses (with accompanying definitions), as well as the option of adding more. These labor categories were:

- Master Schedulers
- Production Schedulers
- Order Writers
- Purchasing Agents
- Material Expediters
- Receiving Inspectors
- Pickers and Kitters
- Planners
- Dispatchers
- Production Control Expediters
- Buyers
- Procurement Quality Assurance

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2 Please refer to the following presentations: "Initial Results of the Inventory Pilot Program", October 1993; "Results of the Inventory Pilot Program for the Electronics Sector", December, 1993; and "Results of the Inventory Pilot Program for the Airframe Sector", January 1994. All presentations were prepared by Dr. James Ling, Christina Houlahan, Renata Pomponi, and Todd Stout.

- Receiving/Payment Clerks
- Stock Keepers
- Internal Transportation
- Crib Attendants

Industry-wide, the most frequently identified and abundantly populated categories were buyers and planners. Figure 3.4 shows a graphical representation of the number of personnel supporting inventory as a percent of total employees, both for the industry as a whole and also for the individual sectors. It is apparent that there is a large discrepancy between respondents' answers. Some companies identified as much as 27-32 percent of their total employees as being affiliated with inventory handling and related support functions, while some companies reported percentages as low as 4 percent. Some industry sectors such as the "Systems", "Engines" and "Others" did not have an enormous range in responses, while other sectors such as "Airframe" and "Electronics" had wide ranges.

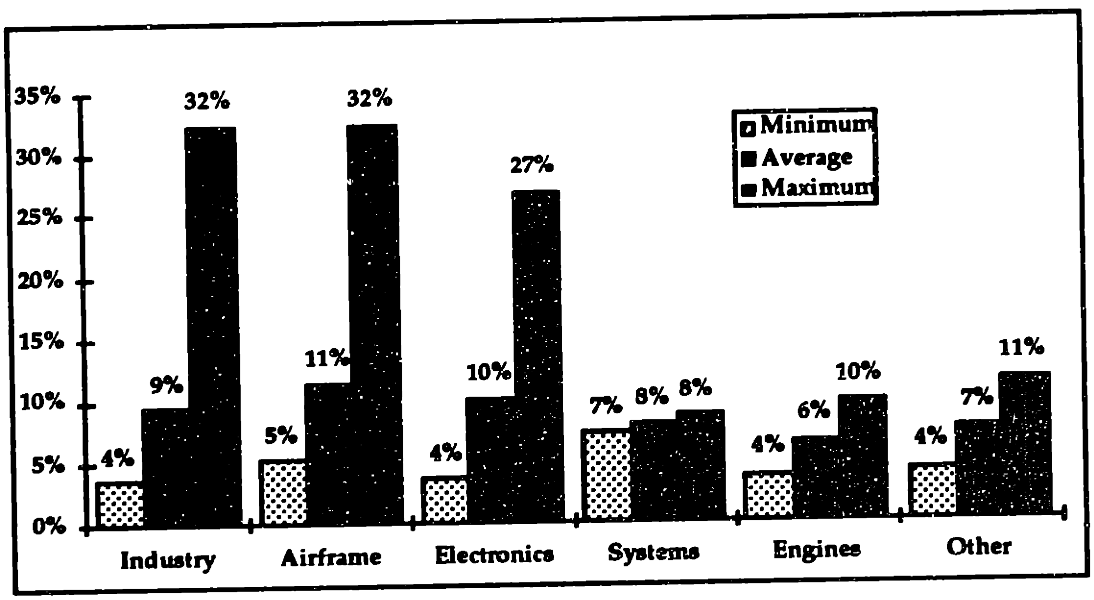


Figure 3.4: Average Number of Personnel Supporting Inventory (As a Percentage of Total Employees)

It seems from these data that there are indeed "best" and "worst" practices within the industry when it comes to the lean management of inventory. "Leanness" is assumed to be inversely proportional to the number of people required in support of any activity.

Another series of questions within the "Organization and Management Policy" section of the Inventory Practices survey related to inventory goals as held by corporate management and government overseers. One such question asked: "Does your organization have a stated inventory goal?" Here, the authors of the survey were looking to see if there indeed was a goal to which the company was working (such as the reduction of inventory). The results were surprising, for not all respondents were aware of a company inventory goal (Table 3.1):

Table 3.1: Percentage of Companies Having a "Stated Inventory Goal"

Airframers	90%
Electronics	77%
Systems	100%
Engines	100%
Others	100%

Following this question, respondents were asked if their corporate level of management played any role in determining inventory. The results are shown in Table 3.2:

Table 3.2: Percentage of Responses Where Corporate Level Plays a Role in Inventory

Airframers	70%
Electronics	54%
Systems	100%
Engines	100%
Others	67%

Most commonly, companies cited the "setting of performance goals" as the specific role which the corporate level played in determining inventory. Finally, companies were asked if the government played any role in determining inventory (Table 3.3):

Table 3.3: Percentage of Responses Where Government Plays a Role in Determining Inventory

Airframers	50%
Electronics	69%
Systems	50%
Engines	0%
Others	83%

Respondents cited the "setting of performance goals", and "MMAS guidelines" most frequently when asked to name more specifically the government role. A "lean" series of responses in this broad line of questioning would be to 1) have a stated inventory goal, and to 2) preferably have the corporate level playing some role in determining this goal or in determining the overall manner in which inventory levels are determined. It is not certain that it is necessary for the government, the customer in this case, to have a *direct* hand in setting goals or in determining inventory in order for a particular company to be moving towards a better state of "leanness." However, given the unique relationship of the government and industry in the aerospace business, it would not be unwise for a corporation to be aware of government expectations in this area.

One last relevant question which was contained in the "Organization and Management Policy" section attempted to gauge the various attitudes throughout a company's chain of command concerning the excess or shortage of inventory. The responses to this question were of interest. While upper management tended to have a moderate inclination to avoid shortfalls and a slight inclination to avoid excess, middle management seemed to have a moderate inclination to avoid shortfalls but a neutral attitude regarding excess. When asked about shop floor workers' attitudes the picture changed somewhat. Here, workers had a moderate inclination to avoid shortfalls, and a slight inclination to encourage excess. In short, although it was reported that the dominant attitude industry-wide was mid-way between upper and middle management's, it is clear that shop floor workers and their management (regardless of what level) have a different approach to inventory shortfalls and excess. It is important to note here that in most cases it was middle management who actually filled out the survey and responded to this series of questions. It is possible that this fact influenced the results somewhat. Regardless, a rift in attitudes does apparently exist (even if only perceived) between layers of the organizations surveyed. Laborers are driven by schedule and by the historical emphasis that this industry has placed on avoiding shortfalls at all costs in order to stick to that schedule. Management at the upper levels has the somewhat more progressive view that a balance should be struck, while middle management plays apparent lip service to the need to avoid excess, while still keeping their eye on schedule and the excess inventory required to maintain that schedule. A "lean" practice or attitude would be to avoid both excess and shortfalls. Also, it is necessary that a shared and consistent attitude or approach towards inventory be held throughout the company's various levels. It would seem the industry, when taken as a whole, has not made this attitudinal transition as of yet.

3.2.2 Metrics

Metrics measure the "pulse" of a company and tell a great deal about what the company believes is important. The "Metrics" section of the survey was extensive and was designed to accomplish two major goals: 1) to determine what metrics were currently being used by responding companies and what these metrics revealed about the state of the industry, and 2) to capture companies' answers to a number of metrics which were identified by the research team (with the help of the Mini-Workshop participants) as indicators of a company's progress towards "leanness." This brief review of the results is not intended to be an exhaustive treatment of the "Metrics" section but instead will highlight a few interesting findings.

Companies typically listed a number of metrics which they tracked. Among these were "accuracy of inventory" as measured by counts or against records, "supplies on hand" in terms of number of days, "cycle time" (both overall and within the various production stages), "turns," and finally "effectiveness" measured by actual performance in comparison to corporate goals. Less common but conducive to progress towards a leaner operation, were metrics tracked by some companies such as "percent of kits released short to the floor," "ratio of actual cycle time to touch labor time," and "ratio of active inventory to inactive inventory."

The "Metrics" section of the survey also asked companies to identify where their inventory was located by dollar value on their government contracts. The results were surprising. Figure 3.5 shows the breakdown within each production stage, both by sector and industry (expressed in terms of percent of the whole). Although some sectors are different, when the number of respondents within each sector is taken into account, one-third of overall inventory for government contracts is located in receiving and storage -- a surprisingly high number. This observation, the apparent "front-end loading" of inventory into receiving and storage will be further elaborated upon in Chapter 4. A lean inventory profile in this case would have a relatively low percentage of total inventory in receiving and storage as opposed to in the fabrication or assembly stages.

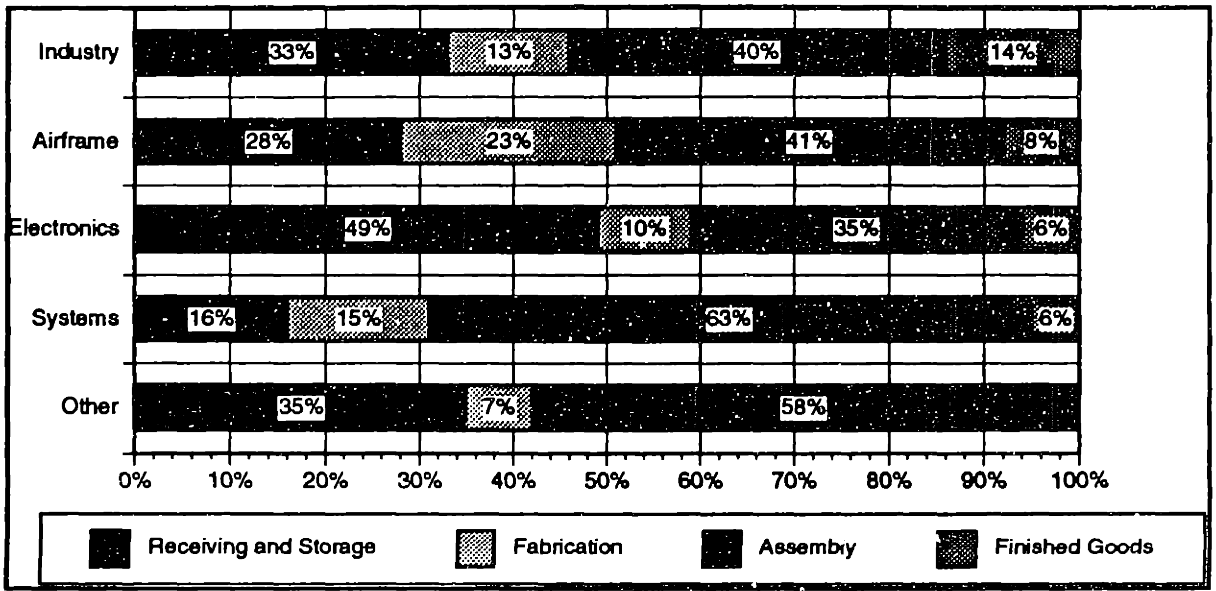


Figure 3.5: Inventory Location by Stage for Government Contracts

Finally, results from the "Metrics" section also gave interesting insights into the extent to which scrap, rework and repair (SRR) are a factor in the aerospace industry. These data can be seen in graphical form in Figure 3.6. The data in this case have been tailored to show scrap, rework and repair as a percent of total sales within each stage for all sectors and for the industry as a whole. Of note here is the variation in response between sectors (some have large amounts of SRR in some stages while others do in different phases of production). As well, it is interesting to see that some sectors seem to have more SRR as a percentage of sales than do others. Some of this difference can be attributed to the fact that certain sectors were represented by a relatively small number of respondents, so some companies might weigh more heavily on sector results than would others. In a related area, companies were also asked to quantify their obsolete and excess inventories within each production stage. These results, again expressed in terms of percent of total

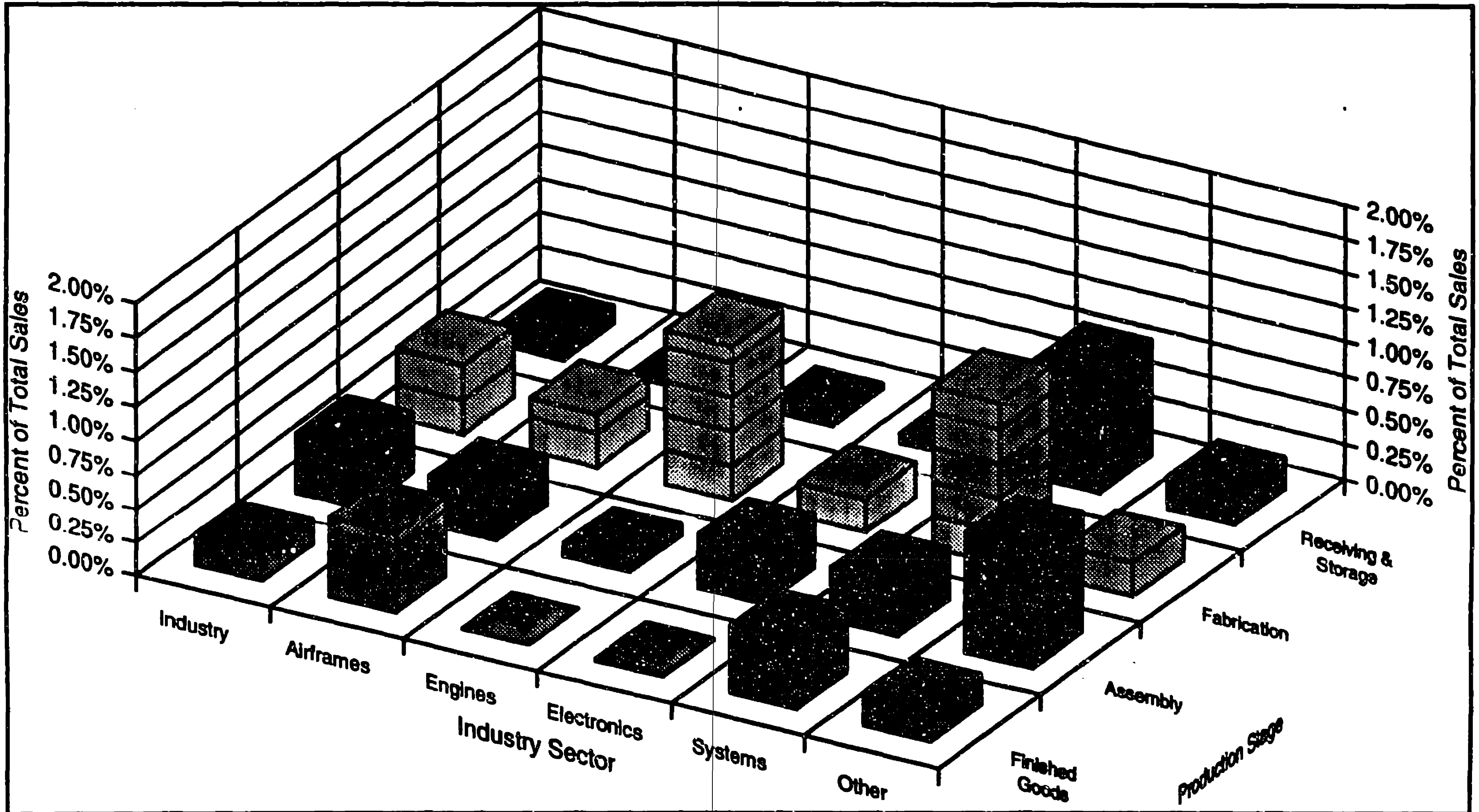


Figure 3.6: Scrap, Rework, and Repair Cost As A Percent of Total Sales

sales, are shown in Figure 3.7. The overall conclusions are similar to those related to SRR -- certain sectors have more of a problem than others. Interestingly, to some extent the data look as if those sectors which are "upstream" of the acquisition process have a problem with obsolete and excess inventory late in their own production process (see finished goods for "Systems" and "Engines" in particular), while those which are "downstream" or customers of the upstream contributors seem to have the problem early on in their individual production flows (see receiving and storage for "Airframe" sector).

3.2.3 Accounting Practices

The third section in the Inventory Practices survey addressed accounting issues. Although not all of the questions were of an accounting nature in the purest sense of the word, at the time the survey was generated it was believed that the majority of questions within this section would be answered by people charged with accounting responsibilities within their respective companies.

A fundamental question was asked at the start of the section: "Are figures readily available for the value of total inventory?" The answer was expected to be a resounding "yes." Instead the industry's answers were surprising as shown in Table 3.4:

Table 3.4: Percentage of Responses Where Figures Are Readily Available for Value of Total Inventory

Airframers	90%
Electronics	92%
Systems	100%
Engines	100%
Others	83%
All Sectors	**91%**

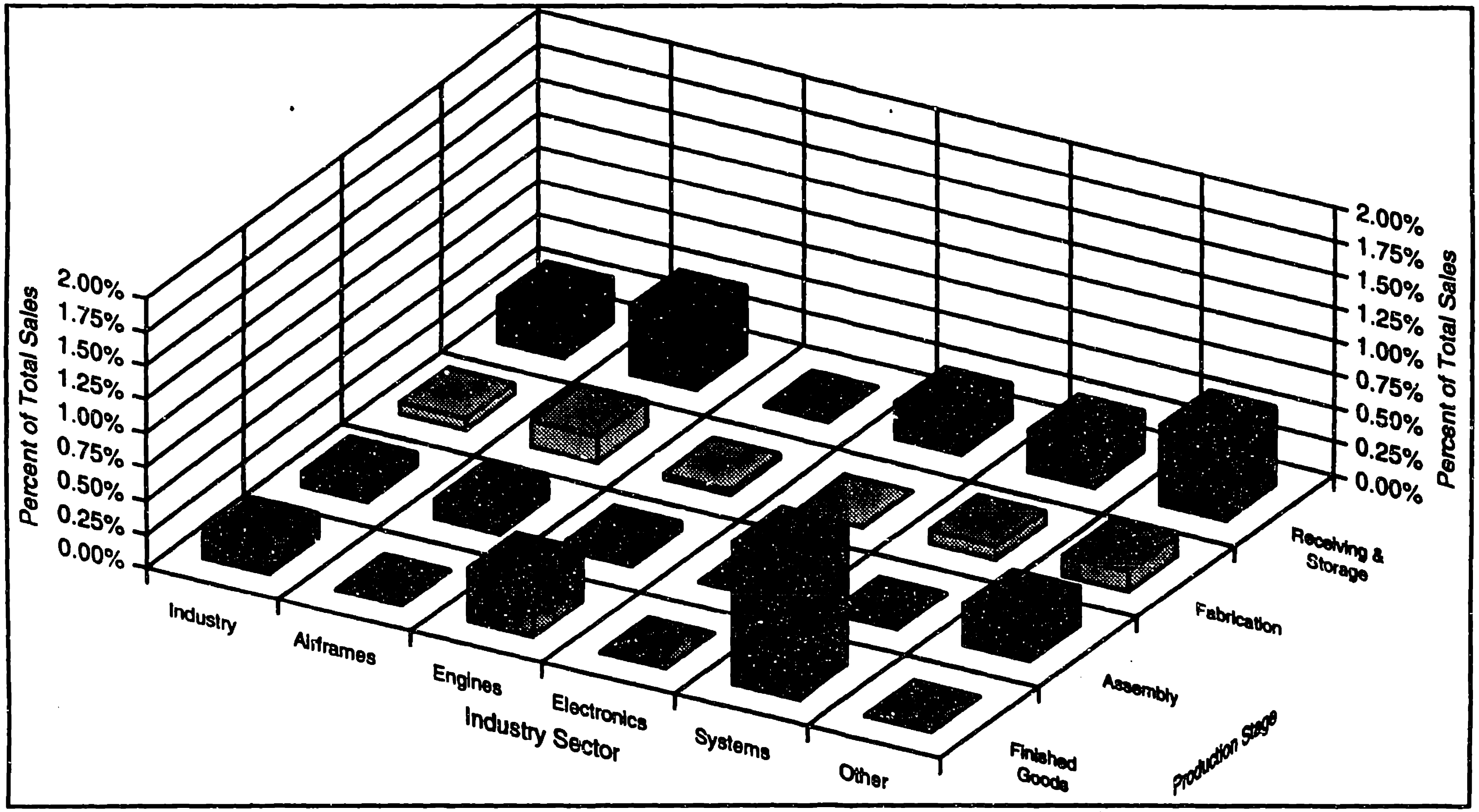


Figure 3.7: Obsolete and Excess Inventory As a Percent of Total Sales

Also within the Accounting Practices section, respondents were asked to provide a profile of the age of inventory within each stage (receiving and storage, fabrication, assembly, and finished goods). These data were then combined with data from the Metrics section which asked companies to provide the *relative* percentage of inventory contained in each stage by dollar value. Figures 3.8 - 3.11 show the resulting inventory profiles (by age and by stage) of the various sectors. Perhaps most interesting about these data is the fact that so few companies were able to respond when asked both for an age distribution of inventory and for a breakdown of the relative amounts of inventory by dollar value within the system. In the "Airframe" sector, only one company out of the ten surveyed had this information available; in the "Other" sector, only one of six was able to respond. Although better, the "Electronics" and "Systems" sectors were still surprisingly low in their response rates, with 46 percent and 75 percent respectively. To some extent, these data and these four charts in particular will be covered again in more detail, for regardless of how sparse the data, they still provide an interesting look at the age and disposition of inventory within some segments of the defense aerospace industry. A lean profile would show inventory which is relatively "young" in age and which is clearly "progressing" out the door through the various stages (i.e. no inventory over a year old in receiving and storage when all other stages show younger inventory). It is not clear that any of the sectors surveyed possess these "lean" inventory qualities.

A third area of interest in the accounting section of the survey was the state of acceptance and usage of Activity Based Costing (or ABC). This relatively new way of looking at accounting is a departure from the traditional manner in which manufacturing systems have been tracked. Typically, individual activities or actions which happen to a part of a process cannot or have not been specifically tracked. Costs instead are pooled into overhead and assigned to various products or processes in a number of (sometimes seemingly random) ways. ABC attempts to address this problem by specifically monitoring individual activities and attributing costs directly to that activity. The result is

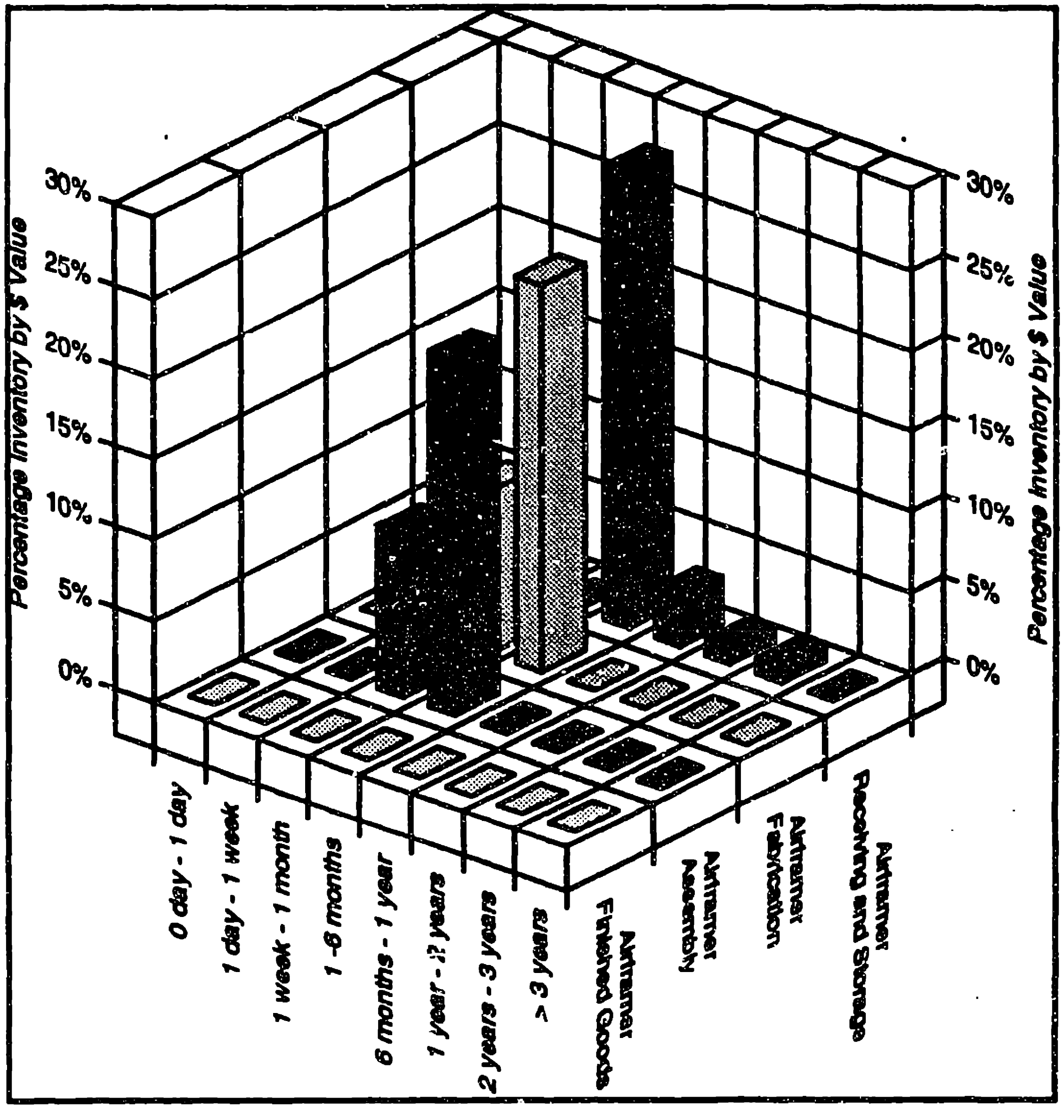


Figure 3.8: Age by Stage for the Airframe Sector (Percent Airframe Responding: 10%)

