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THE ANALYTIC SCIENCES CORPORATION

TR-3370

ANALYSIS OF CRITICAL PARTS AND MATERIALS

December 1980

Prepared under

Contract No. F 33657-79-G-0089

for

Air Force Business Research
Management Center
Wright-Patterson AFB, Ohio 45433

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ABSTRACT

This study analyzes data on selected Air Force systems, subsystems and components with regard to lead time. The first phase of the study resulted in a preliminary analysis of the data and highlighted areas for more detailed analysis. This report focuses accordingly on five components-bearings, castings, connectors, forgings and integrated circuits -- which have long lead times critical to subsystem and system delivery times. Reasons for increased lead times are provided and recommendations made for actions which could result in decreased lead times in the future. A definition of a model for forecasting shortages of critical parts and materials is outlined in a final chapter.

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1. EXECUTIVE SUMMARY

The purpose of this study is to identify the reasons for increasing lead times in Air Force systems and to make recommendations which could help to counteract lead time stretch-outs.

Lead times for many Air Force systems increased dramatically over the period 1977 to 1980. For example, the A-10 aircraft had a lead time of 27 months in 1977, but this had almost doubled to 49 months by early 1980. Similarly, the F-16 aircraft's lead time was 20 months in 1977 but had more than doubled to 42 months by early 1980. Severe stretchouts such as these prompted investigation by Air Force Systems Command in the spring of 1980. These long lead time increases came without warning and one purpose of conducting a study into the reasons for lead time increases was to establish a means of predicting such situations in the future. Any such forecast would need to include the availability of critical materials and components. Air Force Systems Commmand sent selected program offices a questionnaire requesting information on lead times in 1977 and (January) 1980 for systems, critical subsystems and critical components.

This report firstly analyzes information provided by the AFSC survey to determine which components and materials may be seen as critical to a significant number of Air Force systems and subsystems. On the basis of this analysis recommendations for action are made, and data gathering for a predictive system for shortages of critical components and materials is defined.

The preliminary analysis or first phase of this study was completed in a one-month period. This analysis showed that the most dramatic and critical lead time increases had been occuring among five groups of components common to a large variety of aerospace systems and subsystems -- these components were identified as bearings, castings, connectors, forgings and integrated circuits.

In the second phase, all data relating to these five components was extracted and computerized using the Statistical Analysis System (SAS) package on TASC's IBM 370 computer. Statistical analysis demonstrated similarities and differences between the five component groups. For example, it was shown that lead times had been stretching out most significantly (and were also the longest in absolute terms) among forgings, and that, in comparison to forgings, integrated circuits had low lead times in spite of the overall increases. Product-moment correlation and multiple regression techniques showed a statistically high correlation between component, subsystem and system lead times, showing system lead times to be strongly dependent on component lead times. Components, rather than sub-systems, were seen to be the basic cause of system lead time increases.

The most frequent reasons given in the survey for increases in component lead times were lack of supplier capacity, high demand (also from the commercial sector) and methods of doing government business. Other reasons quoted design problems, materials shortages, production problems, labor problems, management problems or the general economic situation as detrimental influences on lead time performance for Air Force systems. The repeated mention of limited manufacturing capacity as a determinant of long lead times prompted a preliminary investigation into capacity within the five industries studied. Suppliers were contacted for clarification of this issue. Although there is a significant element of unused capacity at these Air Force suppliers' plants, this capacity is not usually suited to military aerospace orders. The majority of suppliers are not exclusively in the military aerospace business, indeed, many deliberately minimize their dependence on defense business and maximize their revenues and orders from commercial customers. Frequently, the defense suppliers stated that they would be less reluctant to do more defense business if there was greater certainty about future orders, (e.g., multi-year orders).