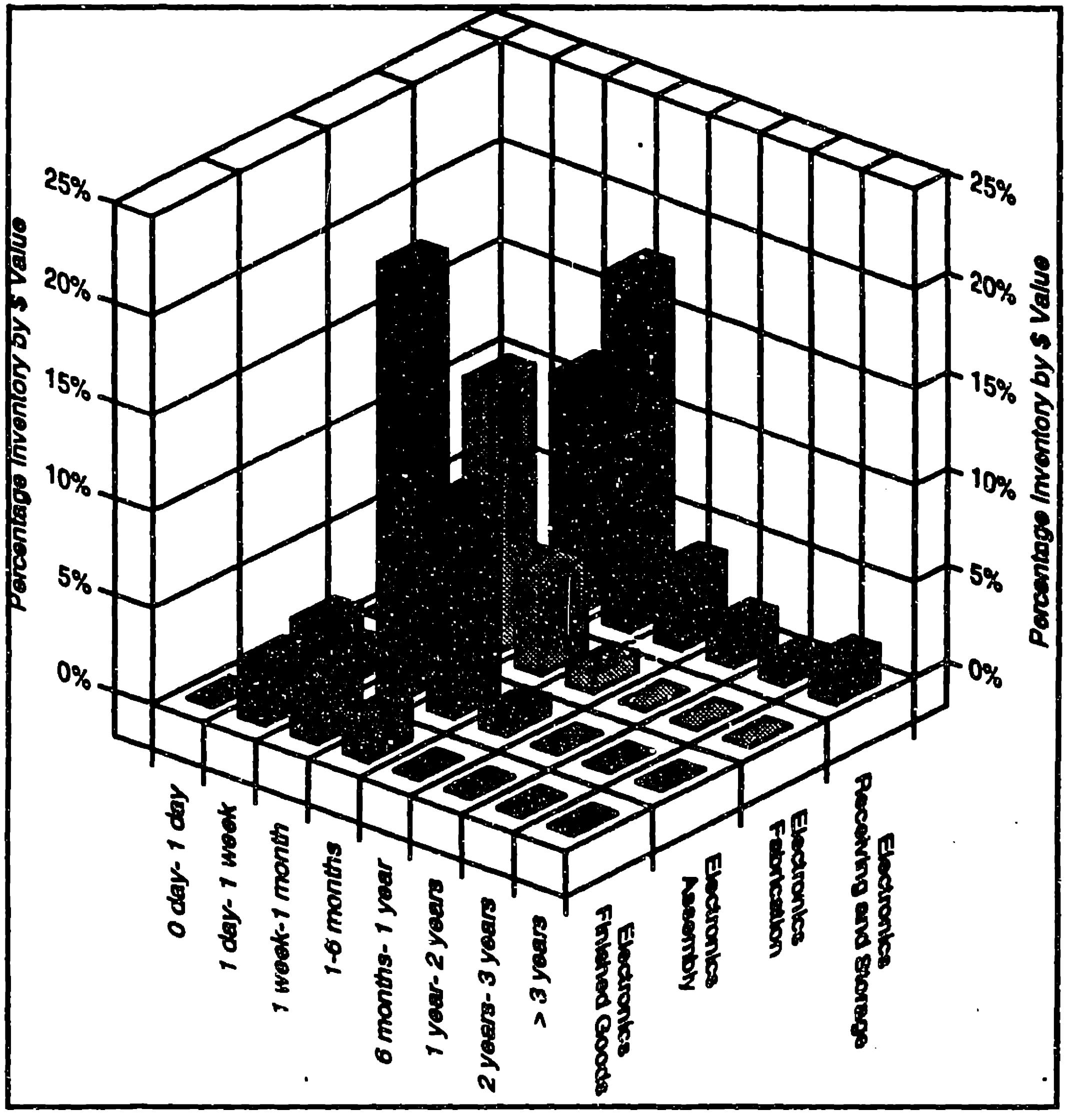


Figure 3.9: Age by Stage for the Electronics Sector (Percent Electronics Responding: 46%)

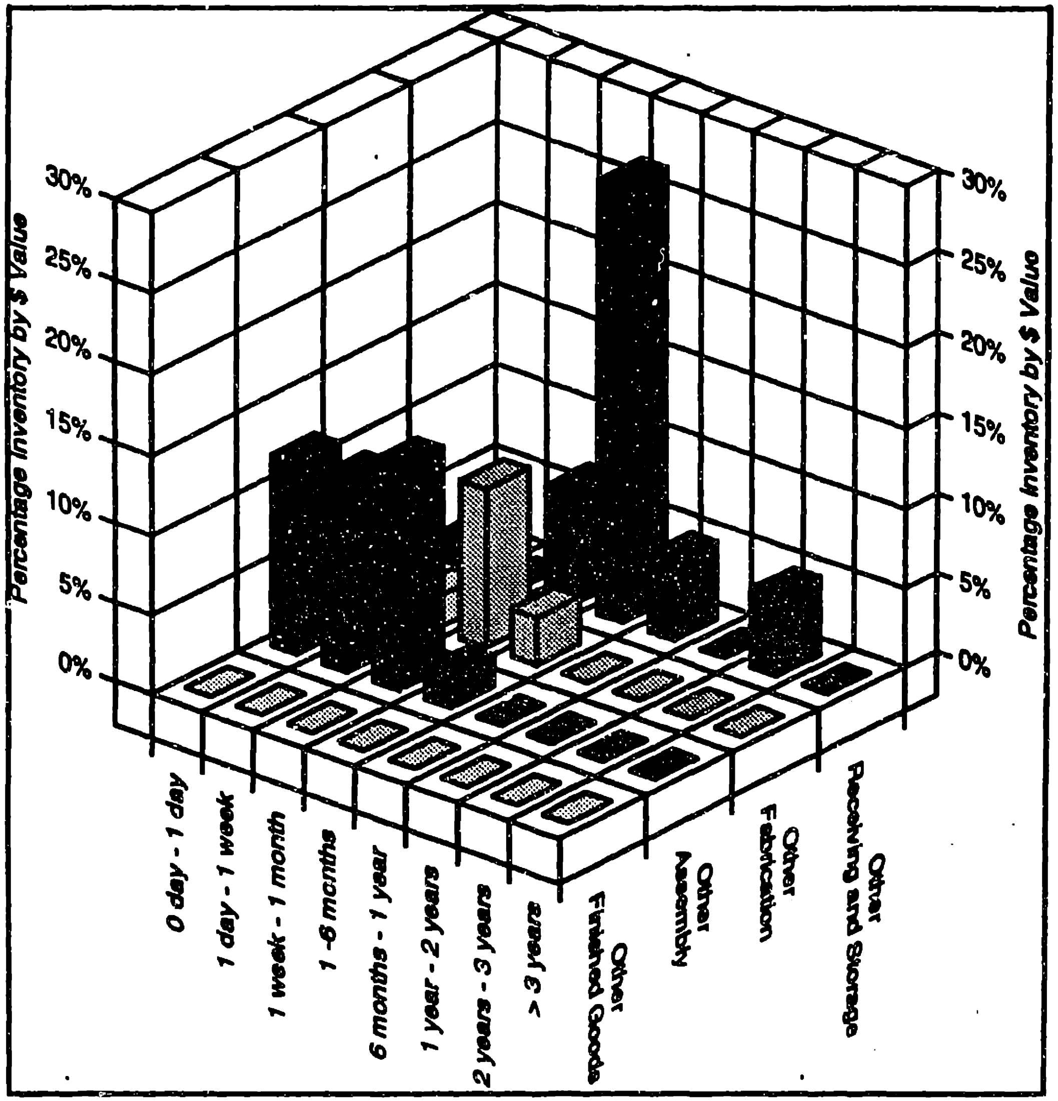


Figure 3.10: Age by Stage for the "Other Sector" (Percent "Other" Responding: 17%)

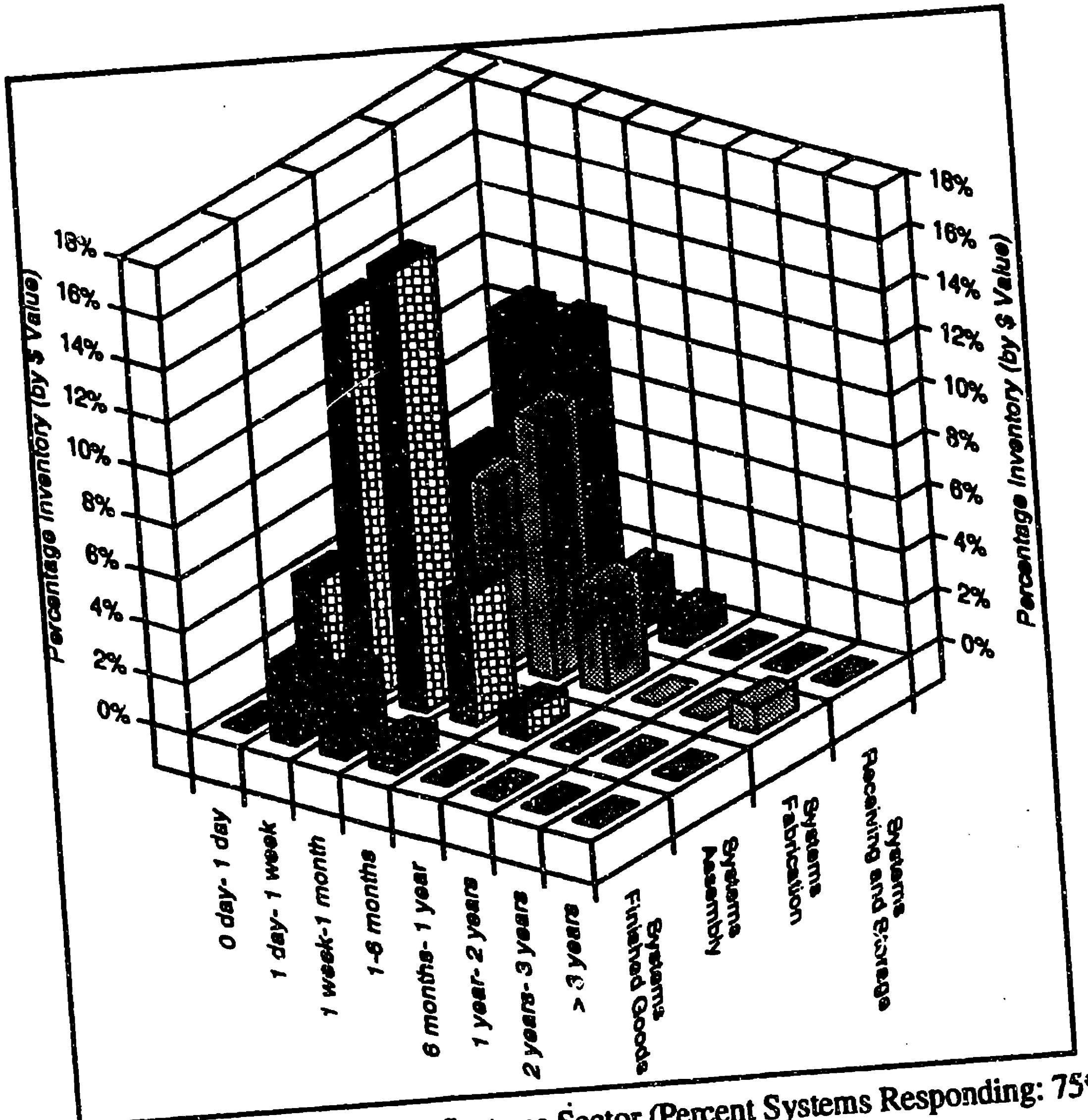


Figure 3.11: Age by Stage for Systems Sector (Percent Systems Responding: 75%)

a much clearer picture of which items or products are profitable or not and to what extent -- a "leaner" way of looking at accounting. Simply knowing where your true costs are is certainly a step toward "leanness." ABC is increasingly being adopted by commercial industry, but its use for a number of reasons is still limited in the aerospace industry as indicated in Table 3.5:

Table 3.5: Percentage of Responses Where Companies are Using Activity Based Costing

Airframers	30%
Electronics	23%
Systems	0%
Engines	0%
Others	33%
All Sectors	**22%**

There is not a great deal of incentive for companies to transition from the traditional way of accounting for costs to this arguably more accurate method. Government representatives have access to much of the data which companies generate on their operations. Industry worries that should government discover an area where profits are high in a particular operation, there would be an attempt to limit profits in this area. On the other hand, industry is concerned that should government discover an area where profits are low or even non-existent that there would be no similar attempt to adjust for this loss. Clearly, the incentive system is not conducive to change. This entire topic is too broad and its impact has too great a consequence to industry and government to be adequately covered here. Activity Based Costing in the aerospace industry should be an area for further research under the Lean Aircraft Initiative.

One final area of interest on which data were collected in the "Accounting Practices" section compared accounting methods for tracking inventory with the actual method of picking inventory being used within companies (LIFO, FIFO, random, moving average, other). Figure 3.12 displays these results. It is interesting to note that the results between picking and accounting methods do not match up well -- in short, the way in which an activity is being accounted for does not align with the way in which that activity is actually being done.

3.2.4 Inventory Handling and Facility Management

The "Inventory Handling and Facility Management" section covered questions which related to the physical handling and storage of inventory as well as to details on the actual management of the plant.

As an example, the section asked responding companies to identify where their preferred storage locations were. Figure 3.13 shows a graphical representation of responses. Again, the answers were sector dependent. As an example, "Electronics" and "Systems" companies tended to prefer on-site central storage sites, while "Airframers" tended to distribute inventory in a variety of locations. For the most part these preferences seem to correspond with the nature of the project -- a large product with a number of manufacturing steps (such as an airplane or engine) is going to be being stored at the workstation itself. As evidenced by the Toyota Production System, a manufacturing system with little inventory as a whole, stored primarily at the stations themselves (in view of the production line), is an optimal arrangement for becoming a leaner process and system as a whole. It would seem with this tenet in mind that the airframe and aerospace industry could do more to reduce inventory in certain phases such as receiving and storage and could also work to move the existing inventory to locations which are more conducive to ultimately eliminating that inventory to the greatest extent possible.

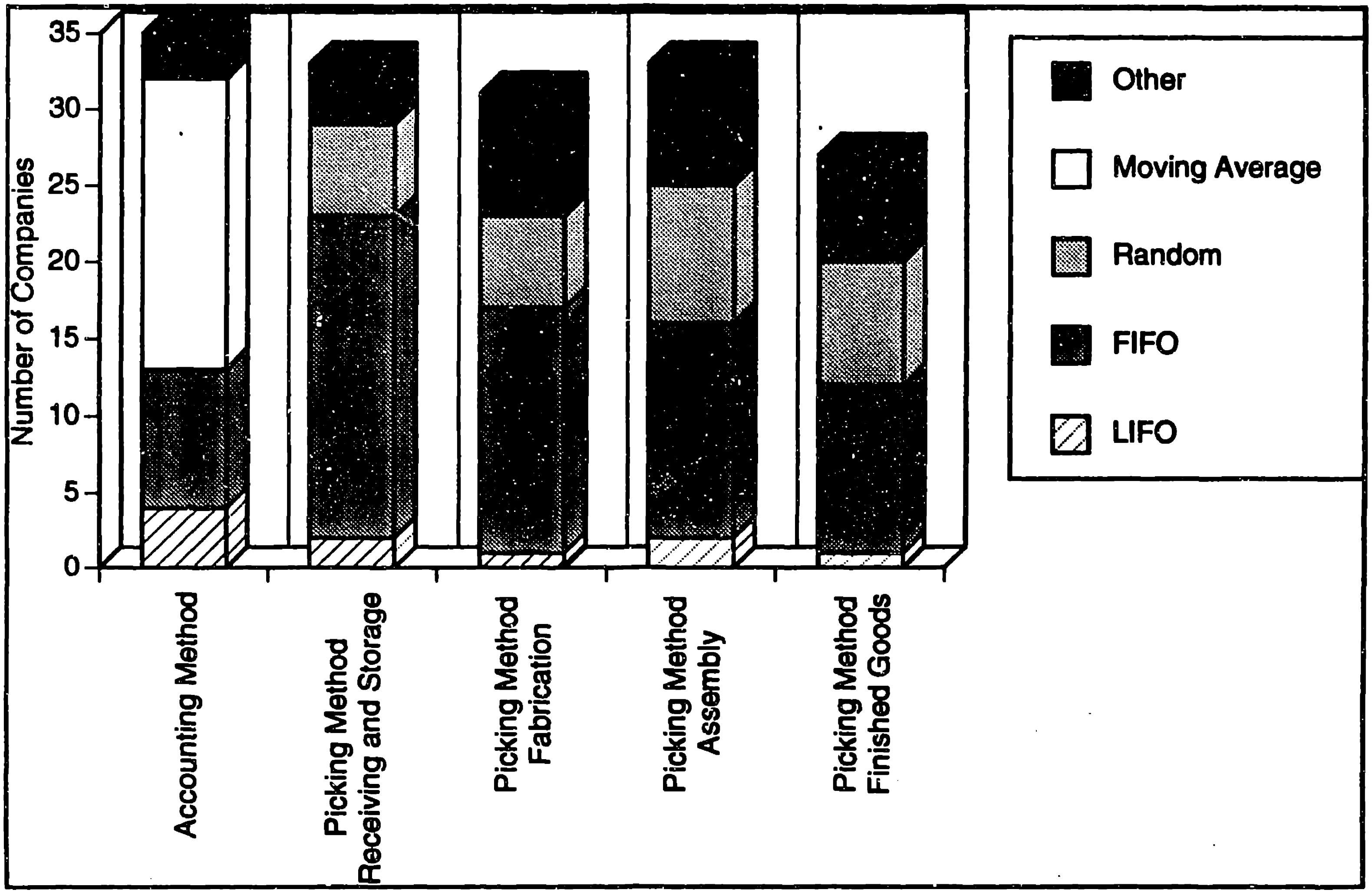


Figure 3.12: Inventory Tracking Practices, Actual vs. Accounting

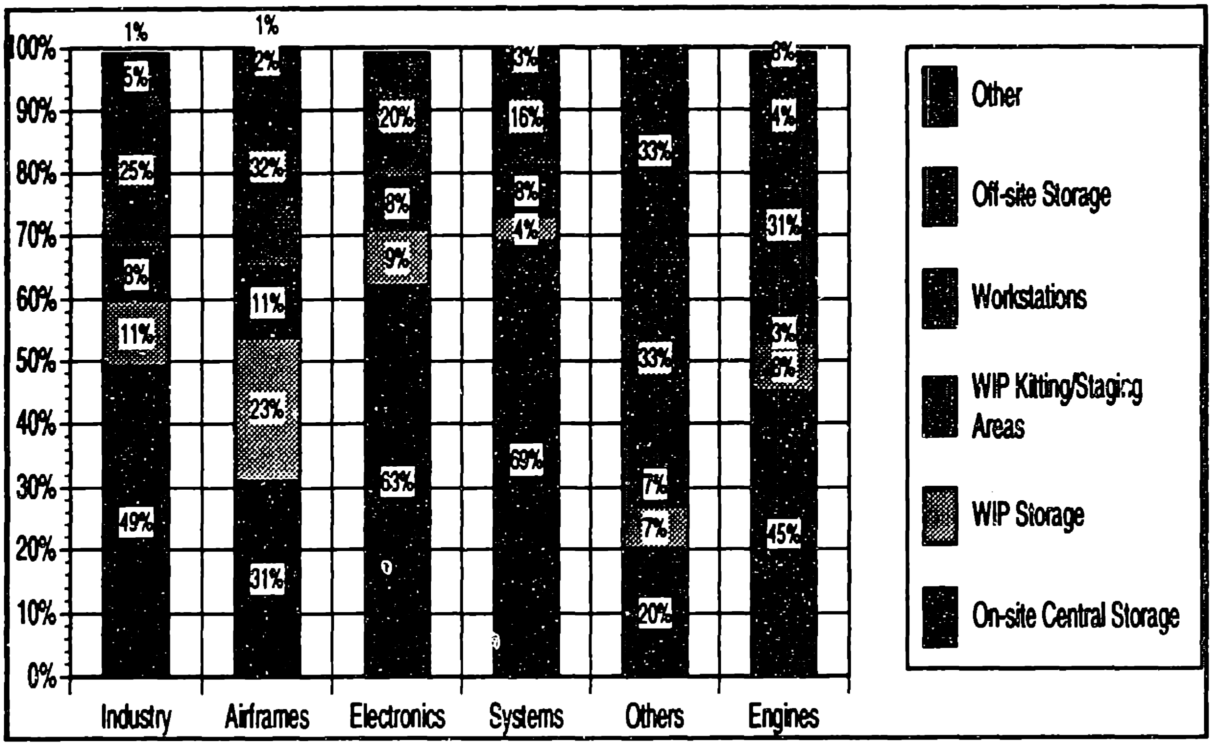


Figure 3.13: Preferred Inventory Storage Locations

3.2.5 Planning and Simulation

The "Planning and Simulation" section was designed to gauge the extent to which companies had utilized and implemented common production techniques and accepted simulation tools into their everyday operations. Companies were asked whether or not they employed job-scheduling to minimize or reduce inventory build-ups or shortages. Although use of job-scheduling is the norm, it is surprising that fully 18 percent of the industry does not utilize this planning practice at all (as is shown in Table 3.6):

Table 3.6: Percentage of Responses Where Companies are Using Job-Scheduling to Minimize Inventory Build-Ups or Shortages

Airframers	80%
Electronics	92%
Systems	100%
Engines	100%
Others	50%
All Sectors	**82%**

Respondents were also asked whether they have a master production control schedule, and if so, if that schedule is automated. Here, most companies do have production control schedules (approximately 90 percent), but of those companies, only around one third of them are fully automated.

In the area of simulation, companies were asked to identify the simulation tools (such as PERT, CPM, and MRP II) they use in their operations. The results are displayed in graphical form as Figure 3.14. Use of any kind of tool appears to be sector dependent, with some sectors more advanced than others in the use of tools such as MRP II (see "Others" specifically). Again, this conclusion comes with the caveat that the sample size for the "Other" sector is smaller than that for sectors such as "Electronics" and "Airframes." Industry-wide, use of any of the simulation tools runs at about 60 percent, with MRP II being the most commonly employed. Use of an automated process flow scheduling and planning system, as well as the use of simulation to model and plan process flow are considered to be essential elements in a company's progress towards more "lean" manufacturing.

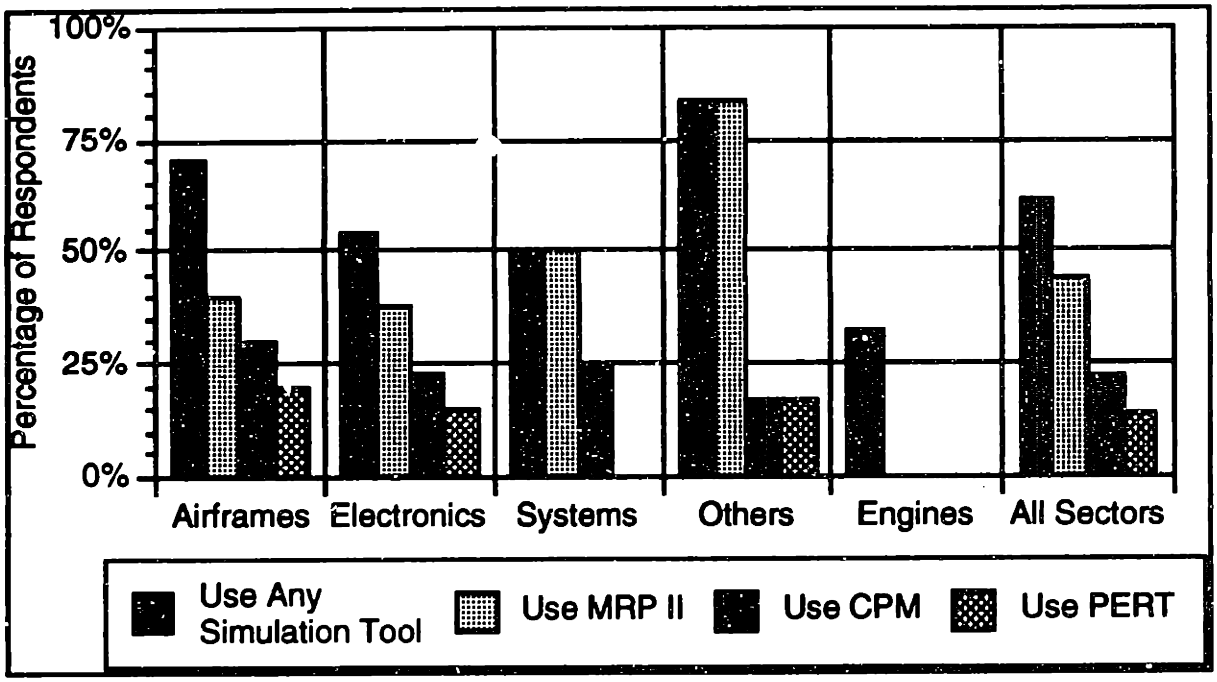


Figure 3.14: Use of Simulation Tools

3.2.6 Inspection and Defects

A great many questions concerning inspection, process control and overall procedures for handling of defective work were contained in the "Inspection and Defects" section. Some of the results from this section are in the paragraphs which follow.

Respondents identified where inspection is performed in the four various stages of production. This inspection is historically performed by any of a number of groups of people: corporate quality control representatives, line workers or "touch laborers", or government inspectors.

As Figure 3.15 shows, the bulk of inspection seems to be done by the quality control organization of a company, almost regardless of sector affiliation. The "Systems" sector seems to be the slight exception to this rule, for with these four companies there appears to be little in the way of inspection by quality control personnel in the stages of fabrication and assembly in particular. Other sectors report an extremely high percentage of inspection being done by quality control; numbers as high as 80-90 percent within a stage are not uncommon.

Companies were also asked to identify the percentage of inspection which was conducted by touch labor. The results are presented as Figure 3.16 and show that the percentage of inspection performed by touch labor is sector-dependent. While the "Engines" and "Systems" sectors show a high percentage of touch labor involvement in inspection (as high as 66 percent), other sectors such as the "Airframe" group show nominal inspection (only 14 percent at the most) being done by those who actually execute value-added, hands-on work on the product. Lean manufacturing tenets hold that manufacturing touch labor should do their own inspection, in place of formal inspections by "quality control" affiliated personnel.

Sponsoring companies were also asked in this section to describe how government inspection was distributed over the four production stages. These results by sector and for the whole industry are shown as Figure 3.17. It seems that, with the exception of the "Airframe" sector, by far the largest share of government inspections are in the finished goods area. The "Airframe" sector reports that the majority of the government inspection effort is in the assembly phase of production. The government is moving to remove the redundancy inherent in its system of inspection and is working towards the inspection of processes rather than products. Results from the survey show that industry is making this move towards process verification as well, and the data show that the source of this initiative is predominantly top management (see Figure 3.18)-- perhaps a sign that government and industry are in fact cooperating to improve the quality assurance process.

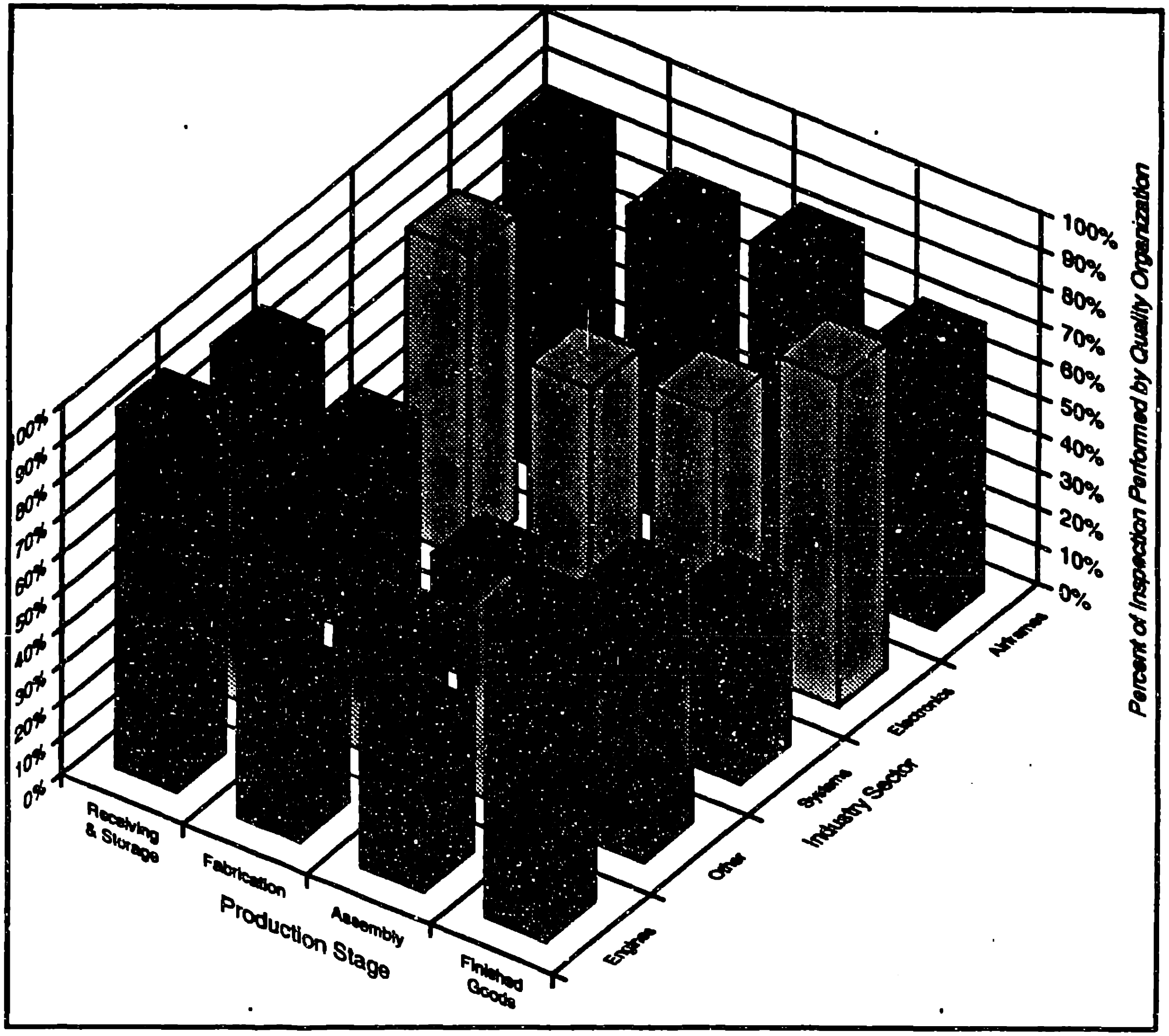


Figure 3.15: Inspection by Quality Control Organization

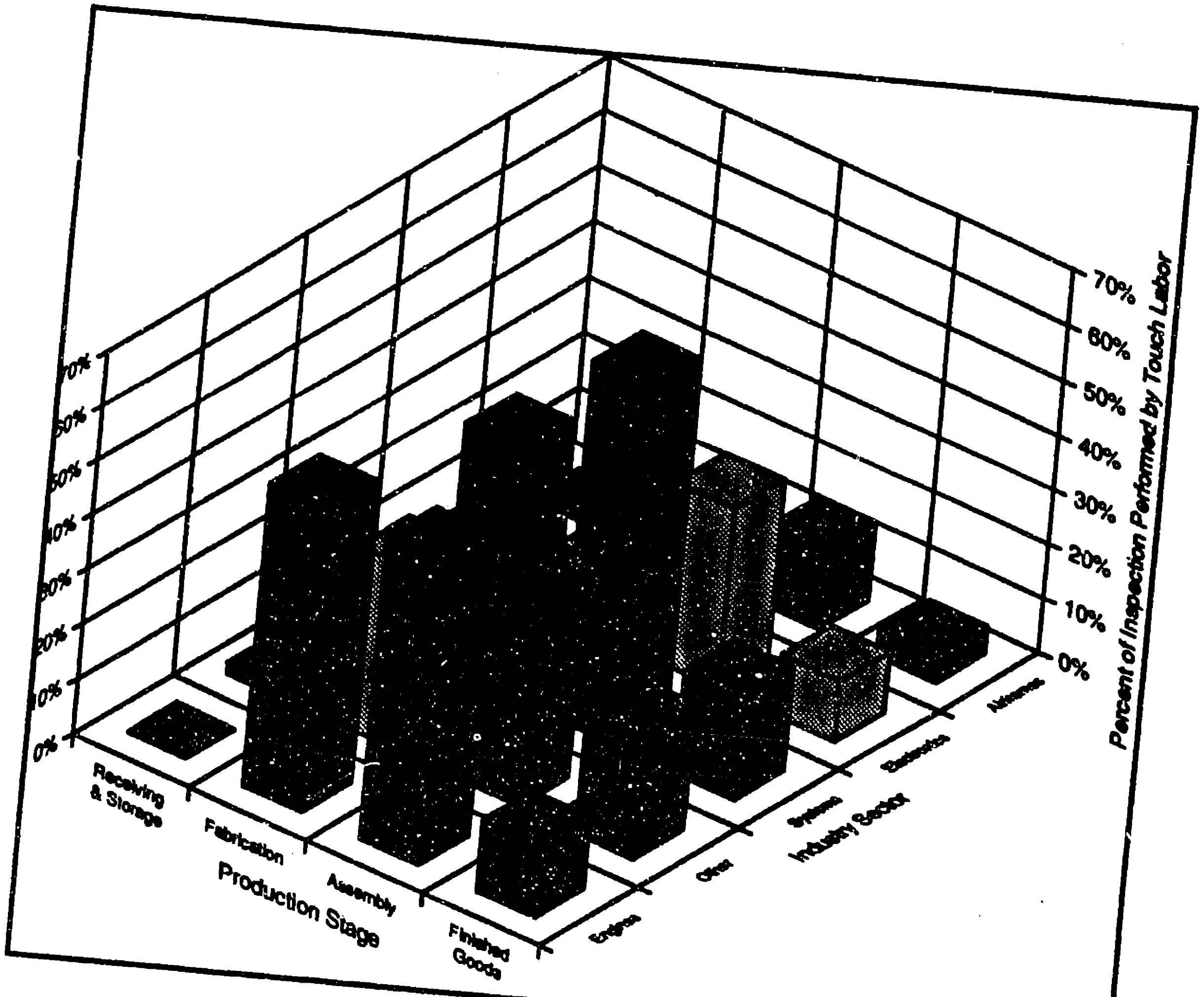


Figure 3.16: Inspection by Touch Labor

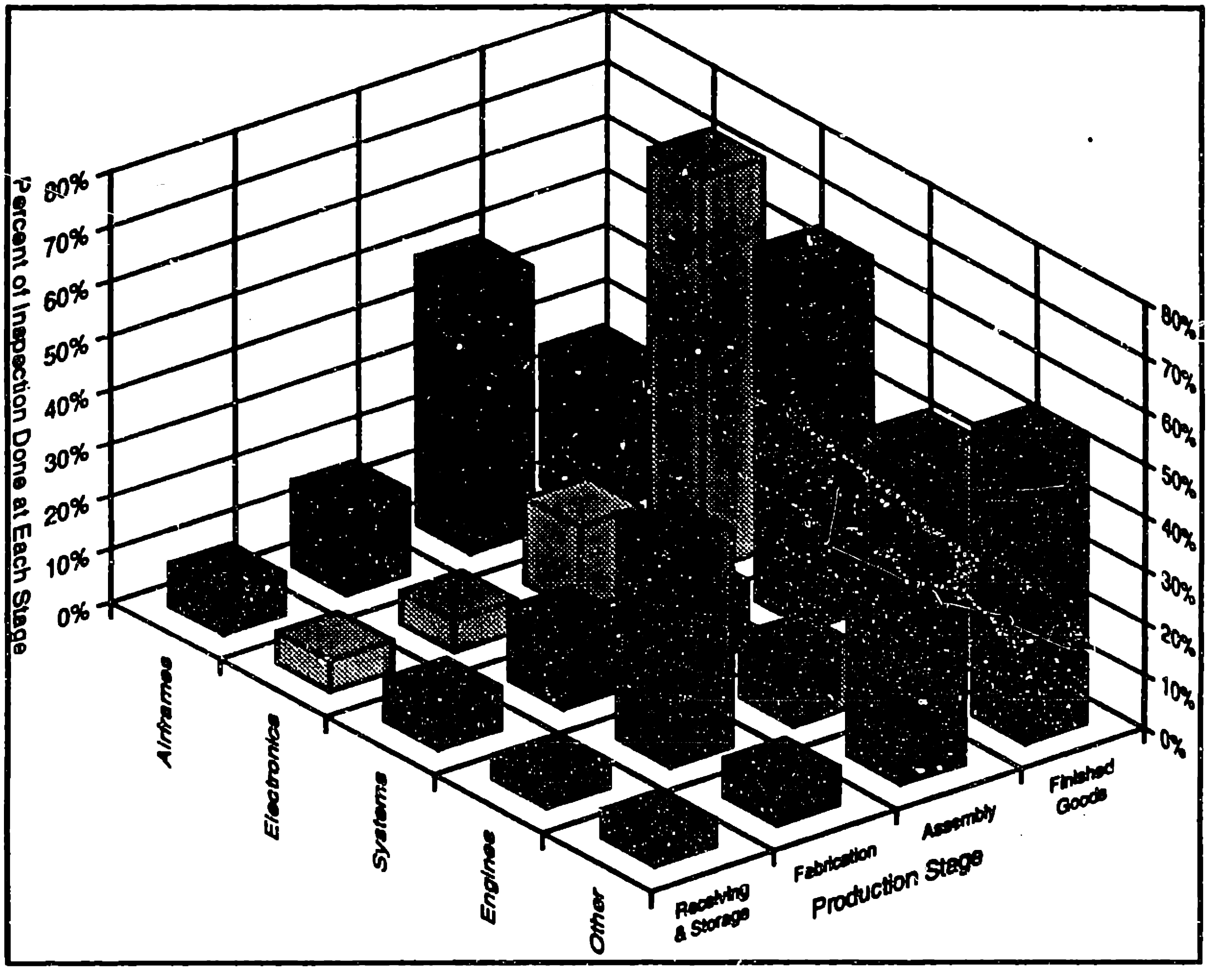


Figure 3.17: Emphasis on Government Inspection

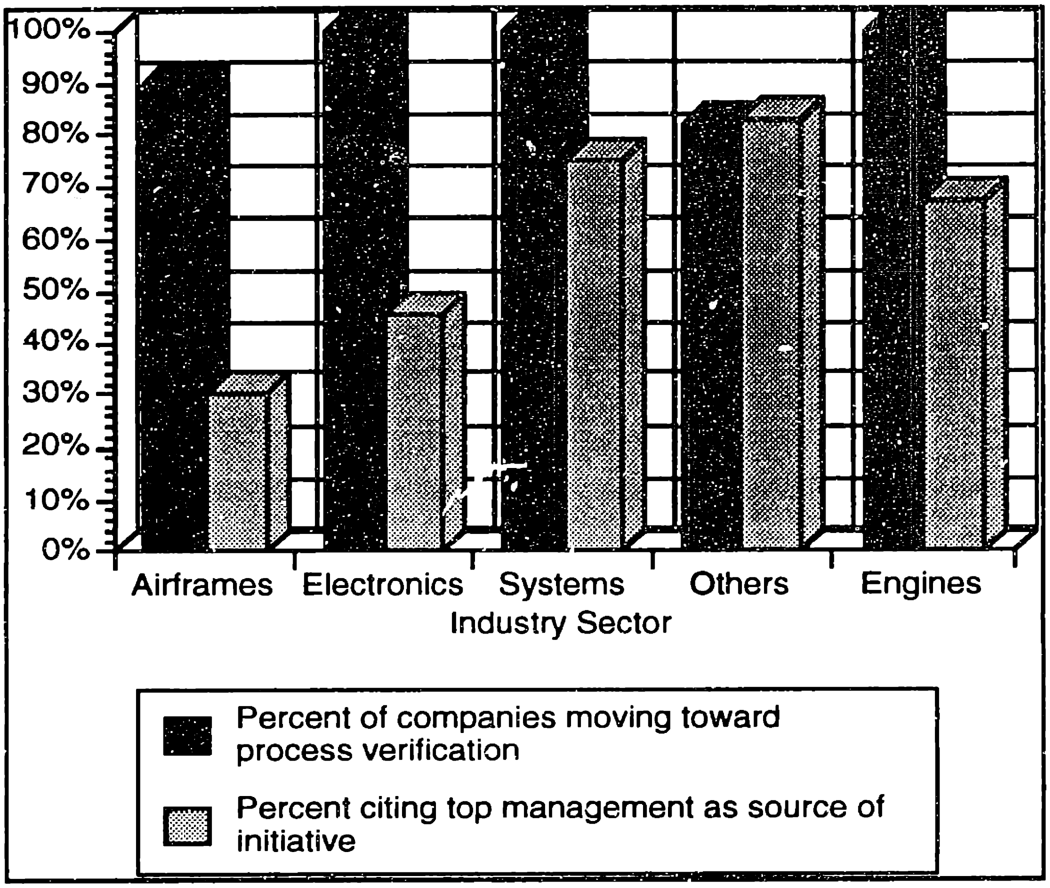


Figure 3.18: Move Towards Process Verification

The "Inspection and Defects" section of the survey also queried participants on the length of repair/scrap/use disposition cycles -- the length of time it takes a company to deal with the disposition of defective parts or products. Results were consolidated over all stages of production for each of the industry sectors, and these results (found in Figure 3.19) show that the "Airframe," "Systems," and "Engines" sectors take approximately five days to determine the disposition of a repair/scrap/use issue. On the other hand, the "Electronics" sector takes an average of 9 days, and the "Others" sector an average of 16 days to make a similar judgment or determination. Lean tenets hold that there should be a rapid decision cycle in place to determine the disposition of faulty parts.

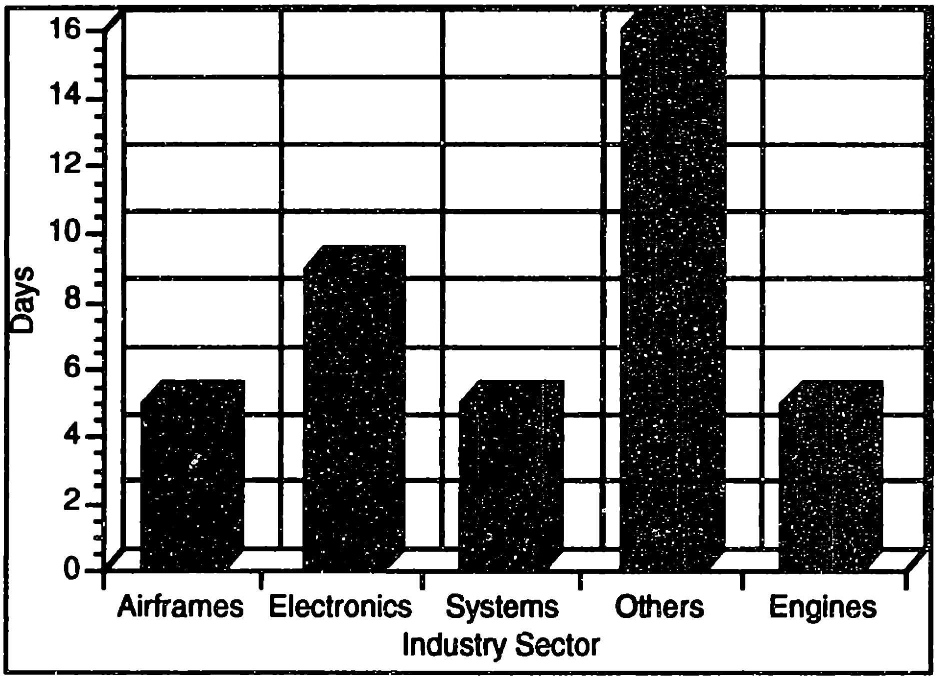


Figure 3.19: Repair/Scrap/Use Disposition Cycles

This section of the survey also included questions about the use of Statistical Process Control (SPC) in production, a practice which is increasingly becoming the norm in commercial manufacturing. As is shown in Figure 3.20, the use of SPC in the aerospace industry is quite limited, with the "Electronics" and "Systems" sectors showing the greatest use of this process control method. When asked why the use of SPC is not more extensive, respondents replied (in order of most frequent explanation to least) that there is a corporate resistance to change, that there are problems implementing this technique with low production volumes, and that there is some government resistance to change.

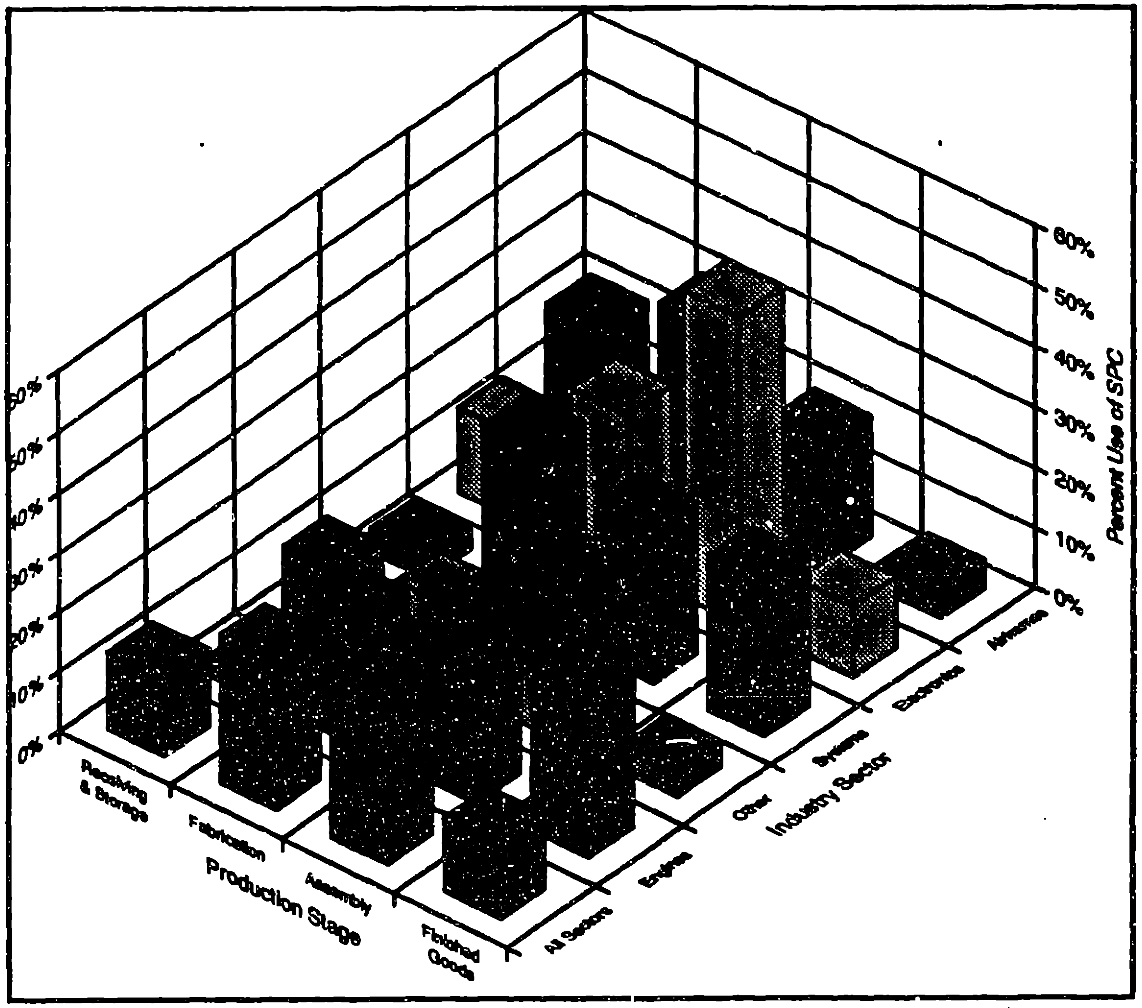


Figure 3.20: Use of Statistical Process Control (SPC)

In a similar vein, respondents were asked about their knowledge of defect rate within their respective production processes. Figure 3.21 shows that companies' knowledge of Defects Per Million (DPM) for *any* stage is extremely limited in most sectors. Even fewer companies (around 10 percent of those surveyed) have this information for *all* stages of production. All responding companies in the "Systems" sector knew DPM for all stages, evidence of their advancement towards more lean production.

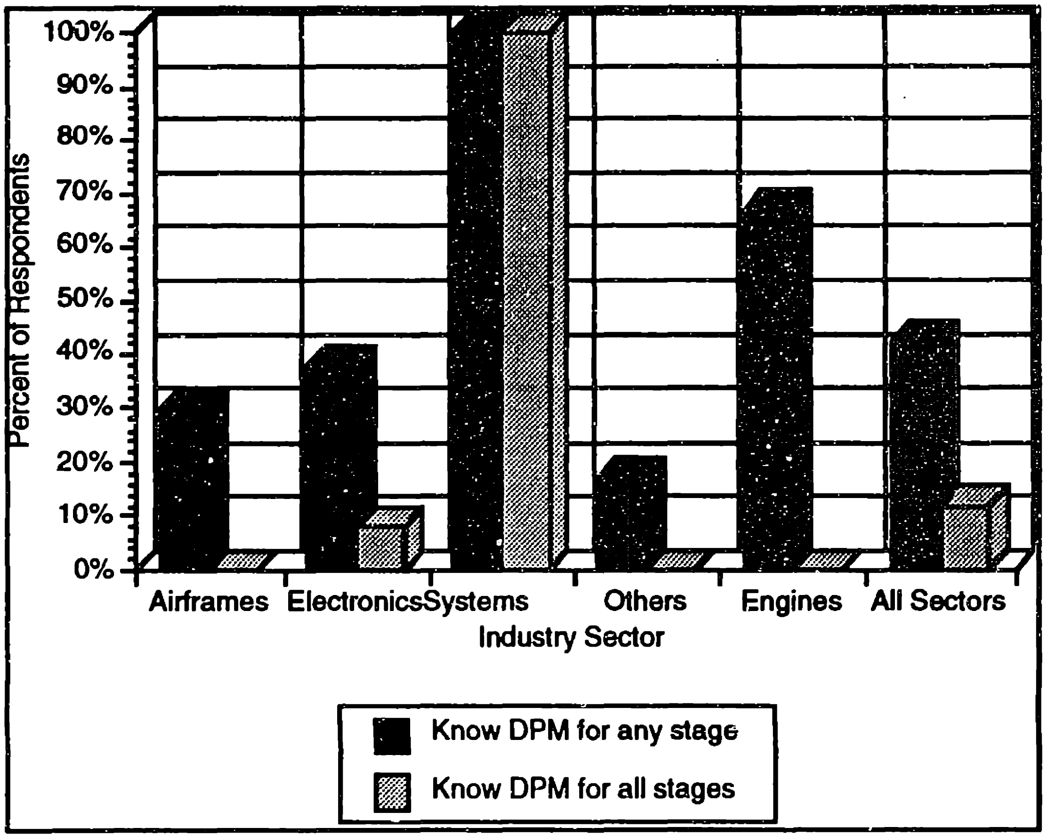


Figure 3.21: Knowledge of Defect Rate

Finally, companies were asked about inspections in the case where tests performed by suppliers are repeated by the receiving company. This practice is most prevalent in the "Electronics" sector with respondents saying this occurred more than 45 percent of the time, and least prevalent with the "Engines" at only slightly less than 5 percent of the time (Figure 3.22).