Some recommendations made by the program offices in the survey were agreed to by suppliers contacted as an aid to reducing lead times and a better way of doing government business in general. Most recommendations made by the program offices fell in the general area of procurement management. These recommendations included a tendency towards more government visibility, such as evaluation of contractors' purchasing systems and lead time records and more communication with primes and subcontractors. Suppliers were against any further government control over their business but were in favor of early planning, larger orders where feasible, and multi-year program funding. Suppliers were also in favor of government incentives such as higher depreciation allowances and investment tax credits. Firms did not want the government to establish new capacity but rather, act to encourage industry if more capacity was seen as a long-term need. Basically, industry will provide military aerospace components, subsystems and systems but would like to have greater certainty that this business will continue for several years.

The government annual planning and budgeting cycle is, of course, the established way of doing defense procurement, but there seems to be a general concensus, certainly among suppliers, that all concerned in procurement would be in a better position if some changes could be made to the annual procurement funding cycle. Although procurement offices and suppliers tend to differ in their views on how to improve lead times and ways of doing defense business in general, there are nevertheless areas of agreement. It seems clear that suppliers will not react favorably to any slight modifications of current systems, but, instead, would welcome departures from certain current practices and new ways of doing government business.

On the basis of the foregoing research and analysis and other studies (such as prior TASC work, and the DSB summer study of 1980), TASC developed some recommendations which are intended not only to aid in decreasing lead times in the future, but also to increase the general effectiveness of Air Force systems procurement. These recommendations are:

- <u>Multi-year Funding</u>

  Introduce multi-year funding for systems which are likely to be procured over several years

  Raise termination liability from $5 million to $100 million

- <u>Improve Capacity</u>

  Dispose of government equipment which uses outdated technology (e.g., more than 20 years old) and use proceeds to improve equipment currently in use

  Encourage industrial expansion of capacity in areas which do not compete heavily with commercial demand and for which there is likely to be a continuing heavy demand for defense purposes, through tax incentives, etc.

- <u>Rationalize Orders</u>

  Simplify military specifications where possible

  Use more off-the-shelf items where possible (e.g., connectors, integrated circuits)

  Buy spare parts with initial procurement

  Combine orders where possible to benefit from economies of large production runs

- <u>Address Critical Source Issues</u>

  Dependency on foreign sources

  Sole source suppliers (e.g., require multiple sources wherever possible, especially at the lower tiers)

- <u>Provide Incentives to Defense Suppliers</u>

  For example, more rapid depreciation, capital investment allowances for defense business, flexibility in profit margins

  Improve cash flow to suppliers

  Utilize Title III of the Defense Production Act to provide loans or loan guarantees, subsidize purchases, or support domestic mineral exploration and development

- <u>Pre-order and/or Stock Long Lead Materials and/or Components e.g., Critical Materials, Raw Forgings (Unmachined)</u>

- <u>Improve Current Regulations and Systems</u>

  Improve Defense Priorities System effectiveness

  Extend Defense Materials System to include other critical materials such as titanium and cobalt

  Increase stockpile of critical materials in light of current and projected needs. Review conditions for release of materials

  Reduce paperwork required by government subcontractors

- Other Recommendations

  Monitor procurement cycle to see where improvements might be made and lead times reduced

  Address issue of actual/projected lack of skilled labor in key aerospace industries

  Develop a forecasting system to give early warning of shortages of critical parts and materials

Data gathering for a predictive system, designed as a decision-making tool for the Air Force, is defined in the last section of this report. Through generating a set of defined indicators to provide early warning of a few, very selective possible lead time increases and bottlenecks (from a data base including commercial demand, defense demand, capacity and manpower constraints, firms in the industry, queue time and manufacturing time) the system will enable the user to take preventive and/or corrective actions. Analytical techniques such as regression and network theory will be used to define the set of early warning indicators. The system will be designed such that other critical aircraft parts and materials can be added in later phases as well as other Air Force programs. The purpose of the predictive capability is to complement the individual programs' visibility -- using their data -- but taking a "horizontal cut" across a lower tier industry to try to give warning on a very few selected items, of future component lead time (and therefore system) problems.

2. INTRODUCTION

Industrial mobilization during World War II and defense production since that time have largely been carried out unrestricted by materials or critical components. During the past 30 to 40 years defense systems have not only become much more expensive in terms of unit costs, but they have also become much more complex in line with modern technology. Air Force systems now require coordination and processing of thousands of individual parts and materials. Due to this demand and competing military and commercial markets, some materials or parts have become scarce, or the waiting time for their delivery has increased drastically.

The Defense Production Act of 1950 established the Defense Priorities System (DPS) and Defense Materials System (DMS) in order to ensure the availability of parts and materials (limited to steel, copper, aluminum and nickel) for defense production purposes. These systems were used effectively during the U.S. involvement in Vietnam. However, since 1973 it has become apparent that the U.S. is not self-sufficient in many vital materials, and that some critical parts for defense systems, as well as materials, have to be imported. This places the U.S. armed forces in a vulnerable position.

In order to take effective action against the apparent trends of increasing foreign dependency and extended lead times, it is first necessary to understand where and why bottlenecks occur in defense production. Corrective action can then be tailored to fit the specific material shortage or industrial capacity problem. Preventive action is more desirable in the long term than corrective action. To achieve this some method of forecasting problems such as bottlenecks within the Air Force systems production chain needs to be determined and established. The purpose of this study is to aid in achieving these goals so that, ultimately, the Air Force will have its systems produced more efficiently and at less cost than is the case today.

This report presents the results of the second phase of a study conducted for Air Force Systems Command (AFSC). The study of critical materials and parts was prompted by a concern within the Air Force that control over systems delivery times was slipping. The extended periods between a supplier's receipt of an order and the actual delivery of a completed system (otherwise known as "lead time") had been increasing due to a number of factors, many of which were beyond the control of Air Force procurement offices. It became apparent that the chain of order (and, in reverse, of delivery) needed to be examined in some detail in order to establish where and why these lead times were increasing. This chain starts with an order from an Air Force procurement office to the prime contractor, who then selects suppliers for sub-systems if these are not supplied in-house. These sub-system suppliers in turn select their suppliers of components, who in turn select their suppliers of raw materials. Although all suppliers in the chain must be approved or "qualified" defense suppliers, once they have qualified as such, the role of government is felt mainly through the next link in the chain, rather than directly. Consequently, a subcontractor is not held to be responsible and responsive to the DOD, but rather to his customer, which is a prime contractor.

AFSC selected a number of systems for identification of bottlenecks and critical parts and materials. For each system, up to ten critical subsystems were identified, and similarly up to ten components for each subsystem. The purpose of this study was to analyze the input received from the AFSC product divisions and identify the short and long term issues. Further, the study was to provide the Air Force with the definition of a forecasting model for potential shortages of materials and components.

The first phase of this study was a preliminary analysis of the data provided by AFSC to highlight some of the findings and to identify major problem areas (bottlenecks) that would require special attention during the remainder of the study. The results of the first phase were provided both in oral presentations and in bound copies of the viewgraphs used in the presentations with accompanying text.

Proceeding from the findings in Phase 1, AFSC agreed that TASC should focus the major effort in Phase II on examining problems which arise from the five specific components which recurred as bottlenecks in a large number of systems and subsystems. These components were:

- Bearings
- Castings
- Connectors
- Forgings
- Integrated circuits.

Data provided on these components were subjected to statistical analysis as described in Chapter 3. This chapter also highlighted the strengths and weaknesses of the data and made recommendations for any related data-gathering in the future. The results are presented in Chapters 4 and 5. Chapter 6 examines supplier capacity and materials shortages, two frequently cited reasons for long lead times.

The data analysis also led to some tentative conclusions about recommendations of methods to reduce lead times. These initial recommendations were tested and amplified to produce a short list of feasible recommendations. This short list of recommendations included both long term and short term recommendations, which are discussed in Chapter 7.

As a logical development of the foregoing analysis, data gathering, and a system for realistically predicting materials and parts shortages were defined and described in terms of key parameters, techniques to be used, data needs and sources, and other technical aspects. The description of this forecasting system is to be found in Chapter 8.