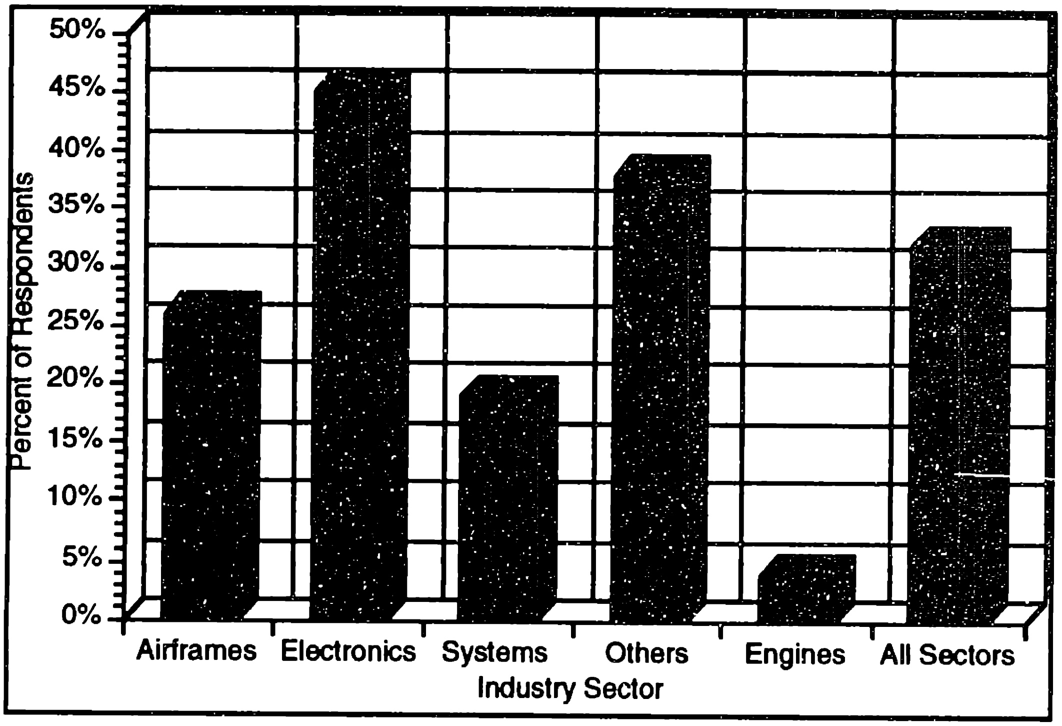


Figure 3.22: Repeat Inspections or Tests

This information matches somewhat with data concerning the use of certified suppliers. As shown in Figure 3.23, an average of 50 percent of the suppliers to engine manufacturers are certified for "dock-to-stock or assembly," with 70+ percent of the value of total receipts for this sector being accounted for by these suppliers. "Lean" manufacturing depends on a close, lasting, and symbiotic relationship between suppliers and manufacturers; a relationship which would be exemplified and encouraged by such a "certified" supplier arrangement and minimum re-inspection performed by the receiving party.

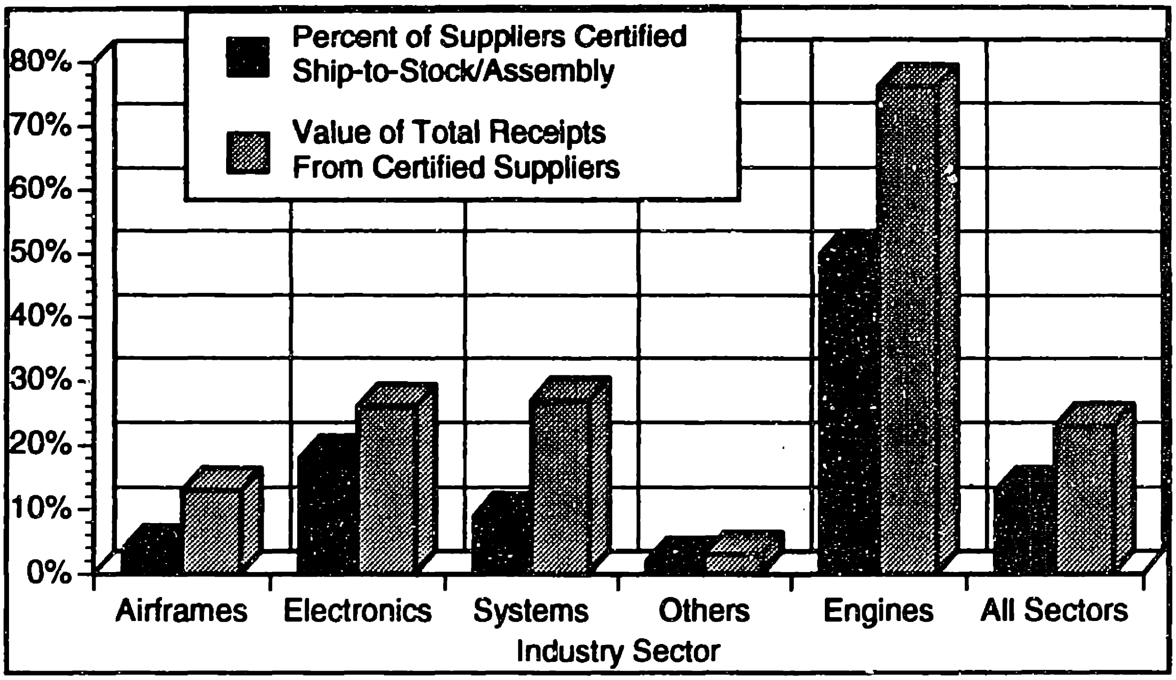


Figure 3.23: Use of Certified Suppliers

3.2.7 Government Relations

There were five questions in the Government Relations section of the survey. Some questions were attitudinal to measure reactions to various government or company standards and practices. Those surveyed were provided with a list of such standards or practices which included:[3]

- Multi-year contracts with funding
- Fixed-type contracts with progress payments
- Fiscal-year buy quantities
- Cost-type contract with public vouchers
- Government interpretation of contract
- Contractor interpretation of contract

[3] All of the standards and practices referred to here with acronyms are defined in the list of acronyms found at the beginning of this thesis.

- MIL-STD-1567A
- C/SCSC
- DCAA audits
- Variability Reduction Guidance
- Government approval of suppliers
- Government socio-economic procurement practices
- MIL-STD-1520
- MIL-Q-9858A
- MMAS
- Government cost accounting standards
- MIL-STD-1535
- Government Property Clause
- Government initiated Engineering Change Orders

They were then asked how much these government standards and practices influenced inventory levels on government contracts on a seven point scale ranging from "tends to drive inventory levels up a lot" to "tends to drive inventory levels down a lot." The industry results can be found in Figure 3.24. Although certainly some items from the list were industry "favorites" (or not-so favorites), there also were varied responses and reactions depending upon the sector questioned. Survey respondents were also asked to evaluate how useful a subset of the selection of the above list was to their company's operations again on a seven point scale (this time from "high positive utility" to "low positive utility") (Figure 3.25). Again, there were standards and practices which were deemed unanimously to be of high or low utility, while still other selections saw varied response of varying strength. Finally, companies were asked to determine on a seven point scale the degree of financial and human resource burden required in support of the activity (See Figure 3.26). This series of three questions was designed to identify which standards, practices, etc., were barriers to the reduction of inventory, required extreme financial resources, were of high utility, or all three.[4] Overarching conclusions would

[4] Data from each of these three questions were normalized to account for the respondents' tendencies to answer all questions to one end of the scale or another. The graphs presented as figures 3.24-3.26 show average normalized responses to each standard or practice *with relation to* the other standards or practices within that same question.

include that multi-year contracts with funding are industry-wide considered to be "positive" (reducing inventory, low burden and high utility), while items such as MIL-STD-1535, MIL-STD-1520, MIL-Q-9858A, MIL-STD-1567A, and government socio-economic procurement practices are considered to be less favorable to optimal operations flow and inventory reduction. In follow-on questioning, Electronics and Airframe sectors were asked specifically why standards such as 1520, 1535, and 1567A drove up inventory. Some who answered explained that the impact was really in terms of additional overhead incurred and direct labor cost increases. Others, however, responded that non-compliant deliveries from suppliers could require expedited deliveries to compensate for lack of quality and maintain schedules. A perhaps more compelling conclusion from these questions is that further research is needed as to why certain standards or practices received favorable or unfavorable responses and the true magnitude of problem.

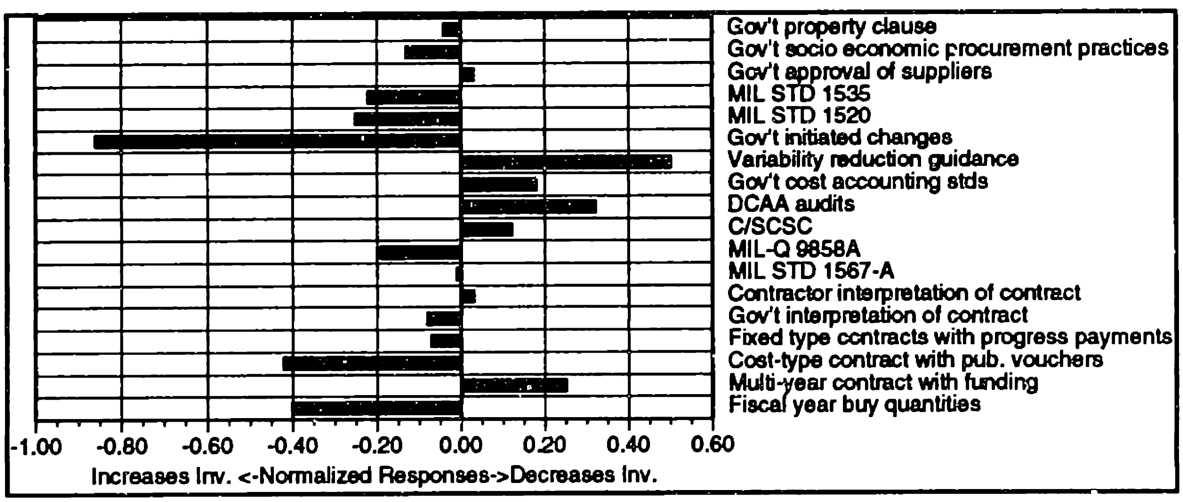


Figure 3.24: Government Influence on Inventory Levels

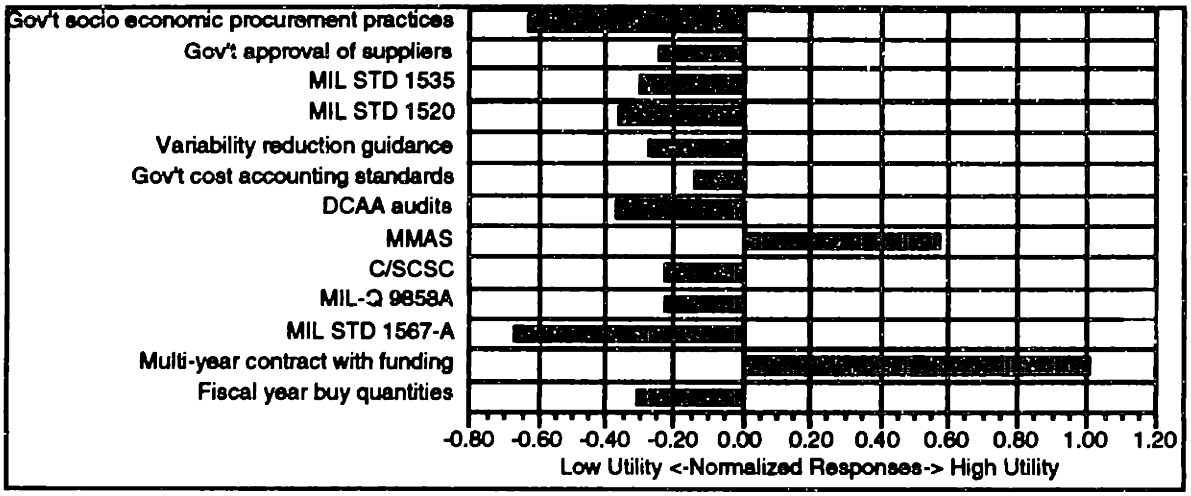


Figure 3.25: Utility of Government Standards and Practices

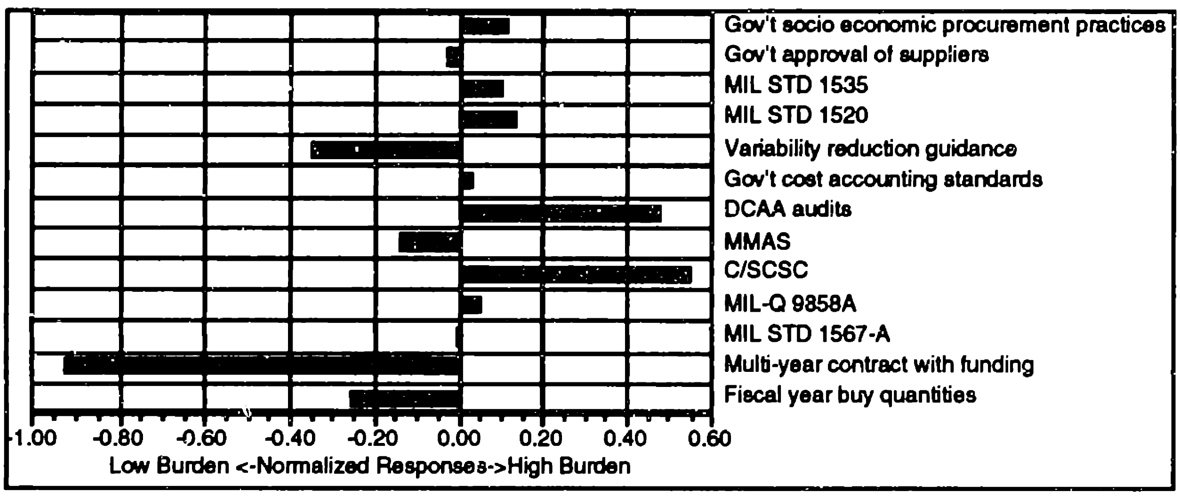


Figure 3.26: Support and Resource Requirements for Government Standards and Practices

Two final questions in the Government Relations section asked about the differences in purchasing or acquisition between government and civilian contracts for various categories of inventory. Figures 3.27A-B show the results just for the "Airframe" sector, but the results for the other sectors and for the industry as a whole were similar. In general, it would appear that ordering practices for commercial and government contracts are not radically different. Within sectors there are "best" practices, or those who are ordering with much less buffer time than others. Some sectors such as the "Electronics" sector as a whole seem to build in longer buffers (ordering more in advance of actual requirements) than others such as "Systems" and "Electronics" do. In this case, lean practice would be to purchase as close to need date as possible. Lead times for the industry are fairly short, but there is room for improvement as shown by the "best" practice participants.[5]

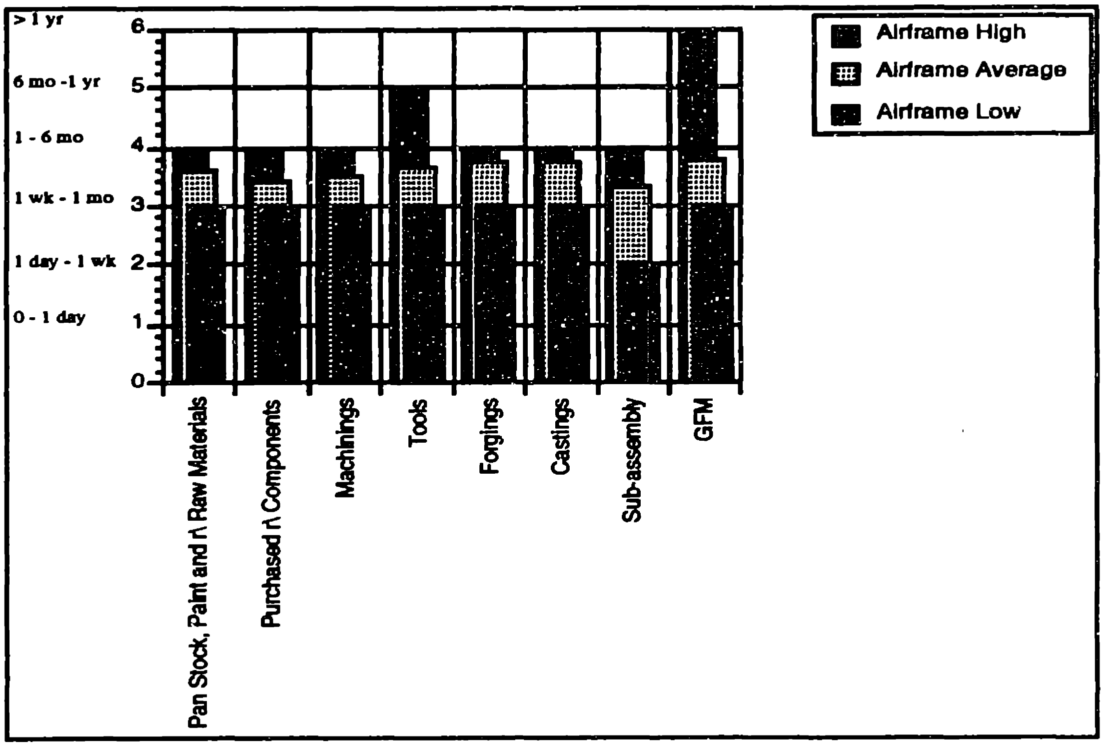


Figure 3.27A: Receipt of Inventory for Government Contracts (Airframe)

[5] Airframe sector participants suggested that they would have preferred even more gradation within the 1-6 month category for more distinction between best and worst practices. These data are being collected and will be analyzed at a later date.

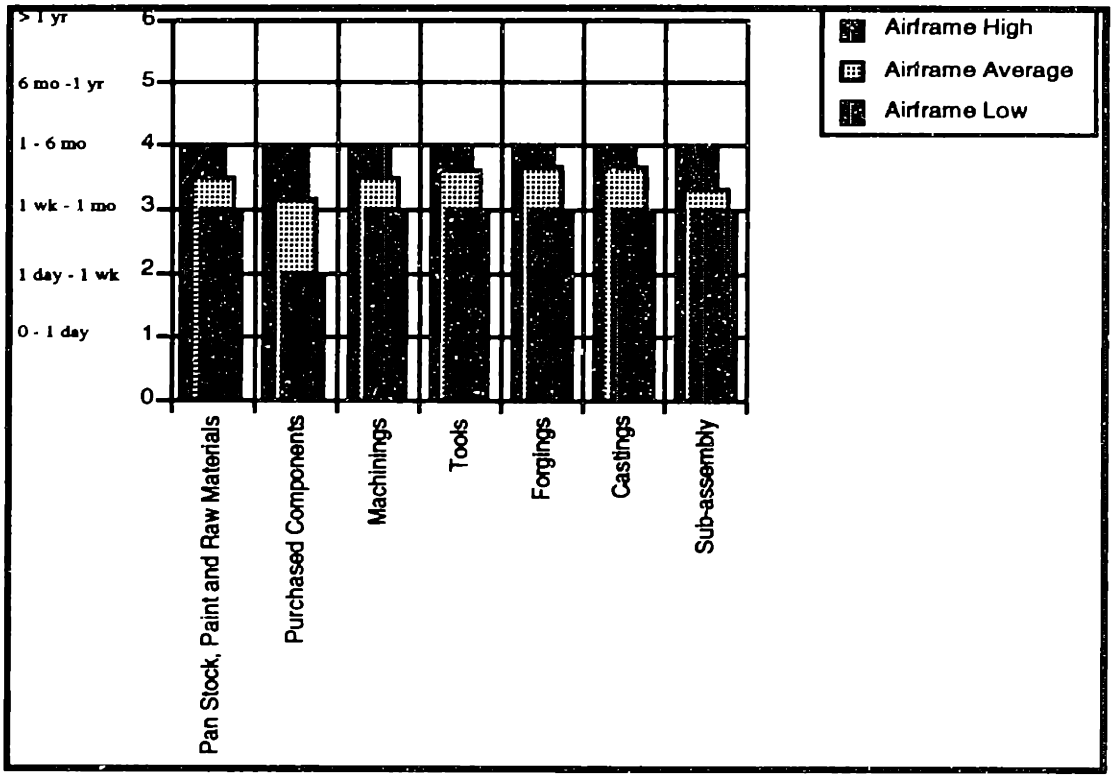


Figure 3.27B: Receipt of Inventory for Non-Government Contracts (Airframe)

3.3 Final Comments/Conclusions

The final section of the survey gave respondents the opportunity to provide more extensive comments in the form of "essay answers" for previous questions in the survey. It also provided them the opportunity to comment on inventory as a measure of the company's health.

Companies were asked whether low levels of inventory were a measure of a company's overall good health. Figure 3.29 shows the results in a pie graph. Industry-wide, fully 94 percent of respondents indicated that low inventory levels were a moderate or strong indicator of the company's good health. Companies were also asked if there were any formal programs in existence within their corporations to reduce inventory. Only two companies surveyed did not have any such program in place, an indication that companies do find that reduced levels of inventory are in fact important to company survival and competitiveness. It seems from the results of the survey that inventory is a strong indicator of overall health -- excess inventory can at times cover problems in other aspects of the production process.

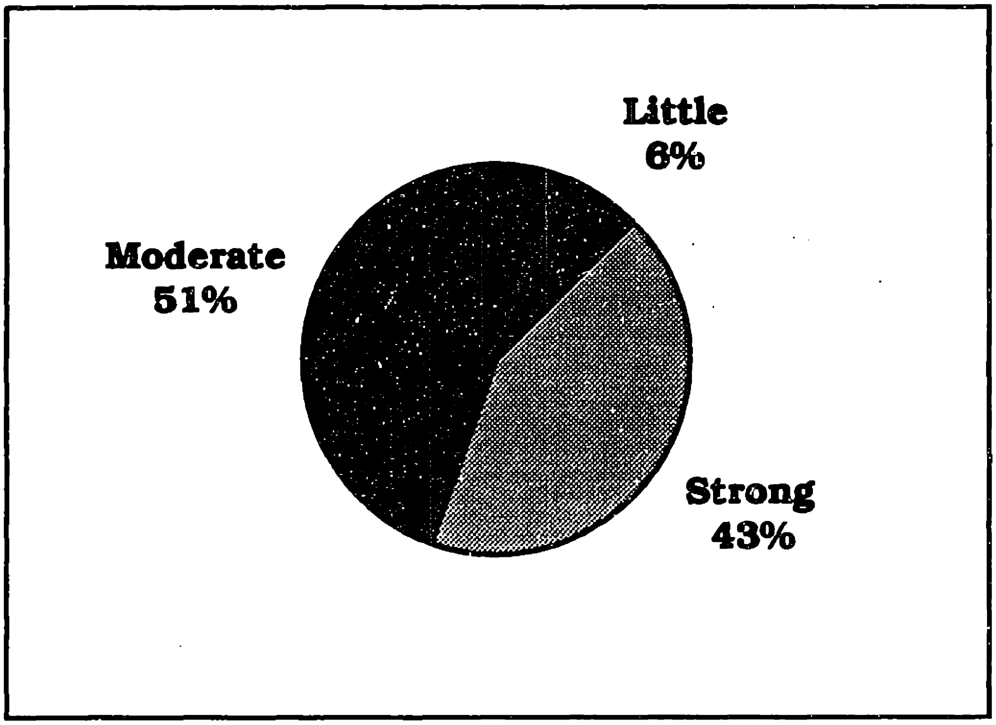


Figure 3.28: Low Levels of Inventory as a Positive Indicator of a Company's Overall Health

Companies were also asked if they could name any company-originated disincentives which would drive inventory levels away from the company goal. Respondents listed corporate emphasis on schedule, problems with the supplier base, desire for quantity discounts, and a focus on bringing in materials early as the top company disincentives which drove inventory levels away from the goal. In a related area, respondents were asked if there were government disincentives which would also tend to keep the company's inventory levels away from the desired goal. Here, the most common responses included progress payments, fiscal year buy quantities, and configuration and engineering changes made by the government after material procurement. Finally, the sponsoring companies were asked to name any accounting-related practices which kept inventory levels away from desired levels. Top responses were the separation of material by contract and the traditional practice of accounting for inventory as an asset. Each of the above issues in and of itself is a worthy topic for further investigation and comes up frequently in interviews with sponsoring companies.

The survey as a whole and this final section in particular show that inventory is an important issue. Companies are looking at the topic of inventory reduction, but progress is slow, as is consensus on what to begin with. The Inventory Practices survey has been useful in revealing the weaknesses and strengths of companies, sectors, and the industry as a whole. It has also been helpful in showing what "lean" practices are or are not. Resulting from the survey, a list of lean tenets has been developed by the research team which outlines the role of inventory in lean practices (Appendix A). The survey accomplished its purpose of giving researchers and sponsors a snapshot of the current state of affairs. From here, best and worst practices can be gleaned, and further areas for research can be identified.

Chapter 4: Front-End Loading of Inventory: Data and Causes

The Inventory Practices survey provided industry, government, and academia with some important insights into the way in which inventory and its related operational practices are being managed both industry-wide and on a sector-by-sector basis. Equally as important, the questionnaire provided ideas for follow-on work -- areas in which the data indicated that there is room for improvement throughout the aerospace industry.

This chapter will further elaborate on data obtained from the Inventory Practices Survey and will specifically concentrate on those data which indicated large amounts of inventory within receiving and storage. Additionally, the chapter will describe some of the causes of excess inventory as evidenced by both the survey results and site-visits.

4.1 Evidence of Front-End Loading

Front-end loading is the over-abundance of inventory in the initial stages of production, most significantly within the receiving and storage portion of the manufacturing process. The Inventory Practices Survey asked a number of questions which were related to this practice of front-end loading. Question C1 in the "Accounting Practices" section of the survey and question B5 from the "Metrics" section were two of these questions. The data from the answers to these two questions were combined to form the inventory profiles which were presented in Chapter 3 as Figures 3.8-3.11. In order for data to be included in these figures, it was necessary for the responding companies to adequately answer *both* questions. Very few companies (30 percent) were able to identify both the age of their inventory within each stage and the percentage (by dollar value) of total inventory contained within each of these stages.

Figures 3.8-3.11 have been reproduced and included again as Figures 4.1-4.4 for convenient reference. Although the data are somewhat limited, they do indicate some interesting trends across the industry as a whole. Not only is inventory apparently located to a great extent within receiving and storage, this inventory also in some cases seems to be older than inventory located within other stages which are downstream of receiving and storage. This would seem to indicate that inventory within this early stage of production is not actively or effectively being used or "pulled" through the system.

Question B12, also from the "Metrics" section of the Inventory Practices Survey, touched on the location of inventory throughout the industry by asking for the exact dollar value of inventory located within each production stage for both government and commercial contracts. Figure 3.5 has also been reproduced as Figure 4.5 for reference purposes and shows the data which were obtained for government contracts. One can see that industry-wide over one third of inventory for government contracts is located in the receiving and storage stage of manufacturing. Although a larger figure of 42 percent of total inventory by dollar value is located in assembly, it can be argued that at this stage of production the product is nearly fully formed and is consequently of a much higher value dollar-wise than at any other point in production. Items within receiving and storage, on the other hand, are for the most part raw material, individual components, and lower dollar value sub-assemblies. More can potentially be done in this stage of production to reduce or eliminate unnecessary parts or inefficient procurement practices. Figure 4.6 shows the data which were collected for *non*-government contracts industry-wide. Interestingly, the non-government contracts data show that there is less inventory in receiving and storage in these types of procurement arrangements. Here, 25 percent of inventory is located in receiving and storage. These data were obtained from companies who had commercial contracts as well as government contracts, and the difference of roughly 10 percent between the two kinds of business

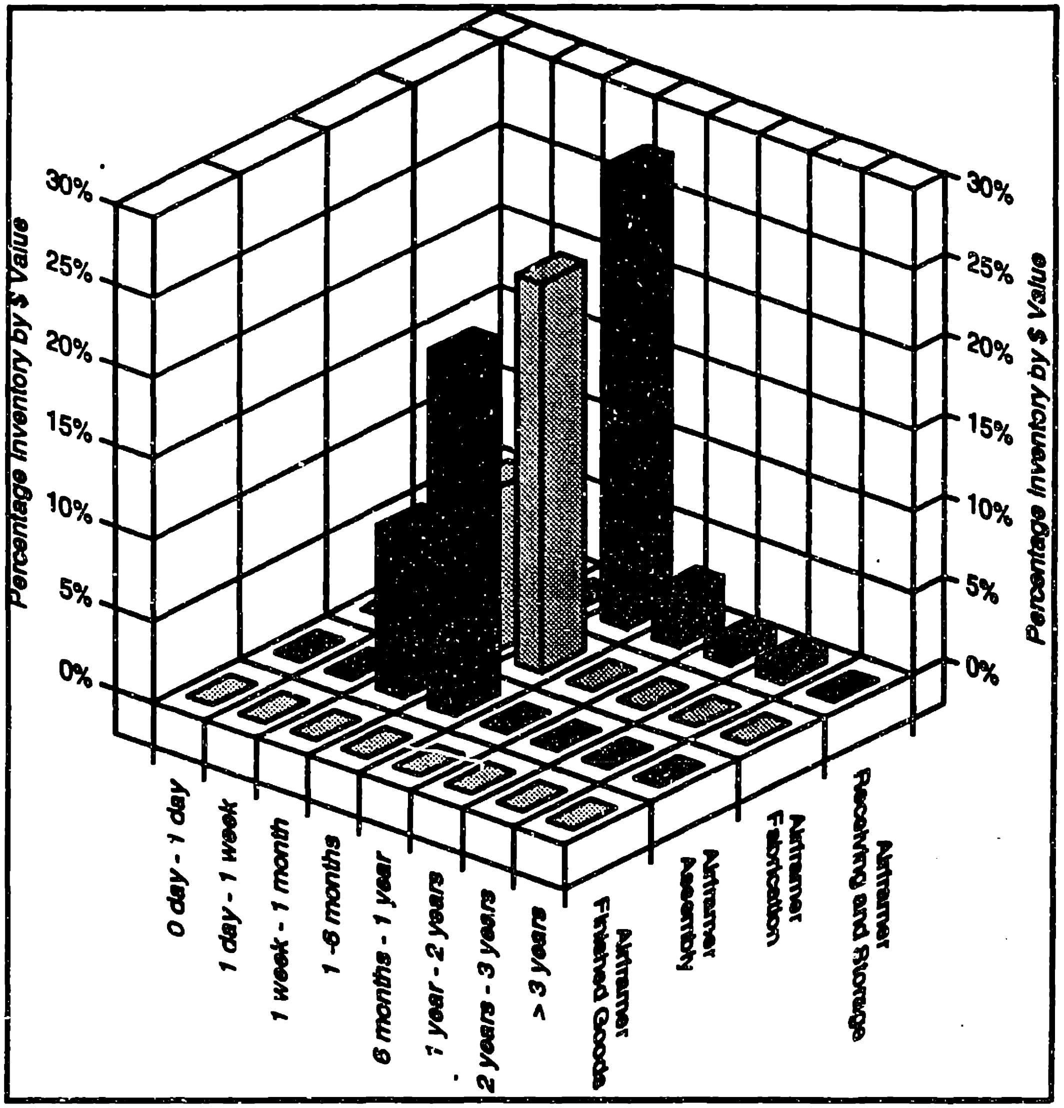


Figure 4.1: Age by Stage for the Airframe Sector (Percent Airframe Responding: 10%)

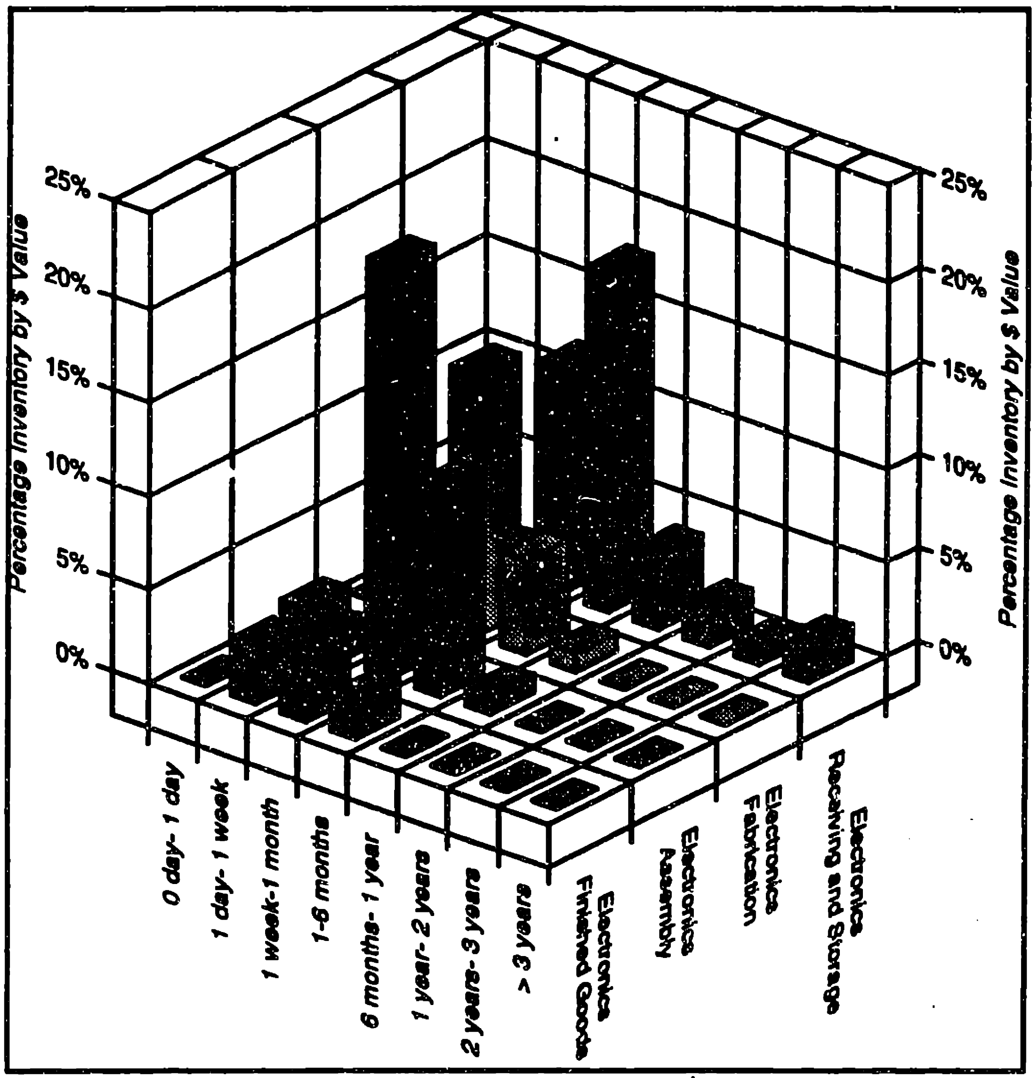


Figure 4.2: Age by Stage for the Electronics Sector (Percent Electronics Responding: 46%)

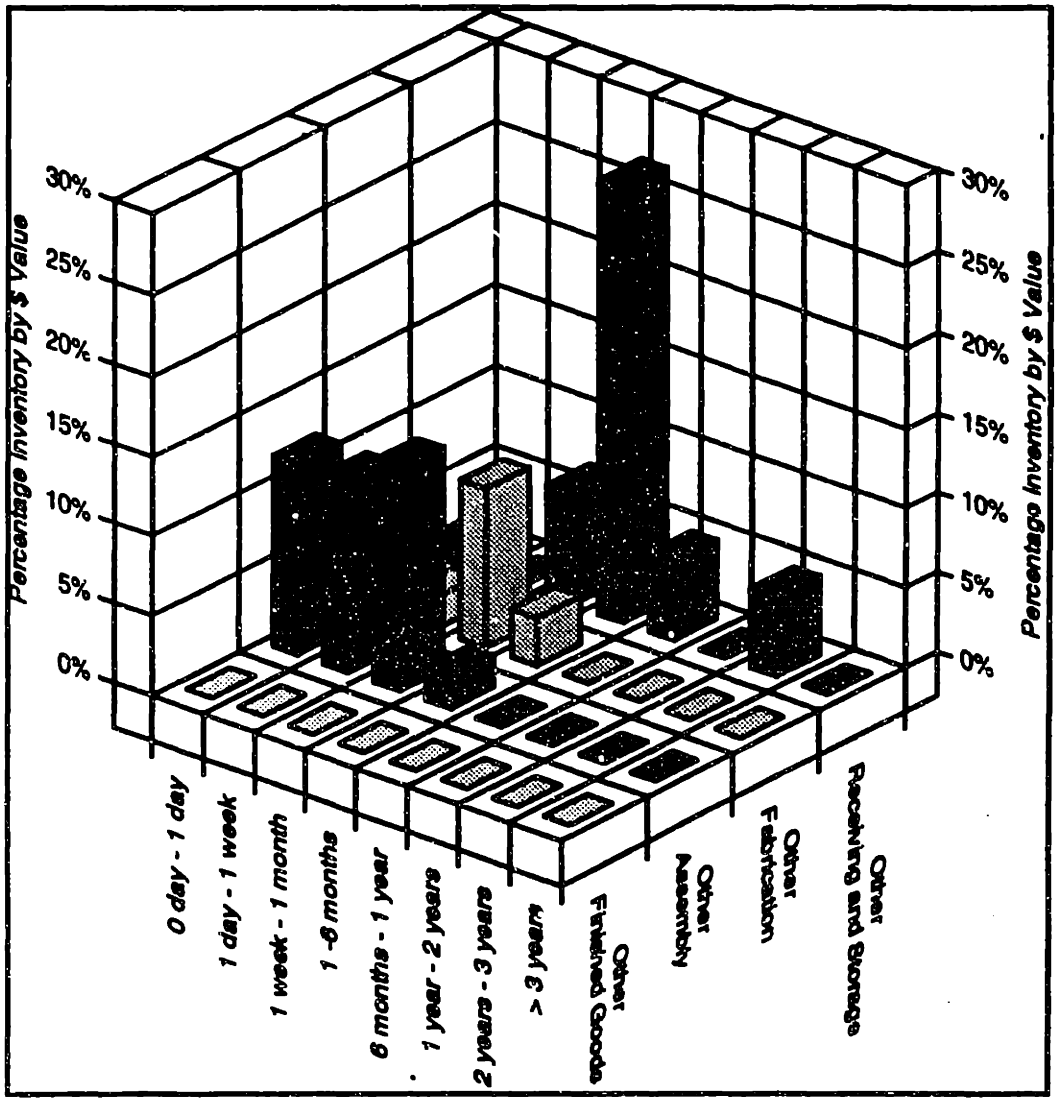


Figure 4.3: Age by Stage for the "Other Sector" (Percent "Other" Responding: 17%)

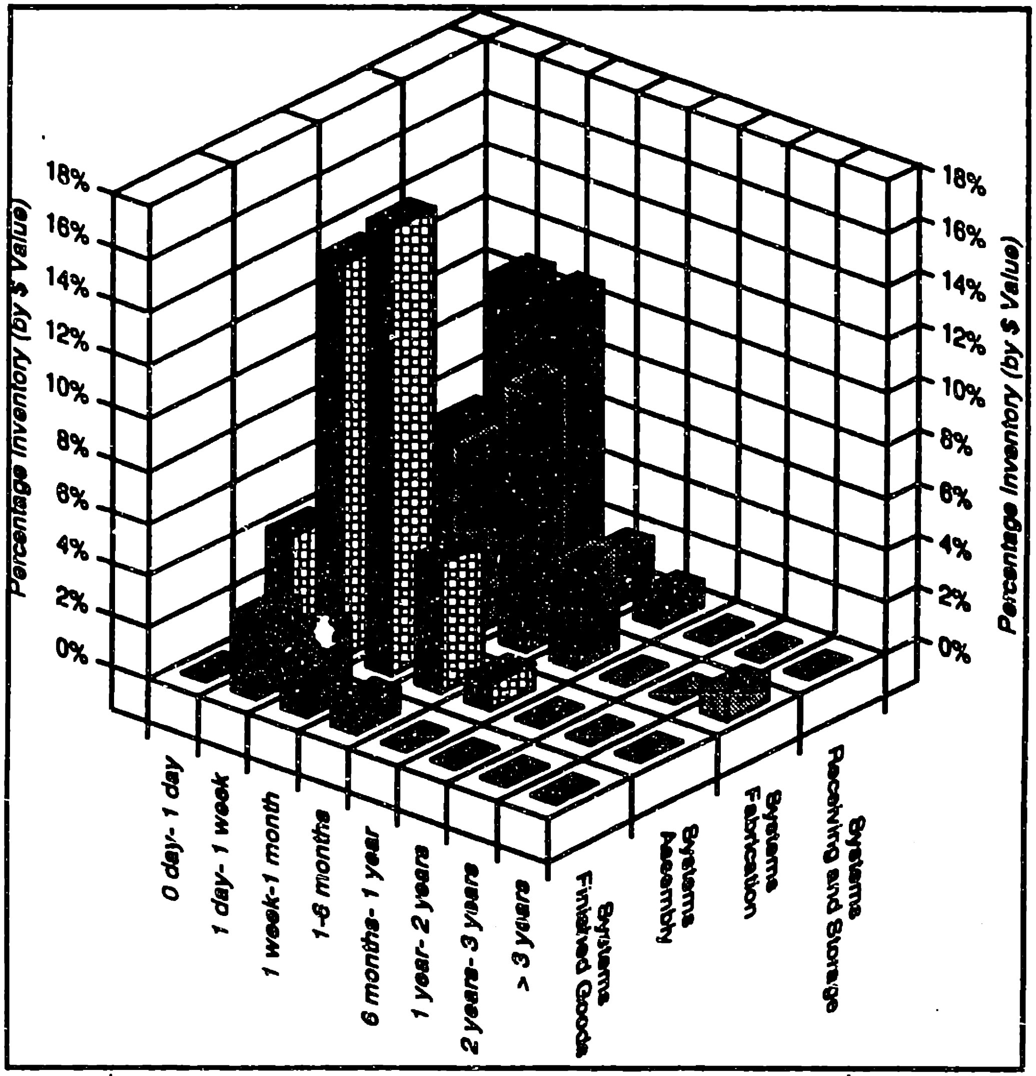


Figure 4.4: Age by Stage for Systems Sector (Percent Systems Responding: 75%)

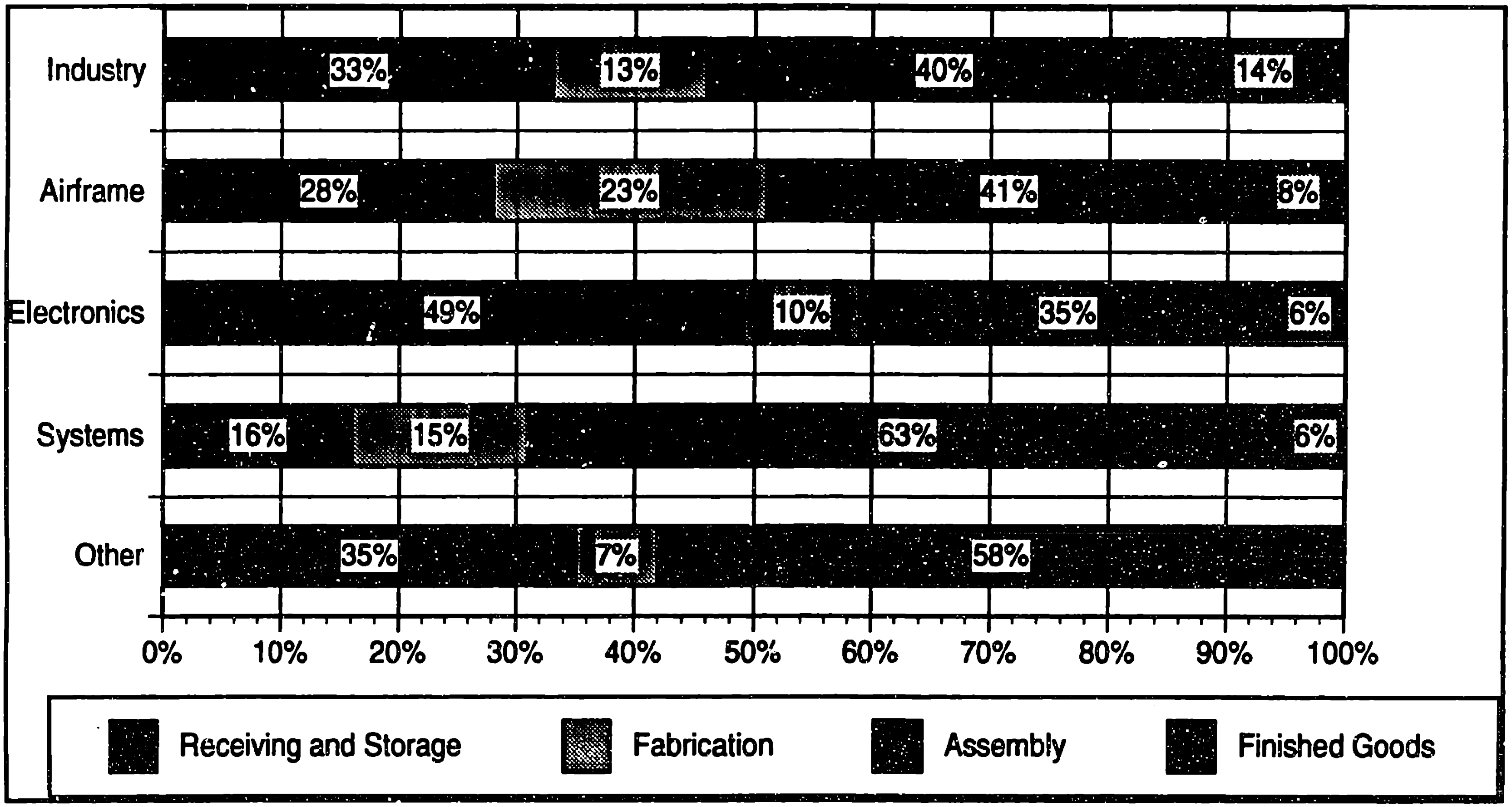


Figure 4.5: Inventory Location by Stage for Government Contracts

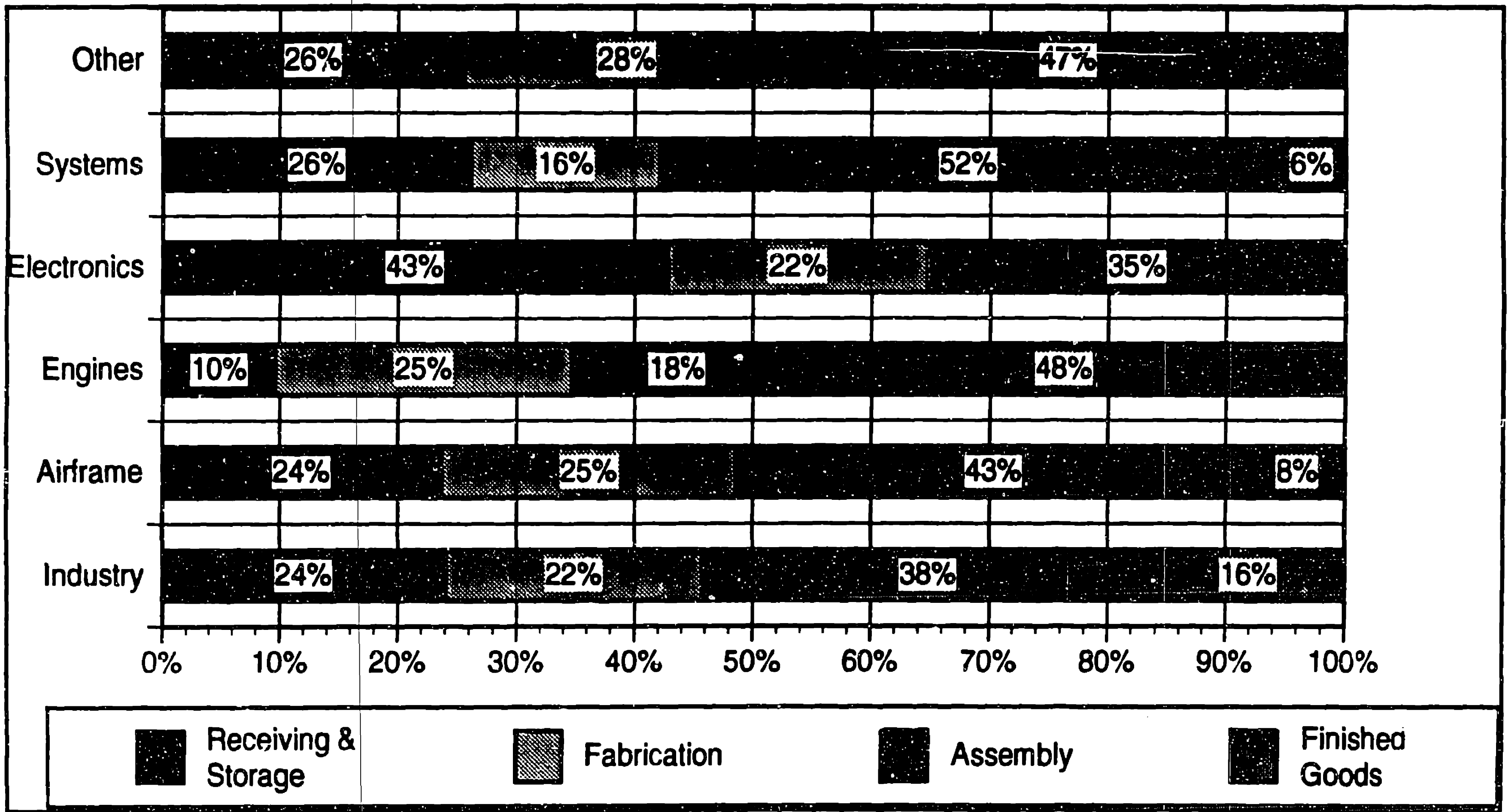


Figure 4.6: Inventory Location by Stage for Non-Government Contracts

could represent a significant reduction in inventory if it could be realized on the government contracting side.

Questions G1, G4, and G5 from the "Government Relations" section of the survey touched somewhat more tangentially on the issue of front-end loading. As mentioned before, these questions more specifically asked industry participants to identify which standards and practices affected their inventory practices (in terms of the levels of inventory maintained, the utility of the particular standard or practice, and the burden required in support of the activity or practice). The results here indicate that industry feels that fiscal-year buy quantities and progress payments encourage excess inventory. On the other hand, initiatives and standards such as MMAS have the opposite effect. The relationship and importance of these standards and practices to the overall issue of front-end loading will be discussed in more detail in the case study which follows.

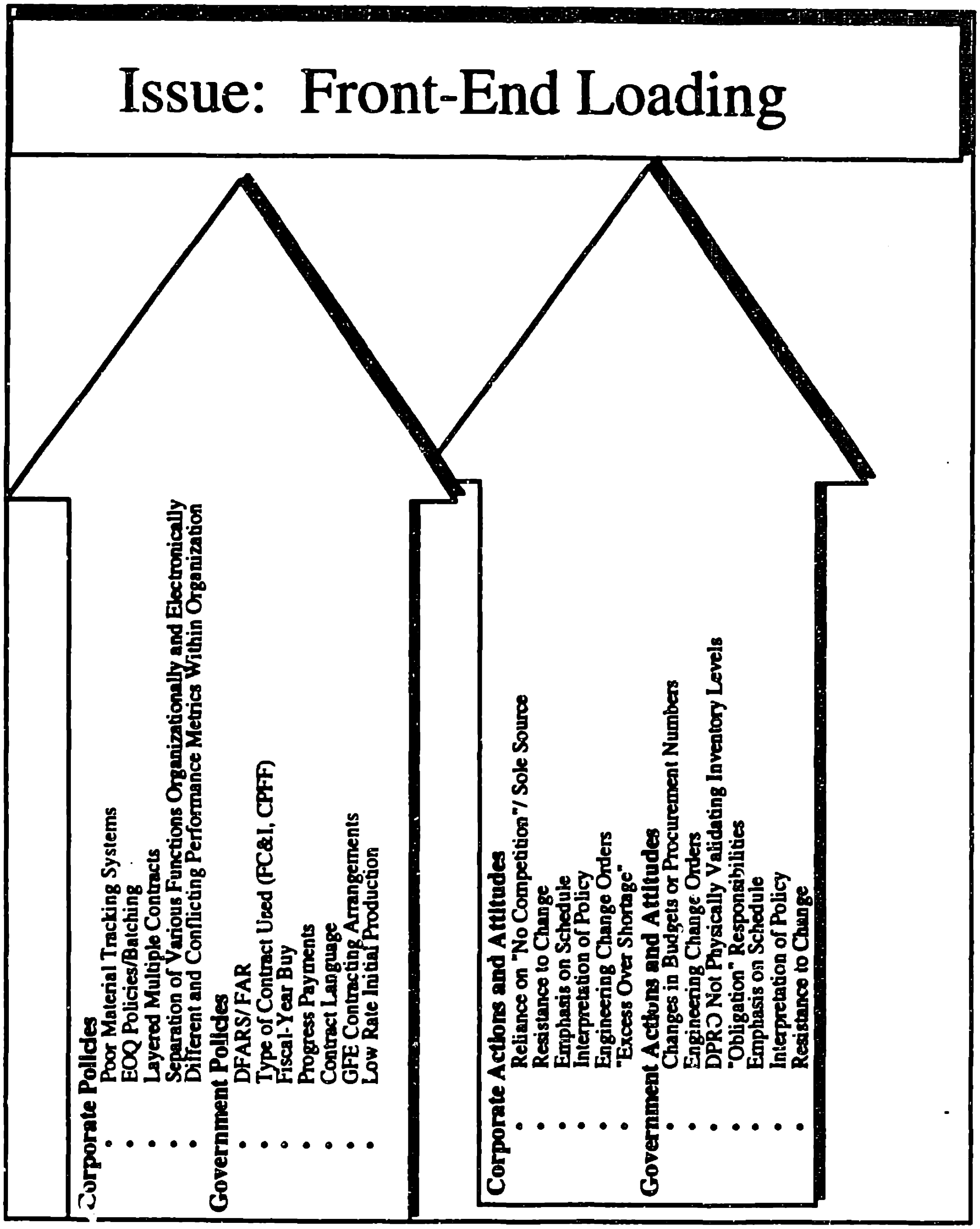
The conclusion which can be derived from all of these data points is that there are a number of companies within the aerospace and airframe industry which have an abundance of inventory within the early stages of production. Consequently, there are significant savings to be realized by reducing the amount of inventory which is typically carried by these companies at least to the levels carried by similar but commercially-oriented contracts. Although a somewhat subjective measure, "too much" inventory in receiving and storage is certainly not a good business practice and is not "lean."

4.2 Why Front-End Loading?

It is one thing to identify a problem and yet another to identify the root causes of that problem so that a solution may be found. Through a series of interviews with industry, government and academia representatives a diagram has been constructed which contains causes which were provided for the phenomenon of "front-end" loading. This diagram is shown as Figure 4.7. The illustration has been broken into the four major categories which "encourage" excess inventory: government policies, corporate policies, government practices and corporate practices. Sub-categories under each of these four main categories have been included in the diagram as well. Each of the main and sub-categories should not be interpreted as an equal contributor to the front-end loading issue; rather their weight is somewhat dependent on the sector and individual company involved. This diagram was used throughout the writing of this thesis as an aid for discussion and was dynamic in the sense that it could be added to at any time by anyone. As a learning aid, it helped focus the issue for all involved in the research of this area and in the identification of potential solutions.

4.2.1 Corporate Policies

Some of the sub-categories in this diagram merit further explanation, for historically they have been viewed as being strong contributors to the problem of excessive inventory. Specifically, in the area of corporate policies, many companies attribute their poor inventory management and acquisition strategies to inadequate tracking systems. Although these systems ostensibly meet the current requirements of the government standards which require that inventory be tracked, they are disjointed in some cases-- one system designed to track inventory *received* does not "talk" to the system which monitors inventory *used.* In other cases, there are distinct and disparate systems within the same company for different contracts which may actually use some of the same raw materials or components. Also, tracking or ordering systems may be "hard-wired" to order additional inventory to account for scrap or shrinkage as a percentage of yield. This can mean that any improvements realized by manufacturing may not be reflected in future ordering. Finally, many information tracking systems used in the industry do not have the ability to recognize



4.7 Causes of Front-End Loading

inventory left over from contracts for use on other contracts until the contract is actually closed out, a process that may take some time to do.[1]

Companies also traditionally have followed Economic Order Quantity (EOQ) principles which weigh annual usage figures against the cost, setup cost, and annual carrying cost of the item. At times, EOQ policies run counter to now-accepted concepts such as just-in-time (JIT). Additionally, companies sometimes are compelled to "batch" orders, ordering more than they would require due to government mandates or due to the need to maintain a steady flow of orders with dependent or critical sub-contractors.

Layered contracts sometimes mean that inventory for a particular year's production may have been ordered over a period of many years through multi-year buys; information tracking systems may not be able to smooth out the ordering requirements as orders may then change from year to year. Inventory accumulates as a result.

Lastly, some companies have chosen for various reasons to separate some organizational functions within their manufacturing operation such as separating sourcing (the group associated with procuring inventory) from operations (those who manufacture the end products). Often this means that these groups work at cross purposes. Sourcing might be evaluated on the basis of their ability to maintain a steady flow of orders and consequently a steady demand in terms of manpower. This may not be what operations needs, for orders placed and received may not reflect required inventory on the manufacturing side. Similarly, accounting and production metrics may not be appropriately aligned to ensure optimal inventory levels, total program costs, and cycle times.[2]

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[1] Much of this discussion was also the subject of interviews with the Director of Material Operations and the Manager Production Planning and Control at the plant which was the subject of Chapter 5's case study ("Plant A"), February 8-9, 1994.

[2] Also discussed in the above interviews.

4.4.2 Government Policies

In the arena of government policies, the issue of progress payments is continually raised in discussions surrounding inventory levels. Conceptually, progress payments are the way in which the government has decided to share the risk of development and manufacturing with industry and to finance high dollar value projects at lower cost than would be realized through commercial financing. Contractors are paid for the "progress" they make in meeting a contract's deliverables. In some cases "progress" can be simply measured by the acquisition of the materials required to manufacture the end product. Progress payments can range from 85-95 percent depending on the size and economic condition of the company and have been as high as 99 percent for extremely risky contract situations.[3] In the opinion of many surveyed, this government and industry relationship has the potential of incentivizing contractors to acquire inventory earlier than it may be needed in order to in effect raise capital. Those on the other side argue that because progress payments are only usually 85 percent[4] of the value of the purchase, that it is unwise and unsound business practice for a program manager to raise capital in this manner, given the carrying costs associated with that inventory and the opportunity costs associated with the other 15 percent the company must put up. Regardless, a great deal of investigation into the importance of progress payments and the contribution that they make to overall costs of programs is ongoing in many areas of the acquisition community.

Another apparent important potential contributor to inventory levels is fiscal-year buys. Here, monies are provided within a specific year to be spent in that year only. The requirement to spend money within that year means inefficient procurement and excess

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[3] See Lappin Wells, Dr. Rita, "The Fundamentals of Progress Payments," T.I.P.S (Topical Issue in Procurement Series), Vol. 3 No 1, January 1992 for more information on progress payments.
[4] It should be noted that Congress reduced progress payments for large firms to 75 percent in 1994.

carrying costs. Subsequently, government orders may even change, leaving unneeded inventory.

The type of contract used may adversely influence inventory levels. A Fixed Cost and Incentive (FC&I) arrangement makes it theoretically possible to move costs from year to year should the negotiated incentive value awarded to the contractor be different in one contract negotiation than another. These costs are artificially "grown" through the transfer of inventory from one year's production to another.

Other times, the contract language specific to the project itself can negatively affect inventory levels on a project. As an example, a defense aerospace plant which was visited in conjunction with this thesis has two contracts, both of which require the same relatively common part. The requirements for this part under one contract, however, are different than those for the other contract Specifically, the first contract (Contract A) requires 100 percent inspection of parts, driving the unit costs up. The second contract (Contract B) does not require the same rigorous inspection of the part which consequently costs less. The two contracts' purchasing requirements cannot be combined due to these different specifications. Consequently, more inventory is ordered due to minimum purchase requirements specified by the supplier. Table 4.1 further illustrates this example:

Table 4.1: Excess Inventory Due To Contract Language

Contract A	Contract B
Part X (100% inspection)	Part X (normal inspection))
Cost $ 1/unit	Cost $ 0.2/unit
Need: 50	Need: 50
Minimum buy: 100	Minimum buy: 100
Procured: 100	Procured: 100
EXCESS: 50 UNITS	*EXCESS: 50 UNITS*

Government Furnished Equipment (GFE) is often a component of a finished weapons system. The government has a strong incentive to deliver this material on time and even early because if delivery is late the contractor has enormous power over the government for defaulting. This translates to more inventory being held in receiving and storage than perhaps is needed at that particular point in time. Finally in the area of government policies is the issue of the low rate of initial production (LRIP) contract phase common to most contracts. LRIP frequently means that inventory needs to be ordered in quantities which are not needed immediately (due to batching and minimum buys, among other things), and may not be needed for some time. Uncertainties in procurement demands from the government plague the industry and inflate inventory levels as a consequence.[5]

4.2.3 Corporate Actions and Attitudes

It is hard to enumerate all of the corporate and government attitudes and actions which contribute to extraneous inventory problems. Many of these items are subjective and intangible, and depend to a large extent on the company or government representatives involved. An attempt has been made, however, to list those corporate and government contributors which have come up consistently in discussions with a variety of

[5] Interview with Prof. Gerald Abbott, Industrial College of the Air Force, February 7, 1994.

representatives of both industry and government alike. Again these "causes" for front-end loading are listed fully in Figure 4.7, but some are further explained below.

Often, a company can become rather complacent because they collectively view their particular product and contract arrangement as being unique and irreproducible in another company. In other words, they believe (in many cases rightly) that there is no competition and that they are assured of a "sole-source" relationship with the government for the life of the product. As a consequence, the strict tracking of inventory levels among other things becomes less of an issue. What is of most importance to all is the need to assure delivery of the product on schedule, and the reflexive reaction is to maintain excess inventory to guarantee that this schedule will be met. The Inventory Practices Survey confirmed this tendency of the shop floor workers especially to avoid shortfalls.

4.2.4 Government Actions and Attitudes

Many of the same actions and attitudes seen on the corporate side of the front-end loading issue can also be seen on the government side. Issues such as the emphasis on schedule, and the misinterpretation or inconsistent interpretation of policy come up often, as do items such as the resistance many individuals have to change of any sort to the status quo. Also commonly mentioned on both sides are engineering change orders (ECO) which are generated by both contractor and government alike. A manager at the plant involved in the following case study estimated that fully 20 percent of the inventory which is procured in his company is impacted by ECOs.[6]

[6] Interview with the Manager Production Planning and Control "Plant A", February 9, 1994.

4.3 Conclusions

Data obtained through the Inventory Practices Survey indicate that there is an excess of inventory in the receiving and storage stage of manufacturing operations throughout the aerospace and airframe industry. There are a variety of causes for this problem, and both the government and corporate sides contribute equally both in terms of policies, attitudes, and actions. The subsequent chapter will shed some light on one way in which these causes can be addressed and inventory can subsequently be reduced through a case study which was performed at one of the sponsoring companies.

Chapter 5: One Company's Path to More Lean Inventory Management

This chapter will examine one company's survey responses on those questions which related directly to the issue of the front-end loading of inventory. In addition, the chapter will evaluate how this company has worked to alleviate the problem of excess materials in receiving and storage and the results they have achieved thus far. Recommendations and observations will subsequently be made as to what the company can do in the future to reduce their inventory levels even further. It is interesting to note that all of the actions taken thus far by this company (and by the government oversight agencies involved) and all of the recommended additional modifications to their operations, fit well within the boundaries of what is considered to be basic "lean" practices or tenets.

5.1 The Company: What the Data Told and Did Not Tell

The plant which was selected for this case study is a division of one of the sponsoring companies of the Lean Aircraft Initiative. For the purposes of this paper and to preserve the anonymity of the company, the division will be referred to as Plant A. Plant A manufactures almost exclusively one product which represents between 90 and 95 percent of the plant's total business each year . This complex weapon system has remained relatively unchanged and has been manufactured in largely the same manner for the better part of two decades. It is comprised of several major components. As an indication of the level of detail involved in the manufacturing this product, one component alone has an 18 level Bill of Materials (BOM).[1] The entire system has a 25 level BOM. The manufacturing process involves 14 distinct work centers. In addition to holding the contract to

[1] Each level of the Bill of Material is one part of a contiguous build stucture with discrete financial and actual material breakpoints.

manufacture all of these components, Plant A also is responsible for the integration and test of the whole system for the government. As of the writing of this document, the plant has been fortunate enough to have maintained a relatively steady production flow and production volume even over the last few rather turbulent years of defense acquisition history. As a consequence, the facility remains a healthy and active one: it supports over 3,100 employees and utilizes 2,500 suppliers.

Despite what appears to be a mature product and a stable manufacturing operation, Plant A is not without its problems. Their data from the Inventory Practices survey indicated a problem with the front-end loading of inventory. Table 5.1 contains their answers to question C1 of the survey which asked the company to identify the total percentage of inventory items which fell within the four categories or stages of production (receiving and storage, fabrication, assembly, and finished goods):

Table 5.1: Plant A Response to Question C1
What Percent of Inventory Items Fall Within the Following Age Categories?

	Receiving and Storage	Fabrication	Assembly	Finished Goods
0 day - 1 day	0%	0%	0%	0%
1 day - 1 wk.	5	0	30	0
1 wk. - 1 mo.	0	15	30	5
1 - 6 mos.	15	65	35	85
6 mos. - 1 yr.	60	20	5	10
1 yr. - 2 yrs.	10	0	0	0
2 yrs. - 3 yrs.	0	0	0	0
> 3 yrs.	10	0	0	0

Table 5.1 shows that a great deal of the inventory which is located in Plant A's receiving and storage (80 percent) is greater than six months of age. Table 5.2 shows Plant A's

response to question B5b and question B12a of the survey, which asked the company to break out the percentage by dollar value of inventory contained within the same four stages, and the actual dollar value:

Table 5.2: Plant A Response to Questions B5b and B12a Percent of Inventory That Exists in Each Stage (By Dollar Value)

	Receiving and Storage	Fabrication	Assembly	Finished Goods
Percent	45%	16%	39%	0%
Actual Dollar Value	62 M	2 M	55 M	0 M

Table 5.2 shows that in terms of total dollar value, fully 45 percent of the inventory at this facility is located in receiving and storage -- more than in any other phase of production. One must also keep in mind that as this product moves down the production line, it should as a consequence *increase* in value, making downstream "inventory" have naturally a higher dollar value than upstream. Also, within this stage are lower level sub-assemblies which are waiting to be added to the next higher level of assembly. This does not seem to be the case with this particular plant's data. It is preferable, and indeed indicative, of a lean system that inventory a) be kept to a minimum within receiving and storage and b) be of an age which reflects that it is not stagnant within that stage or the system as a whole.

Arguably, the above survey data indicate that Plant A could afford to be carrying less inventory, probably at significant cost savings to the company and the government, than they are currently. In fact, it is these data which helped to identify this facility as being a good site on which to conduct a case study. It should be kept in mind, however, that although their data looks less than desirable, it is to their credit that this company even had the data available at all to provide to the research team (the majority of companies surveyed did not). As well, it is important to remember that this case study is intended to show what can be done to alleviate the problem of excess inventory in receiving and storage. Although some details of this company's specific approach may not be applicable across the entire industry, and some of the company's history may be peculiar to that company only, lessons still can be learned on the whole.

Plant A's data indicate that their inventory management process is not perfect. What the data do not show, however, is that the situation had been much worse six or seven years ago (and even as recently as three years ago). Originally, this site was selected for this thesis so that an investigation could be conducted into what could be done *starting now* to lessen the front-end loading problem in this company, and for the industry as a whole. Instead, it was discovered that the company being researched had in fact already been taking a hard look at this problem and had already done a great deal to address the situation. Even more importantly perhaps in terms of finding "quick" solutions to difficult problems, what happened to Plant A from 1987 to now is of interest because it shows what can be done *within* the current government procurement system without disturbing such "sacred cows" as progress payments or the budgeting/procurement cycle.

5.2 The Catalyst for Change

It has been suggested that meaningful change cannot come to a system without a crisis situation existing first. Plant A and the government had in a sense become complacent about issues concerning inventory and materials management. There had been, and it appeared would continue to be, a long-standing relationship between the two parties. The government needed and would continue to require the product, and Plant A was the sole provider of the product and had never missed a major delivery. In the late 1980s, during a routine audit or "health check" performed by government representatives, Plant A found themselves in serious trouble for not being able to account for a large ($80 M +) portion of their inventory and for not being able to properly justify their yield, scrap and shrinkage projections (which are traditionally based on data from previous contracts). At one point, progress payments (as high $100 M in total) were to be withheld by the government until the situation was addressed to the government's satisfaction. As would be expected in a crisis situation of this magnitude, the company scrambled to find where the problem lay. They found that although they had "approved" systems in place to monitor and track inventory, the systems themselves were in fact inadequate, and their control of their manufacturing processes (in terms of scrap, rework, yield, etc.) also left a great deal to be desired.

A strategy to manage these two major shortfalls evolved over time; some aspects of the company's approach addressed the weaknesses of the materials management systems, others addressed the problems the company was experiencing in maximizing yield (and therefore minimizing unnecessary material acquisition). In a sense this was a two-pronged attack, with the government and the company on either side. In the company's case, new initiatives were introduced, such as Statistical Process Control (SPC) and Continuous Process Improvement (CPI). On the government or policy side, existing standards and practices were looked at under a new light both by the Defense Plant Representative Office (DPRO) involved and by the company with some interesting results. Table 5.3 shows both the company initiatives which were undertaken over the past six or seven years and the government policies which were interpreted and utilized to make Plant A's manufacturing process more lean. The next two sections of this chapter will go into greater detail on each of the table's entries.

Table 5.3: The Strategy[2]

Government "Policies"	Corporate Initiatives
MMAS DFARS 242.72	SPC (Statistical Process Control)
FAR 45.5	CPI (Continuous Process Improvement)
C/SCSC 5000.2	MRP II Implementation (Ongoing)

5.3 Company Initiatives

As was mentioned, the company involved in this case study undertook a number of initiatives in their attempt to bring their material management and tracking systems and manufacturing processes under control. To a casual observer, but one well-versed in current thinking on manufacturing technology, the steps taken by Plant A would not appear to be radical and in fact may even seem to be somewhat "behind the curve" in terms of state-of-the art commercial manufacturing advances. One must keep in mind, however, that concepts such as Statistical Process Control and Just In Time inventory management are not currently standard practices in the aerospace and airframe industry. More on the reasons behind this gap between the defense and commercial industries will be included in the sections that follow.

5.3.1 Statistical Process Control

As was covered in Chapter 3, the Inventory Practices Survey asked companies several questions regarding their use of Statistical Process Control. They were specifically asked for information such as their Defects Per Million (DPM) within each stage of production. Very few of the respondents for these companies were aware of the DPM figures for their

[2] All of the standards and practices referred to here are defined in the list of acronyms found at the beginning of this thesis.

respective operations. Composite results can be seen in Figure 5.1. Once again, answers are sector-dependent, with "Electronics" and "Systems" sectors utilizing SPC the most. Industry-wide, use of SPC is most prevalent in the assembly stage of production, and even within this stage only approximately 34 percent of the companies surveyed were using SPC in assembly at the time of the survey. It seems that companies within this industry are reluctant to implement SPC. Reasons given for not using this relatively common form of process control ranged from the low production volumes associated with the industry, to government and corporate resistance to change.

Unlike many other companies involved with the Initiative, Plant A has recently embraced Statistical Process Control in all aspects of its manufacturing operations. Management recognized that their manufacturing processes, which had remained relatively unchanged for so long, had not been checked in a rigorous and quantifiable manner. Aside from having historical data on metrics such as scrap and yield, the company had little else to explain or predict future manufacturing performance. The company decided to begin to implement an SPC system to provide them with better visibility into their manufacturing operations. In 1987, a pilot effort was started at a low level sub-assembly work center. It was believed that the continuous process of this selected work center lent itself easily to an SPC application. A consulting group was brought in to implement SPC, and to simultaneously involve the workers themselves in this process. Eventually, SPC spread to the entire factory floor (to all fourteen yielded and non-yielded[3] work centers alike). A database was also concurrently created to store all of the collected SPC information for subsequent analysis. This whole process took approximately two years to fully implement.

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[3] "Yielded" centers are the lower level sub-assembly work centers which involve the purchase of "raw materials." "Non-yielded" are the higher level work centers which require "purchased components" as their inputs.

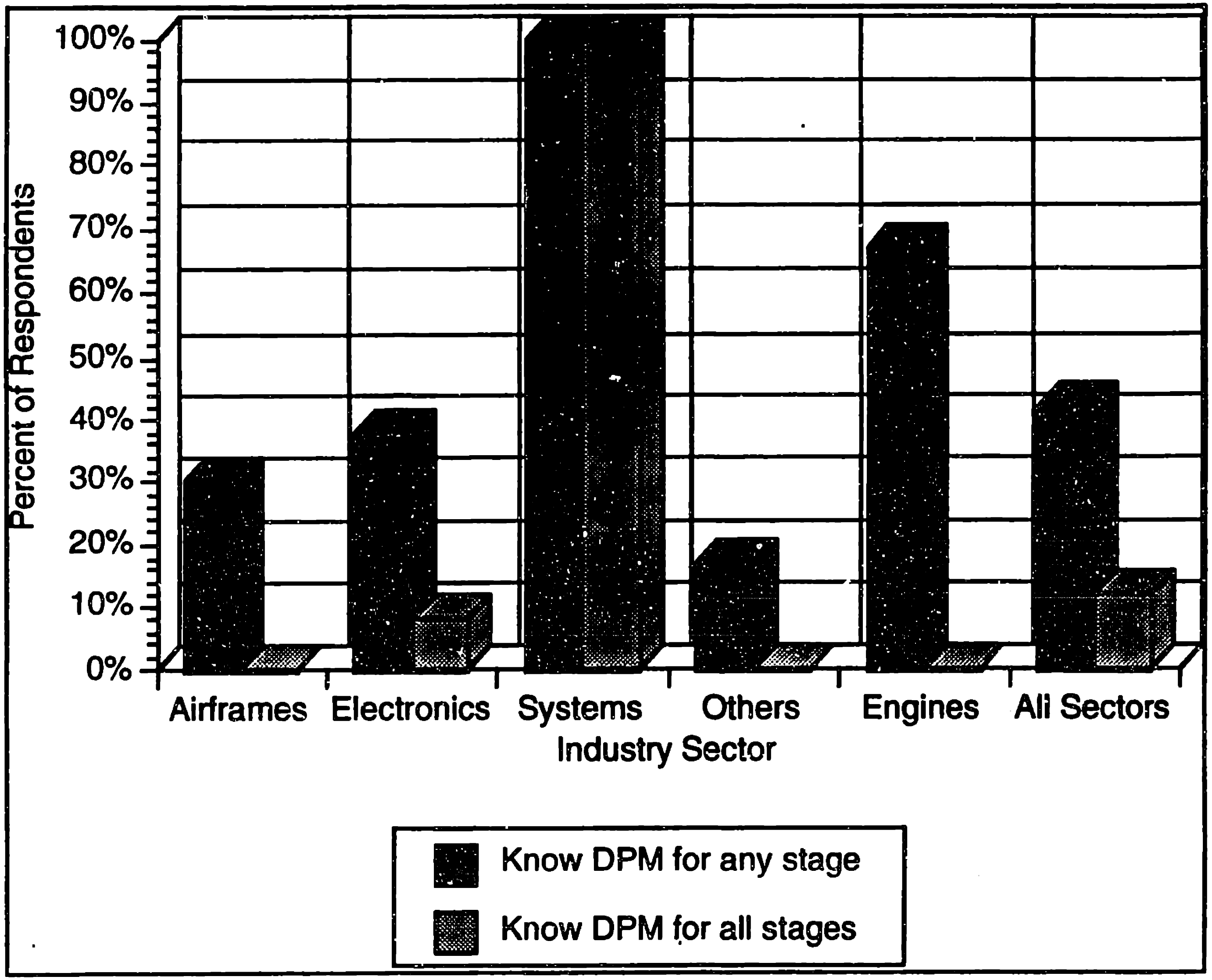

Figure 5.1: Knowledge of Defect Rate

5.3.2 Continuous Process Improvement

Following the successful insertion of SPC into their operations, Plant A began to rigorously implement a complementing Continuous Process Improvement initiative. Management and labor used the measurements taken from the newly implemented SPC system and its database to ask *how* to fix various processes. Starting again on a small scale, the same work center as before was used as a pilot project. First, Pareto analysis was used to identify where there was the most variability and scrap within this particular work center. The workers themselves were then allowed to use normal production equipment to experiment with the process in controlled lot tests. This CPI initiative resulted immediately in cycle time reduction and reduction in scrap. Consequently, there was an accompanying reduction in total costs and in inventory ordered. All of Plant A's work centers eventually were included in the CPI initiative with the goal being to reduce cycle time by 50 percent and total production cost by 25 percent.

5.3.3 Aggregate Results from SPC and CPI Initiatives

It is difficult to distinguish between the results achieved by Plant A with the implementation of SPC and the subsequent addition of CPI to the total manufacturing process. The following, however, is a summary of improvements which have been realized in the past which have been attributed to the combined effects of both initiatives.

As mentioned above, it was the company's goal to reduce cycle time by 50 percent and total cost by 25 percent. This goal was met. After just two years of SPC being used throughout the shop floor, Plant A observed 30-35 percent reductions in defects across all centers. This result can be broken down further in terms of the reductions realized in their yielded and non-yielded work centers. "Yielded" centers are measured by yield in terms of a metric called Normal Production Allowance (NPA). "Non-yielded" work centers have as their primary performance metric a Material Allowance Factor (MAF). NPA is a subset of the MAF measure.[4] With the addition of SPC and CPI, Plant A saw a 40 percent reduction in NPA and a 10 percent reduction in MAF. Additionally, the combined effects of the two programs also have resulted in a 10 percent per fiscal year buy reduction in "the cost of quality" -- those costs associated with having to repeat poor work both in terms of labor and materials. Clearly from the above information, programs such as SPC and CPI which monitor and attack issues of quality can result in significant savings in time, labor and materials. These savings are passed on ultimately to the customer.

5.3.4 Manufacturing Resource Planning and Results

Both the SPC and CPI initiatives fundamentally addressed the issue of process control. With increased control of the manufacturing process comes increased yield and decreased scrap, negating significantly the need for procuring unnecessary raw and purchased materials and maintaining these materials in receiving and storage. The third tactic which Plant A employed to address the recognized shortfalls of their manufacturing system focused directly on reducing inventory in the production process flow.

Although the inventory management and tracking system used by Plant A into the late 1980s satisfied the fundamental requirements of such systems as set forth in government standards such as MMAS, the system was still woefully inadequate for several reasons. First, the existing system did not allow for the tracking of residual material across all contracts in real time. Contracts had to be officially closed out (a process which can take a number of years) before inventory could be transferred. As a consequence, excess material was being procured which was already in the inventory. Second, the tracking system had

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[4] NPA is the procurement quantity of purchased parts above configuration requirements to accommodate for material attrition caused by the manufacturing processes. MAF is the total value of materials and supplies above configuration requirements needed to support product manufacture and delivery (e.g. scrap, rework, yield, design changes, test support, and destructive testing). In Plant A's case, NPA is roughly 20-25 percent of MAF.

no "owner," and inputs could be made by virtually anyone without the knowledge of how their actions would affect the system. Transfers could theoretically be done from contract to contract on a "borrow pay back" basis. The reality was, however, that the pay back would never happen in a timely manner. The contract which borrowed the item would recognize their inventory deficit and procure more parts, while the contract from whom the borrowing was done would be without the parts which it had purchased.[5] The result was an over-compensation for shortages due to poor communication and a cumbersome data set and process. The system was also rigid and inflexible, and did not readily allow for the changing of schedules. Lastly, the existing system did not have any feedback between the Inventory Management System (IMS) (where inventory was "used") and the Consolidated Purchasing System (CPS) (where inventory was being procured).

Plant A management, in combination with their government procurement counterparts, recognized the shortfalls of their old system when they were faced with the fact that they were not able to accurately account for inventory levels. The company began to act on this problem in two ways: they commissioned a large inventory analysis study, and they began plans to launch a new Manufacturing Resource Planning (MRP II) system.

Plant A initiated an internal study of their inventory systems and how they affected and were affected by corresponding manufacturing activities. The study group was organized into cross-functional teams of employees who examined diverse topics related to inventory ranging from Work In Process (WIP), to shipping, to the accuracy of lead times. General results of these teams included the reduction of the supplier base by 60 percent, the reduction of dock-to-stock cycle time by 75 percent, the reduction of sourcing cycle time by 50 percent, and the reduction of inventory by 40 percent in three years.[6]

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5 Shortfalls of inventory management system were subject of interview with the Manager of Production Planning and Inventory of Plant A, February 8, 1994.

6 Results taken from internal Inventory Analysis briefing from Plant A, dated November 16, 1993.

One particular project which was undertaken by the Inventory Measurement team looked at the effective time phasing of inventory and its associated benefits. In a sense, this was a "manual" simulation of what the benefits would be to Plant A of an MRP II-like system. Using the existing material management system's data, part numbers were identified, their raw numbers were counted, the numbers which were needed in the future were determined, and ordering/procurement plans were adjusted accordingly to account for excess material in house. Particular suppliers were targeted who provided the largest (80 percent total) dollar value of those parts whose ordering arrangements had to be significantly modified. All told, over $6.6 M savings of inventory was quickly realized in the first pass efforts of this project team by modifying ordering plans. Subsequent analysis and inventory adjustment by this team is ongoing, and more savings are expected.[7]

In perhaps its most fundamental definition, an MRP II system asks the following questions: what are we going to make, what does it take to make it, what have we got, and what do we have to get?[8] It can project when items will be needed and can smooth out inventory levels by providing insight on where bubbles or peaks in inventory levels are. Concurrent with the inventory analysis studies, Plant A also began the process of implementing an MRP II system. The process has taken the better part of two years to insert, and just went on line in February of 1994. Although actual results are unavailable as of the writing of this thesis, the company's management and consultants involved in this particular implementation conservatively predict that there will be at least a 10-25 percent reduction in inventory across all stages as a result of the new inventory management system. This is thought to be a low estimate, and it is not out of the ordinary to see

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7 Information found in briefing entitled "Effective Inventory Time Phasing and Associated Benefits," provided by a Senior Operations Financial Planning Analyst at Plant A. Briefing dated May 26, 1993.
8 Wight, Oliver W., *MRP II: Unlocking America's Productivity Potential*, CBI Publishing Co., Inc., Boston, 1981, p. 50.

reductions in inventory as large as 40 percent depending on how bad the old inventory tracking system was.

As can be seen from the above results, a combination of an aggressive program and process to seek out and eliminate inefficiencies in the current system, and a forward-looking attitude which embraces such changes as MRP II systems has resulted thus far in significant savings and reductions in inventory to Plant A and will presumably continue to do so well into the foreseeable future.

It is interesting to note, that according to the Inventory Practices data, only 44 percent of the companies surveyed by the Lean Aircraft Initiative currently use an MRP II system (Figure 5.2). In contrast, almost all companies reported that they had some sort of "formal program to decrease inventory or streamline processes" (see Table 5.4).

Table 5.4: Percentage of Companies Having a "Formal Process to Decrease Inventory or Streamline Processes"

Airframers	100%
Electronics	85%
Systems	100%
Engines	100%
Others	100%

It would seem that although sponsoring companies are attempting to be more "lean" in their handling of inventory and its related issues, they have not yet all adopted MRP II systems to aid them in reducing inventory levels.

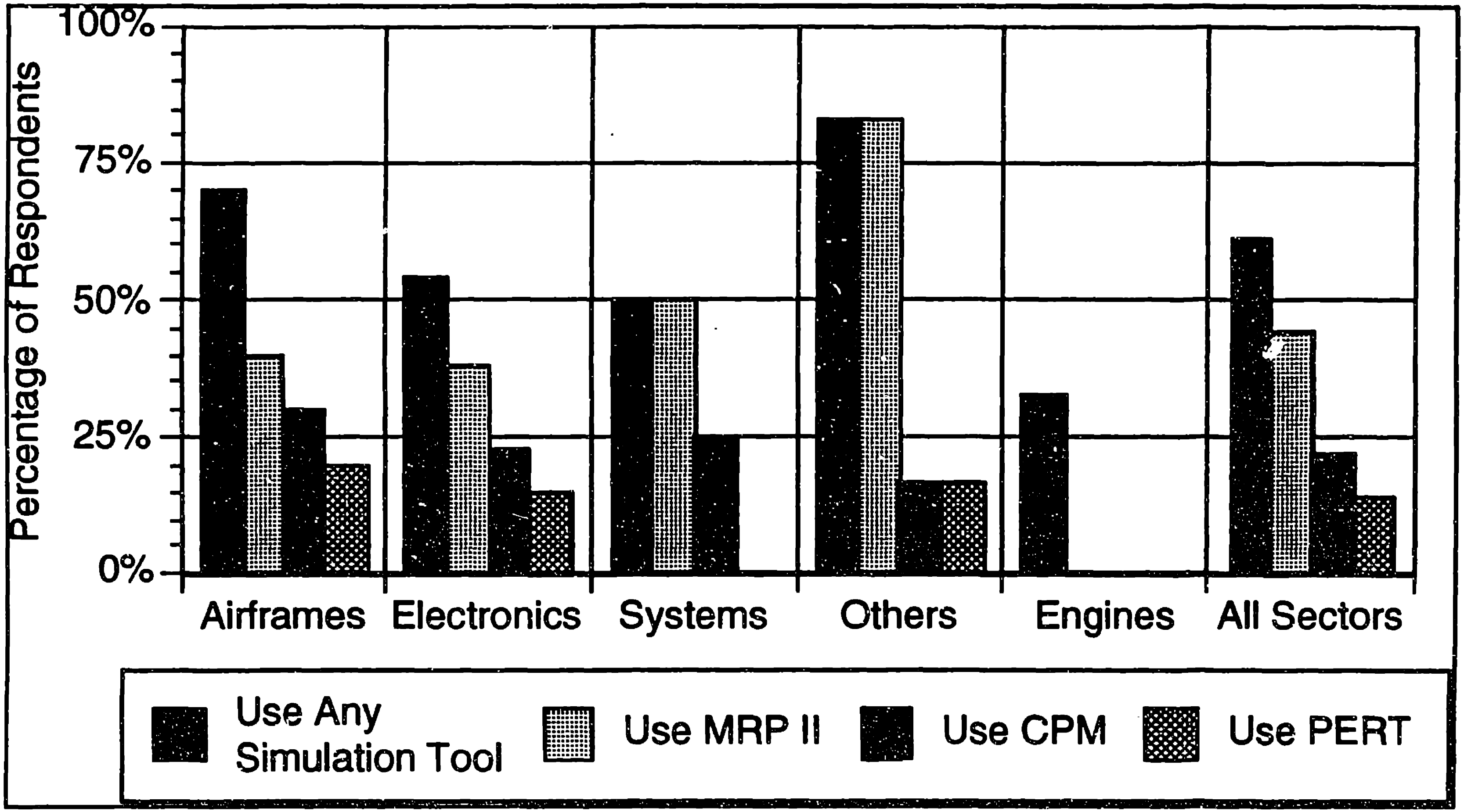


Figure 5.2: Use of Simulation Tools

5.4 Government Policies and Actions

The success which Plant A has experienced over the past several years in reducing total cost, cycle time and inventory has not been solely as a result of company actions such as the adoption of SPC, CPI and MRP II. Rather, the company and the government oversight agencies involved in this case have been working *together* to achieve this success. For the government's part, several military standards have been reinterpreted or enforced differently than they had previously. In particular MMAS DFARS 242.72, FAR 45.5, and C/SCSC 5000.2 have been particularly instrumental to the recent changes in Plant A. Modifications to and adjustments within these already existing policies have aided the company and accelerated their progress towards a more lean operation. The following sections will go into greater detail on these policies and actions.

5.4.1 Material Management and Accounting Systems (MMAS)

Prior to the initiation of MMAS compliance standards, there was the nagging issue of determining what to allow as scrap rate, rework, shortages, breakage, inspection failures, etc. on any given contract proposal. The issue was how to evaluate a contract proposal and contractor's historical figures on these measures if the contractor did not adequately demonstrate that there were back-up data to support them. MMAS and its ten primary guidelines have helped to solve this problem, by providing guidance on what is and is not an acceptable inventory management and tracking system to the government. Some of the ten primary guidelines have been included as Appendix B. Even since the introduction of MMAS, however, interpretation of the standards by various DPROs and companies has led to varying degrees of accountability in tracking systems. Following the problems which Plant A had in the late 1980s and early 1990s in justifying their inventory data, a stricter interpretation of many of the ten MMAS guidelines was agreed upon and implemented by the DPRO and the company.

As an example, MMAS II requires the valid time phasing of materials and a 98 percent BOM accuracy. The DPRO involved with Plant A reinterpreted this guideline to mean that "valid" was within 30 days of delivery date. In some other cases, as much as 180 days has been interpreted as being "valid". Clearly the difference between these two interpretations can potentially translate to a great deal of excess inventory in receiving and storage, much in advance of need dates for this material. In another example, MMAS V requires 95 percent inventory accuracy. In this case, the DPRO and the company changed their previous interpretation from being 95 percent accuracy on the *dollar value* of inventory to 95 percent accuracy on the actual *piece count* of inventory. It is much more difficult this way to maintain such a high degree of accuracy, for the company has to monitor inventory closely on even low dollar value items such as screws. MMAS VII speaks to the transfers of material, which need to be financially reconciled "within one accounting period." In this case, the standard was reinterpreted to have an accounting period be 30 days instead of the previous 6 months. Clearly, this tightening of the definition limits the time in which inventory has to be reconciled, allowing for the more expedient transfer and usage of excess inventory. Finally MMAS I calls for a system description of the inventory management and control system. It is possible to interpret this standard as requiring simply a short narrative on the system. Instead Plant A and the DPRO have agreed that the description should be much more detailed. In fact, this standard is currently satisfied with 17 three inch binders of information which detail the flow of information, and even job control language. This allows for greater and accessible insight into the system on the part of all involved parties.

5.4.2 Cost/Schedule Control System Criteria (C/SCSC) 5000.2 and Federal Acquisition Regulation (FAR) 45.5

C/SCSC 5000.2 requires that the contractor maintain a comprehensive management system that satisfies the Cost/Schedule Control System Criteria. FAR 45.5 addresses the management of government property which is maintained by contractors. In essence, both policies address the need for the contractor to assure adequate management and control of the inventory which belongs to the government (which is the case with cost-plus contracts) or which will ultimately be used by the company on government contracts. It is the DPRO's responsibility to actually "validate" compliance with the standards and inventory levels.

As was described previously, in the case of Plant A a government audit team discovered that the company could not provide the government with a proper inventory profile for a number of reasons including the borrow pay back problem mentioned previously and the issue of the closing of work packages. Concurrently, a DPRO representative actually physically counted inventory levels on the shop floor and in the storage area and warehouse, instead of the common practice of validating levels by checking the inventory systems' electronic data. As a consequence, the company was found not to be in compliance with C/SCSC 5000.2 and FAR 45.5. At roughly the same time, the DPRO was reorganized to its current form to have a program and technical support, quality, and contracting group. All of these new groups are tied together by a common "program integrator" who has insight into all aspects of the program. Prior to this arrangement (which is now being used by all DPROs), the organization was largely functional, with personnel dedicated to quality, engineering, and contracting. This arrangement did not allow for as much of a cross-functional look at the manufacturing operation.

All of these activities combined resulted in a much more watchful DPRO presence and a much more strict interpretation of C/SCSC 5000.2 and FAR 45.5. This increased vigilance has translated to strong governmental support for change at Plant A and, in the opinion of many in the management of Plant A, greatly aided company efforts at reducing inventory levels both through control processes and more sophisticated information and inventory management systems.

5.5 Future Improvements to Reduce Inventory

As has been explained in the previous sections of this chapter, Plant A has already done a great deal to start on the path to lean. If one uses decreased inventory levels and the increased accuracy of inventory management systems as a gauge for progress towards leanness, then the above data seem to show that the company is moving in the right direction with its strategy of implementing modern manufacturing technologies and control processes, and through its strict compliance with existing government regulations and standards. Of course all of the benefits of such things as SPC, CPI, and MRP II have not yet been fully realized. Beyond these initiatives and actions, however, there are still other activities which the company can undertake to further streamline their operations and reduce their inventory levels. These changes can take place in the areas of supplier relations, organizational and performance metrics, and manufacturing operations.

5.5.1 Supplier Relations

Although Plant A has worked extremely hard over the last several years to reduce the supplier base on which they depend, the company and its suppliers still have some distance to go to improve supplier relations to a point where they would be considered lean or best practices. Over the past three years, the company has reduced the supplier base from roughly 7,000 to 2,500 -- a 65 percent reduction. This reduction alone has resulted in a 6 percent per year reduction in material cost, a savings which has been passed on to the government.

What the company has not been so successful in accomplishing, however, is working with the remaining suppliers to assure the timely and accurate delivery of materials. Like other defense contractors, the company is in the position of working with a dwindling supplier base whose very existence often depends on the continuation of the prime's contract. This means that Plant A must sometimes agree to batch orders that are not necessarily optimal from their perspective just to keep the supplying company viable. In addition, the company must attempt to keep their supplier options open, which sometimes translates to maintaining a contractual relationship which is less than ideal. In fact, as recently as November of 1993, 69 percent of sampled material (measured by purchase orders) arrived late to meet the manufacturing need date. Along a similar vein, 56 percent of the monthly purchase orders from this month were late and therefore did not meet the supplier's own negotiated delivery date. On the other side of the equation, it is not uncommon in Plant A for deliveries to be received *earlier* than the negotiated date (24 percent of purchase orders arrived early in the month of November 1993). Figures 5.3 A-C show this and more data in greater detail. In short, there is a chronic problem with unreliability in the supplier base of Plant A. The supplier pool is so commonly late, in fact, that Plant A routinely inserts a 30 day buffer between delivery and need dates to account for this expected delay. Clearly the amount of excess inventory (inventory which is in receiving and storage well in advance of when it will actually be used) is potentially large under these largely uncontrolled circumstances. The Supplier Relations focus group of the Lean Aircraft Initiative is currently investigating many of these issues which have arisen in this period of downsizing in order to suggest solutions.

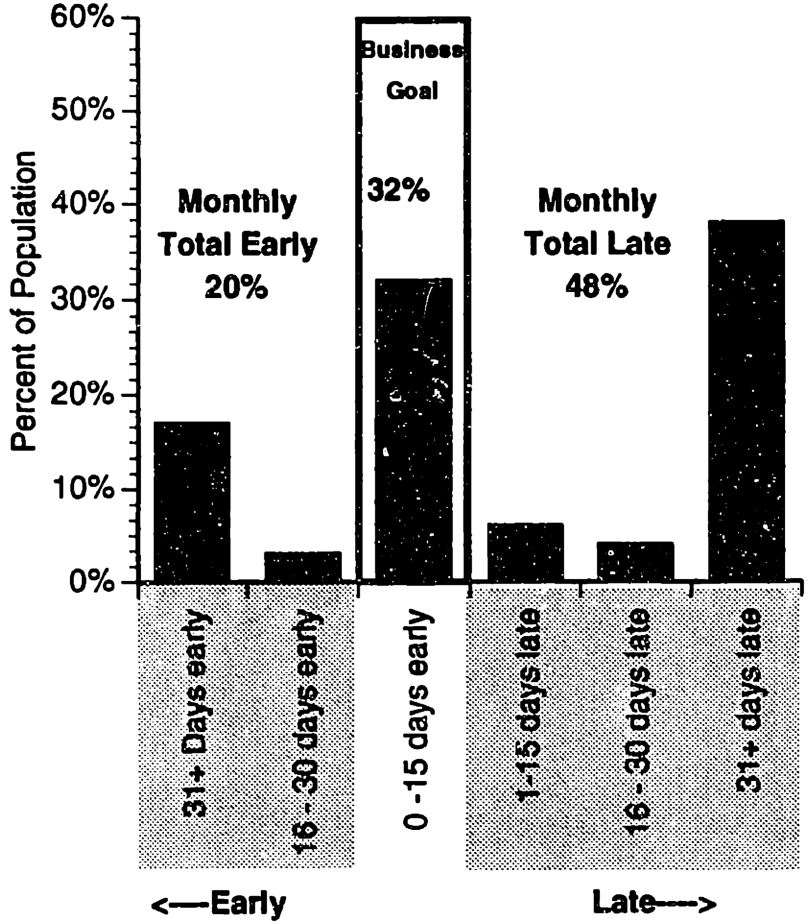


Figure 5.3A: Does the Negotiated Supplier Delivery Date Meet the Manufacturing Workcenter Date?
Source: Material Management and Accounting System Material Systems Measuring Book, December 1993.

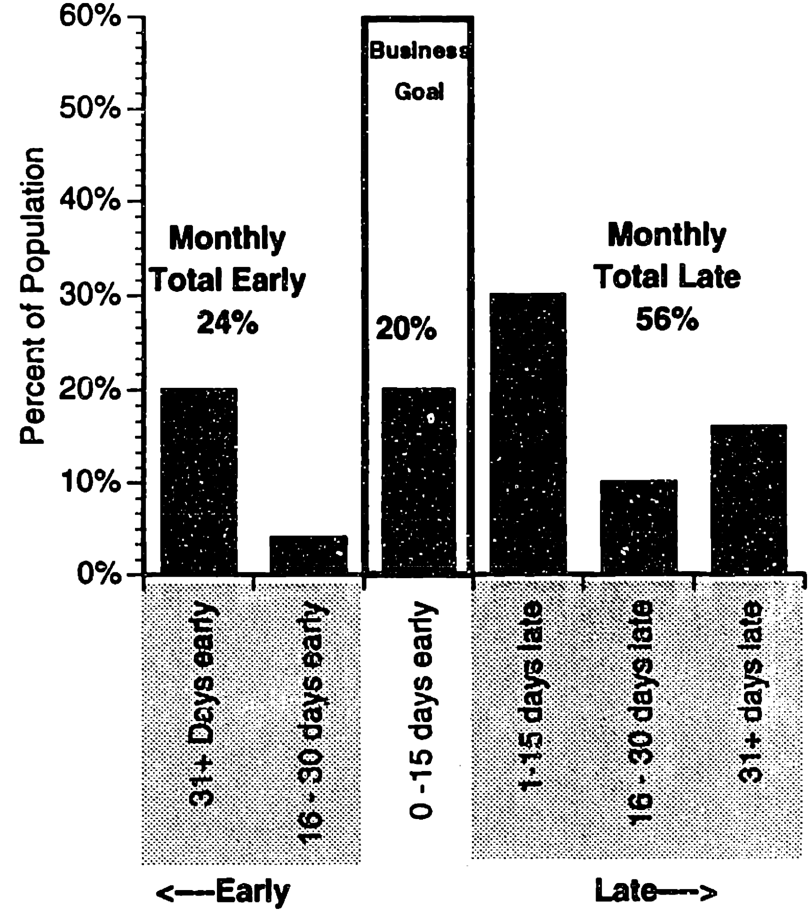


Figure 5.3B: Did the Supplier Meet His Negotiated Delivery Date?
Source: Material Management and Accounting System Material Systems Measuring Book, December 1993.

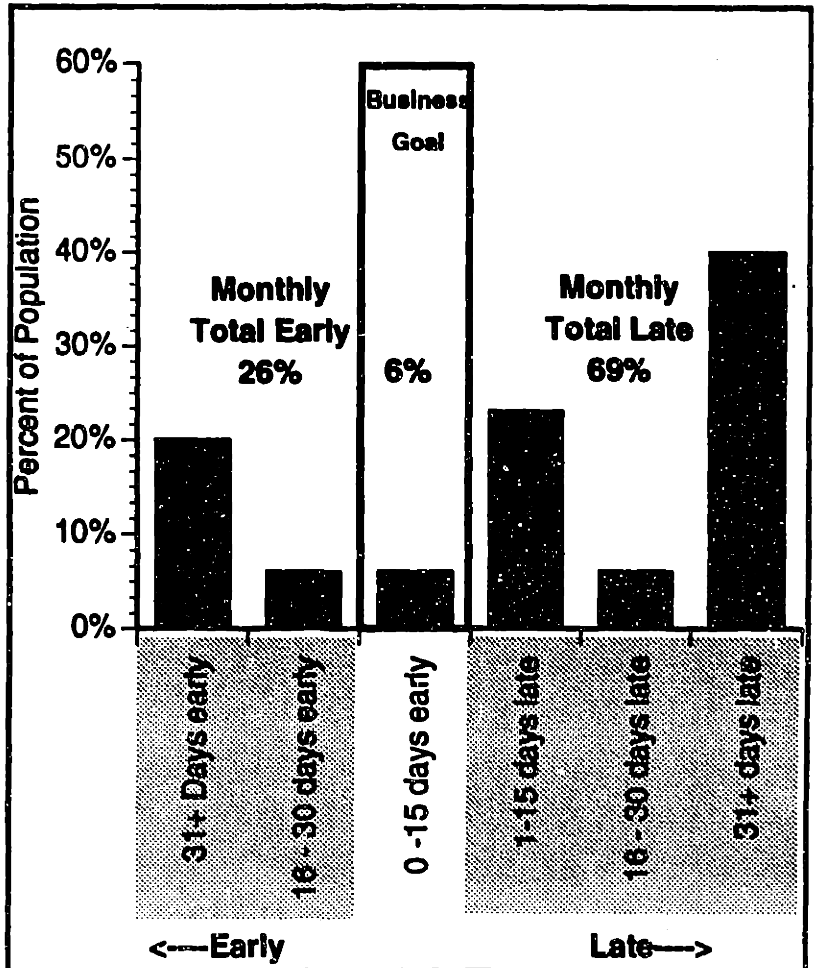


Figure 5.3C: Did the Material Arrive in Time to Meet Manufacturing Workcenter Need Date?
Source: Material Management and Accounting System Material Systems Measuring Book, December 1993.

5.5.2 Management Considerations and Performance Metrics

Like many other companies, Plant A organizationally separates sourcing (the group which orders and receives delivery of material), from operations (those who manufacture the product and use the procured material). As mentioned before, in the very recent past this separation even went so far that the inventory management systems of the two groups were separate and not electronically connected to each other in any way. In addition to having different organizational chains of commands, the two groups of sourcing and operations also have different performance metrics on which they are measured. While sourcing in Plant A, and in many manufacturing companies, is measured on and concerned with things such as economies of scale, reduction of purchase orders, administrative cost reduction, and supplier relations; operations is typically worried about meeting schedule, reducing inventory and WIP, and the impact that engineering change orders will have on inventory which has already been purchased.

It is evident that one of two things needs to happen if inventory is to be further reduced and if operations and sourcing are to be compatible: either sourcing and operations need to be organizationally bound together, or at the very least, their performance metrics need to be congruous. Currently, the manufacturing operation is measured on sales, return on investment (ROI), income, overhead, and return on sales. All of these metrics concentrate on the reduction or liquidation of unnecessary inventory, and the efficient use of materials. Counter to this, sourcing is measured on their ability to maintain a certain rate of receiving goods (to maintain a steady use of manpower and other resources), as opposed to receiving inventory to meet the manufacturing schedule. The goals of the two groups should be better aligned with one another in the future to assure the further reduction of inventory levels.

5.5.3 Pull Factories

Now that Plant A has worked to improve quality and reduce WIP through the use of SPC, CPI, and MRP II, their next planned area for improvement will be to implement a "pull factory" system -- an additional layer of time phasing which involves the internal customer actually requesting or "pulling" orders from upstream work centers, as opposed to the order-launch system which is currently being used by Plant A and the majority of the aerospace and defense industry.

With the advent of the pull factory concept in Plant A, it is estimated that in the company's two main yielded work centers' WIP will be further reduced by 25-30 percent. Additionally, due to the plant's fairly flexible work force (there are only 14 job classifications plant-wide, and these are broken into three larger categories within which employees can move freely) it is anticipated that there will be little personnel impact with these changes. In the areas where there is a lower level of assembly, it is expected that there will be a 3-5 percent reduction in WIP (there is a fairly low amount of WIP in these areas in the first place). Clearly, the move from the traditional manner of pushing product through the pipeline to pulling this product instead will result in significant reductions in WIP, and most likely will be accompanied by corresponding reductions in raw materials and purchased parts in inventory stores.

5.6 Conclusions from Case Study

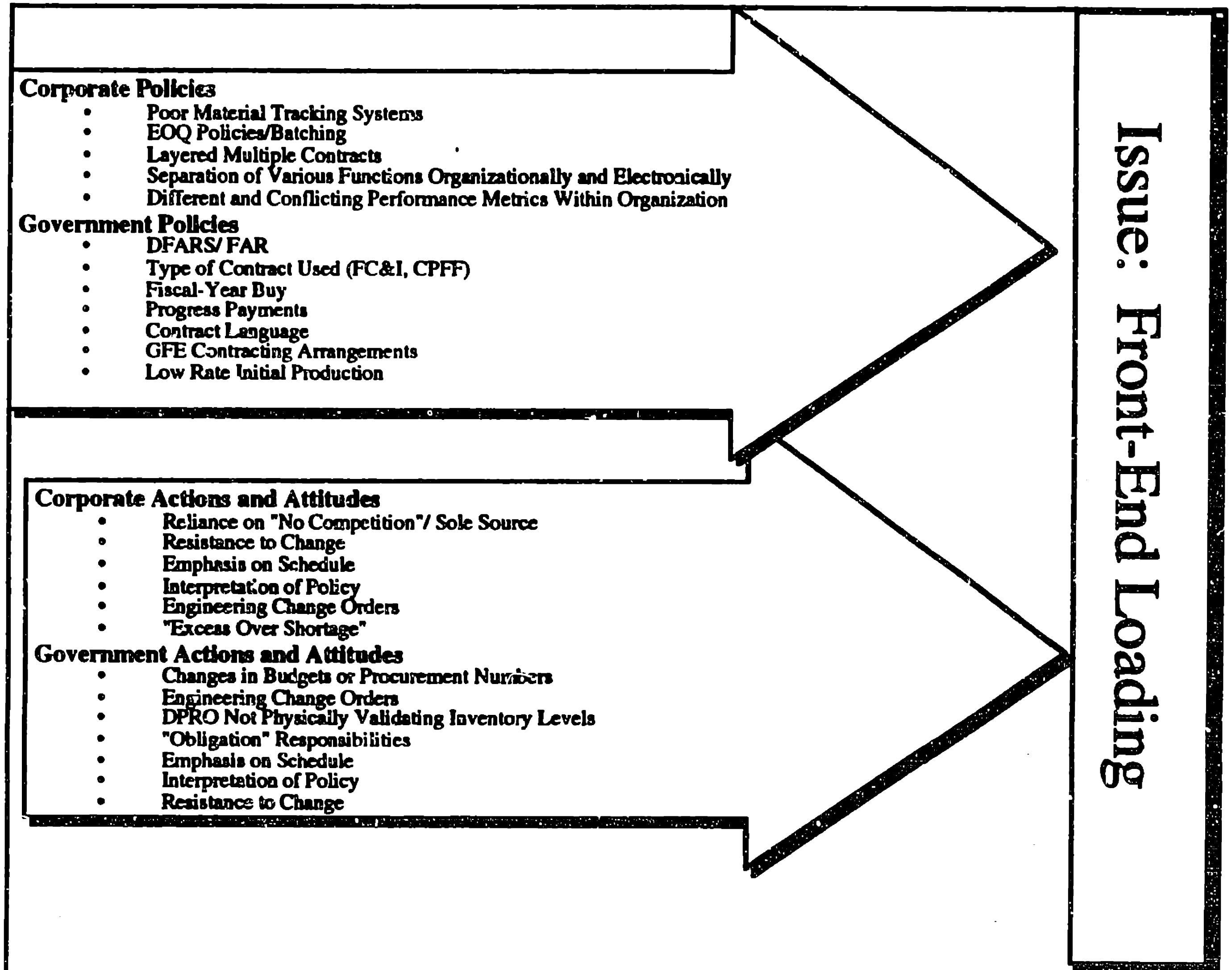
There still is a great deal to be done in this company and even more in the industry as a whole to reduce inventory, especially to reduce inventory in the crucial and arguably non-value added stage of receiving and storage. This company, however, has at least begun the process of addressing their inventory weaknesses and has begun to smooth out the bubbles in their inventory profile. They have done this thus far by complying with a number of pre-existing government regulations and standards. This means that they have not simply paid lip-service to their existence, but that they (in combination with their DPRO counterparts) have actually evaluated the impact of all of these standards and practices and implemented management and technical systems which address these requirements fully. In the instance of MMAS, as a case in point, the company has genuinely embraced the ten principles of material management as outlined by this standard. Their information management system is consequently much more accurate and useful than it was previously. In addition, the company has adopted a number of its own initiatives which have been common-place in the commercial sector for quite some time, but are still rather uncommon in the military aerospace industry. Specifically, these initiatives are SPC and CPI. Most recently, they have adopted an MRP II system, which will provide them further visibility into their manufacturing and materials management processes, and will consequently allow them to realize further reductions in inventory and savings in total cost to the program.

Finally, the company recognizes that there are additional areas where more economies and savings can be realized and is currently working to address them. Specifically, the company intends to move more towards a "pull factory" system with its 14 work centers. Additionally, the issue of supplier relations is being looked at with great interest and carefully monitored in terms of the number of suppliers in the supplier base and the promptness and reliability of their shipments. As well, efforts are being made to work with suppliers in forming more successful and non-adversarial relationships. This business, more than others such as the commercial automobile industry, relies very strongly on its supplier base. Like perhaps no other industry, here is where a truly symbiotic relationship must exist. Lastly, it is essential that the company continue to measure its operations and manufacturing efforts with metrics and performance measures which get to the efficiency of the system to *sell* product and not simply to *acquire* the materials or parts to make that product. This to some extent is already being done quite successfully in some aspects of Plant A, but there are still areas within the plant (i.e. sourcing) which are not being measured to the same standards. In fact their standards are not even compatible with those of the other areas of the operation.

In once again examining the "Front-end Loading Causal Diagram" which has been provided as Figure 5.4, one can now clearly see the areas which this company has addressed and most likely will next address in the relatively near future on the issue of the front-end loading of inventory:

- "Emphasis on schedule" referred to the company's need to meet delivery schedules at all cost. This need will still be met, even more so with the "pull" factory concept. Emphasis on schedule does not have to mean excesses of inventory when material management systems are efficient and accurate. Systems such as the company's newly implemented MRP II system will provide this accuracy.

- "EOQ policies/batching" still will exist, as they do in most modern manufacturing operation. There will always be economies to be had in carefully weighing annual usage figures against the cost, setup cost, and annual carrying cost of the item. However, with better supplier relations, and with more visibility into the needs of the manufacturing operation, there will doubtless be less "rote" ordering of materials by a system which has until now been largely unattached from and unaffected by the actual manufacturing process.



5.4 Causes of Front-End Loading

- The "separation of various functions and different and conflicting performance metrics" are certainly issues which are recognized by Plant A, and hopefully these issues can be reconciled shortly with a combination of modified metrics and/or a reorganization or realignment.

- The overall attitude of the company ("resistance to change", "excess over shortage", "no competition/sole source") has certainly shifted over the last six or seven years, and this new attitude is making its way down to the working level.

- "Poor material management and tracking systems": with implementation of an MRP II system, a great many problems will hopefully be solved. The system will finally have an "owner," and changes to the system will not be allowed without informing the inputter of implications/ramifications throughout the system and on other contracts, etc. Information on multiple contracts will be connected in the same database as well.

- "Interpretation of policy" has changed over time to mean, if anything, the more literal interpretation of existing government policy, largely to the benefit of inventory levels and government/company relations.

One can also see from this same diagram that the government (for the most part in the form of the DPRO) has also modified its behavior over the past years, and this modification has also been beneficial to the reduction of unnecessary inventory, especially in the receiving and storage area:

- The DPRO is actually "physically validating levels" and is moving actively toward more process inspection rather than product inspection. This will most likely mean less scrap, rework, etc. and therefore less inventory.

- "Resistance to change" on the part of the government is somewhat of an issue at the System Program Office (SPO) level, but has been greatly changed in the DPRO.

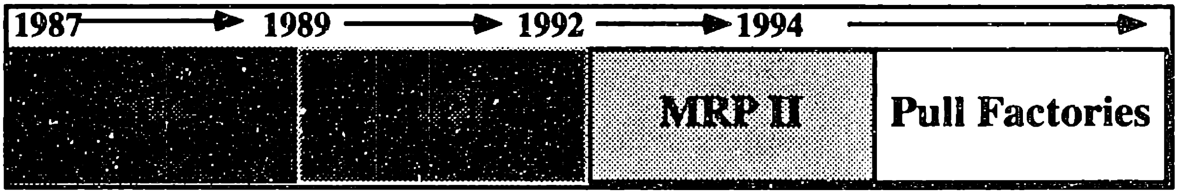
- "Interpretation of [some] policies" has changed slightly to the benefit of reduced inventory levels. Other policies and standards have been more rigorously enforced than they had in the past.

Although Table 5.1 and 5.2 do indicate that the company still has some distance to travel to further reduce inventory, they have made marked progress over the past several years in lowering these levels. The SPC, CPI, and MMAS initiatives all focused on fixing the *existing* processes and procedures -- providing an accurate picture and documenting the current inventory situation. These efforts needed to be undertaken in order for subsequent endeavors such as MRP II and pull factories to successfully change the inventory picture of the *future*. Referring to Appendix A, one can see that Plant A has recently addressed a number of the "lean" criteria presented in this figure. They have a formal program for decreasing inventory and streamlining inventory handling. There increasingly is a shared attitude at all levels of the organization concerning the need to reduce inventory. The plant managers now know the quantity, location and value of their inventory. There has been a successful effort to reduce the number of suppliers, and there is a very low number of job classifications on the shop floor. The plant has worked at replacing after-the-fact inspection with process verification through the use of Statistical Process Control at all levels of the production process. Above all, there has been strong top management support for all of these initiatives and changes. The above listing does not include every item included in Appendix A. Some of these items were not covered within the scope of the case study, while in still others the company still needs to make progress (such as the reduction of obsolete and excess material).

All of the progress which Plant A has made was, and will be, done without any modification to the government progress payment infrastructure or to the procurement and budgeting process which is already in place. This is certainly not to say that modifications to these policies and practices are not necessary or warranted, but instead to suggest that it is possible to affect change *within* the existing system as well as by modifying the external environment. This case study also should not suggest that the *only* path to lean in the aerospace and defense industry is to adopt *exactly* the same initiatives and the same interpretations of standards and policies as Plant A and their government counterparts did. Rather, this case study is intended to show that practices such as SPC and CPI can be utilized in a low volume, low production run environment with success and significant savings in total cost, cycle time, and reduced inventory. As well. MRP II is an option which provides companies increased visibility into their production planning.

This brief look at one company's progress towards lean should also pointedly demonstrate that "leanness" cannot be achieved overnight. Rather, it is a process which takes years to accomplish, even with enormous pressure and support from upper management and the government. Figure 5.5 provides a rough timeline of the events which have occurred over the past six or seven years at Plant A. The initiatives do overlap one another in time. Each individual initiative such as SPC, CPI, or MRP II takes a great deal of time to implement and must be properly sequenced with others so as to achieve the most optimal end results.

Figure 5.5: Timeline of Plant A Initiatives Which Reduce Inventory



This should not discourage companies from aggressively pursuing lean practices; efforts such as the insertion SPC, the empowerment of workers, or the reduction of the supplier base are inevitable steps which must be taken to remain competitive, regardless of the timelines required. Rather, this caveat is intended to warn that "lean" is not a panacea which can be invoked without any accompanying dedicated action to address problems.

What this brief case study has done is to confirm that inventory and inventory practices are indeed a window into what is or is not lean practice in a company. Excess or elevated inventory levels result when scrap, rework and repair levels are higher than they should be. These problems can be successfully addressed with the implementation of methods such as SPC and CPI. Poor material management and excess inventory buffers can occur when supplier relations are sub-optimal, and can be improved by reducing the supplier base, and maintaining close and long-term relationships with remaining suppliers. Inventory levels can be higher than necessary when poor communication exists between management and workers, either because inventory goals are not adequately conveyed to workers, or because workers are not sufficiently empowered to seek out and eliminate problems which might encourage excess material procurement.

All of the above listed issues have as their common thread the poor management of materials, but this is just a symptom of a larger problem: the lack of a lean manufacturing system and supporting operational infrastructure. A system which reduces waste and non-

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Chapter 6: Recommendations for Follow-on Work

The Inventory Practices Survey has resulted thus far in several outputs which are of use to both industry and government sponsors alike. Presentations on survey results have been given to the sponsoring companies as a group, and to the Airframe and Electronics sectors as well. Scorecards which outline individual company's responses in relation to those of their sector peers have been distributed, and companies are in the process of evaluating further what these data tell them about their own operations. This thesis and a planned thesis on the implementation of MRP II systems are also products of the Survey process thus far. In the near future, however, there is certainly additional work which can be done to glean further benefit from the vast amount of information captured by the Inventory Practices Survey. This chapter will briefly cover a few ideas for this follow-on work.[1]

6.1 The Front-End Loading Issue

Although the case study included as Chapter 5 provides some insight into the issue of excess inventory in receiving and storage, there is still a great deal which can be done to complete the picture on this important issue. Although the case demonstrates that in this company's case inventory, total cost, and cycle time were successfully reduced using SPC, CPI and MRP II, it still remains to be seen how these initiatives can be successfully transplanted into other companies and what the associated implementation issues might be. Currently, a very low number of the surveyed companies use MRP II, and an even lower percentage use SPC in any stage of production. Clearly there must exist barriers which

[1] Aside from section 6.1, these ideas have been derived largely from the follow-on questions to the Inventory Practices Survey which resulted from the sector briefings given to the Airframe and Electronics sectors. The Airframe and Electronics sectors combined comprise over 63 percent of the total companies responding to the original survey.

have hindered the insertion of these relatively proven manufacturing techniques and control methodologies into the majority of defense contractors involved in this study. As well, the government and the case study company experienced positive results using very specific interpretations of the rather broad language contained in several governmental policies and standards (in particular with MMAS). It is not certain that the same results can be replicated in a different contractor environment. Each DPRO/contractor pair has a distinct relationship grounded in history and experience, and tempered by the influence of individual personalities. It might be difficult to modify interpretation of policy without significant effort and/or resistance on the part of all involved. All of these issues merit further study, perhaps with another case study on a different company with a relatively new product and contract (e.g. the F-22 project).

6.2 Excess Material at Contract's End

The survey process identified that there was an issue with both government and contractor personnel alike with the disposition of excess material and inventory remaining when a contract is closed. The problem does not seem to be what to do with the excess material (material is sold as scrap, sold to follow-on contracts or other contracts which use the same items, given to trade schools, etc.), but instead the issue is the *time* that it actually takes for the government and contractor to jointly identify that a) the material is excess and b) that it should be dispositioned elsewhere. In some cases, this process can take months and even years. In the meantime, this excess material lies unused, contributing to contractor overhead rates among other things. At the same time, duplicate material and inventory may be requisitioned for other similar contracts at an unnecessary additional cost to both contractor and government alike.

When queried on this matter, industry representatives had a number of good ideas on how to shorten the timelines associated with this process. Among them were to shorten the maximum time allowed by government regulations for identifying excess material upon contract close-out. Currently, according to the FAR, the contractor has 90 days *once the government formally notifies the contractor that material is excess* to properly disposition this material elsewhere. It has been suggested that 30 days is perhaps a better interval. The same suggestion also said the responsibility should shift from the government to the contractor to start this clock. Presumably, the contractor has more of an immediate incentive to identify excess material and reallocate it to some other billing area. Another recommendation said that better inventory management systems which communicate *across contracts* would go a long way in helping speed up the process of identifying excess material which might be used elsewhere. As was demonstrated by the case study in this thesis, some contractors' material management systems do not yet have this capability. At a corporate level, if stronger emphasis were placed on minimizing floor space it has been suggested that this would further encourage reduction of inventory from completed contracts. A final suggestion holds that pre-contract determinations of minimum and maximum requirements on the part of the government would help to avoid excess inventory at contract end.

This issue needs to be further explored by consulting with the Lean Aircraft Initiative's government representatives on the ideas which industry has presented to alleviate the problem of excess inventory due to slow contract close-out procedures. It would appear that the problem can be solved administratively by the government and in a very short time.

6.3 Accounting Related Issues

Accounting issues seem to be a ripe area for immediate exploration by the Fabrication and Assembly group. In particular the topics of Activity Based Costing and direct charges for inventory have surfaced as a result of the survey as being of particular interest on the part of industry, government and academia for insertion of lean practices.

6.3.1 Activity Based Costing (ABC)

As mentioned in Chapter 3, Activity Based Costing was covered in the Inventory Practices Survey in the Accounting Practices section (see Chapter 3.2.3).[2] Many commercial manufacturing operations are currently in the process of adopting this form of accounting because it corrects the deficiencies of conventional cost systems and provides better support for lean manufacturing. From the data collected through the Inventory Practices Survey, ABC is still relatively uncommon in the aerospace and airframe industry. In researching this further, Airframe and Electronics sector representatives were asked to identify the barriers that they perceived in inserting and utilizing ABC. Among their responses were governmental inhibitors such as Cost Accounting Standards (CAS), the Federal Acquisition Regulations (FAR), and the need for the DPRO to approve accounting changes. On the corporate end, issues such as cost, complexity of redesign, administrative burden, and lack of perceived benefit due to such things as low production runs and small lot sizes were common. In general, respondents worried that there was a pervasive lack of commitment and education on the part of both government and industry representatives; both of which would be required to support such a major initiative successfully.

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[2] Activity Based Costing is a "method of measuring the cost and performance of activities and cost objects. [It] assigns cost to activities based on their use of resources, and assigns cost to cost objects based on their use of activities. ABC recognizes the causal relationship of cost drivers to activities." Turney, Peter B.B., *Common Cents*, Cost Technology, 1991, p. 72.

These same industry representatives had some ideas on how to overcome these barriers to the implementation of ABC. Some of these suggestions included modifications to the CAS and FAR, government subsidies on the costs of industry redesign, non-retribution periods during the change-over phase, and training for government and industry representatives.

What is needed to further investigate this area of interest related to inventory practices is a case study or series of case studies. Although use of ABC in the aerospace industry is limited (22 percent of the companies surveyed), there are companies which are currently using ABC in various aspects of their manufacturing operations. These companies should be investigated by the Lean Aircraft Initiative to collect information on the processes and procedures which they have followed thus far, and the barriers that they encountered along the way.

6.3.2 Direct Charges for Inventory

In a follow-on question to the Inventory Practices Survey, Electronics and Airframe companies were asked whether or not they direct charged inventory handling or storage costs. The majority of those who responded (8 of 13 for storage and 6 of 12 for handling) do not use direct charging. There appear to be few barriers to adapting this kind of accounting practice. Those who do successfully use direct charging were required to get Cost Accounting Disclosure statements, DCAA approval and/or extensive management review and approval to do so. A case study could answer whether this switch over to direct charging should be made (what the benefits are) and if that decision is sector-dependent.

6.4 Re-inspection of Certified Suppliers

The inventory survey showed that there was a great deal of reinspection going on on the part of prime contractors of certified suppliers (see Chapter 3.2.6). The question arose as to why this redundancy existed and whether or not it was driven by government policy and regulations. Answers from the Electronics and Airframe sector most frequently cited MIL-STD-1535 (Supplier Quality Program Requirements) and MIL-Q-9858 (Design for Quality) as the causes of this additional level of reinspection. Although in no place in these standards are prime contractors required to inspect per se, they are required to take "responsibility ... that all supplies and services procured from ... suppliers ... conform to contractual requirements."[3] The majority of contractors surveyed interpret this as meaning reinspection. At the same time, the MIL-Q-9858 also states that the "contractor shall utilize to the fullest extent objective evidence of quality furnished by his suppliers." The question would seem to be whether or not by virtue of using a certified supplier, one has enough "evidence" to avoid the redundant inspection process. Also, what are the savings to be had by eliminating this layer of inspection in terms of overhead costs, administrative activities, and lead time reduction? These questions can perhaps best be answered by a case study which quantitatively examines the economics of the issue, and qualitatively probes the limits of the existing standards and their interpretation.

6.5 Commingling

A final issue which arose as a result of the Inventory Practices Survey and the Fabrication and Assembly group's activities concerned that of the practice of commingling inventory. Commingling refers to the actual physical storage of materials together which might either

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[3] MIL-Q-9858, Paragraph 5, "Control of Purchases."

be from a different contract or from a different owner (i.e. a particular item of inventory might be owned by the government and the same kind of item owned by contractor, but the two are physically stored together in the same bin). Some involved in the Initiative believed that commingling was an issue; that companies were prohibited by regulations and standards from doing the most cost effective thing -- to share storage space. Upon investigation, it was found that of those surveyed over 90 percent (14 of 15) did commingle, and with relatively minimal prerequisites to do so by the government (such as DCAA/DPRO/SPO approval, or proof of a sound inventory tracking system). It would appear that the commingling issue is really not an issue. Rather, those companies and DPROs who still believe that it is prohibited should be put in touch with those who do it as standard practice.

Appendices

Appendix A: Evidence of Lean Production from the Inventory Practices Survey

Source: Dr. James Ling and the Inventory Practices Research Team (December 1993)

1. Have a stated inventory goal.
2. Have a formal program to reduce inventory or streamline inventory handling processes.
3. Same attitude at all levels of the organization with regards to shortfalls and excess inventory.
4. Know age distribution of inventory.
5. Know quantity and value of inventory, and communicate that information to all levels of the organization.
6. Know location of inventory.
7. High use of JIT or near JIT.
8. Low number of suppliers (high $/supplier ratio).
9. Low and declining number of job classifications.
10. Inventory age distribution that shows young inventory at all stages and a definite progression out the door.
11. Use of manufacturing touch labor to do inspection.
12. Small number of inspectors.
13. Use of process verification to replace after-the-fact inspection.
14. Total top management commitment to process verification.
15. Rapid decision cycle for disposition of faulty parts.
16. Have effective system of tracking problems to root causes.
17. Use of systematic variability reduction .
18. Use of Statistical Process Control (SPC).
19. Use of SPC charts as evidence of quality.
20. High use of SPC in all production stages.
21. Have data on defects for all stages of production.
22. Low rate of re-inspection for items already inspected by supplier.
23. Large percentage of suppliers certified for ship-to-stock/assembly.
24. Small number of people supporting inventory.
25. Minimal (ideally zero) scrap, rework, and repair.
26. No obsolete or excess inventory.
27. Low cycle time.
28. Use of automated process flow scheduling and planning system.
29. Use of simulation to model and plan process flow.

Appendix B: Excerpts from Material Management and Accounting Systems 252.242-7004 (f)

MMAS standards.

MMAS systems shall have adequate internal accounting and administrative controls to ensure system and data integrity, and comply with the following:

(1) Have an adequate system description including policies, procedures, and operating instructions which comply with the Federal Acquisition Regulation and Defense FAR Supplement;

(2) Ensure that costs of purchased and fabricated material charged or allocated to a contract are based on valid time-phased requirements as impacted by minimum/economic order quantity restrictions --

(i) A 98 percent bill of material accuracy and a 95 percent master production schedule accuracy are desirable as a goal in order to ensure that requirements are both valid and appropriately time-phased...

(5) Establish and maintain adequate levels of record accuracy, and include reconciliation of recorded inventory quantities to physical inventory by part number on a periodic basis. A 95 percent accuracy level is desirable. If systems have an accuracy level below 95 percent, the Contractor shall demonstrate that --

(i) There is no material harm to the government due to lower accuracy levels; and

(ii) The cost to meet the accuracy goal is excessive in relation to the impact to the government...

(7) Maintain a consistent, equitable, and unbiased logic for costing material transactions --

(i) the Contractor shall maintain and disclose a written policy describing transfer methodologies.

(ii) The costing methodology may be standard or actual cost, or any of the inventory costing methods in FAR 30.411-50(b). Consistency shall be maintained across all contract and customer types, and from accounting period to accounting period for initial charging and transfer charging.

(iii) The system should transfer parts and associative costs within the same billing period. In the few circumstances where this may not be appropriate, the Contractor may uses a loan/pay back technique only if approved by the administrative contracting officer. When the technique is used, the Contractor shall have controls to ensure --

(A) Parts are paid back expeditiously;

(B) Procedures and controls are in place to correct any overbilling that may occur;

(C) Monthly, at a minimum, identification of the borrowing contract and the date the part was borrowed; and

(D) The cost of the placement part is charged to the borrowing contract...

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