Profiles supplying background information on the industries studied in this phase are provided in appendices.

3. METHODOLOGY

Phase II of this project focused on the five components which appeared to be major causal factors of lengthy lead times. Bearings, forgings, castings, connectors and integrated circuits are the components most frequently cited as negatively affecting the lead times of both Air Force systems and subsystems. To better understand how these components influenced the delivery of Air Force orders, information about the five were coded and input to TASC's IBM 370 computer.

The data for the computer were obtained from responses to questionnaires developed and distributed by the Air Force Systems Command manufacturing staff. In March, 1980, program officers of the Armaments, Space, Aeronautics Systems, and Electronics Systems Divisions were asked to provide industrial base data about specified systems. The information requested included:

- The name of each system and ten of its principal influencing subsystems
- 1977 lead time for each system and subsystem
- Current (January 1980) lead time for each system and subsystem
- Lead time growth for each system and subsystem
- Manufacturers of each system and subsystem.

In addition, the above information was requested about the principal influencing components of each subsystem.

Program officers also were asked to discuss the causes of the lead time growth and offer recommendations for reducing lead times.

Although the questionnaire requested specific information and provided a format for data entry (see Appendix D), there were disparities in the data provided. Several program officers were most complete in their presentation, even to the extent of specifying the type of component (e.g., aluminum forging) about which they were reporting. In contrast, others neglected to name the subsystem or its manufacturers. The largest group of missing data (41-51%) concerned 1977 lead times. This omission can partially be explained by systems which were not in production at that time.

Another area of concern was that when more than one supplier of a component or subsystem was specified, only one lead time was provided. This omission precluded us from thoroughly investigating whether the lead time for components with multiple suppliers was lower than that of sole source contractors.

The AFSC staff sent a second request to program officers as an attempt to complete the data set. This information has proved most helpful and has facilitated our analysis. However, not all missing data problems have been solved.

After reviewing the data, a codebook was developed to represent the given information and transpose it into a computer readable format. The codebook is presented in Appendix E. Subsequently, the data were entered onto a computer file and statistical analysis was undertaken.

The Statistical Analysis System (SAS) package was used for the analysis. This package provides computer programs for a wide array of statistics, including univariate, bivariate, and multivariate techniques. Univariate statistics, especially the mean, were used in this report to describe the data distribution. Chi-square tests and analysis of variance were useful tools for assessing whether there were statistically significant differences in lead times between components, manufacturers, and Air Force Divisions. Bivariate tables facilitated two-way displays of the data, which were used as the basis for various charts. Product-moment correlation and multiple regression techniques permitted evaluation of the relationships between component, subsystem, and system lead times.

It should be noted that, at best, the information provided only 1977 and 1980 lead times. Therefore, it is insufficient to undertake a valid trend analysis. However, Phase II has highlighted the strengths and weaknesses in the data and outlined the data needs for Phase III.

In addition to the computer work, telephone interviews and literature reviews were undertaken during Phase II. The interviews were conducted with selected personnel from the Department of Commerce, trade associations and various contractors responsible for supplying the five components. The purpose of these interviews was to gain different perspectives about the causes and possible remedies for lengthy lead time.

Purchasing magazine, Air Force publications and reports, trade association statistics, and other literature have been reviewed for industry-wide data on lead time and industry capacity and expansion capabilities.

3.1 SAMPLE DESCRIPTION

The data set represents information on 185 components; 10 bearings (5.41%), 26 castings (14.05%), 53 connectors (28.65%), 43 forgings (23.24%), and 53 integrated circuits (28.65%). These components are parts of 12 systems and 64 subsystems. A total of 100 manufacturers of components (N=57), subsystems (N=31), and systems (N=12) are represented in the data. Lead times varied from 12 to 49 months for systems, 7 to 46 months for subsystems, and 2 to 53 months for components. The four Air Force Divisions are represented in the sample; 6.49 percent of the components were those listed by the Space Division, 21.08 percent by Electronic Systems, 61.08 percent by Aeronautical Systems, and 11.35 percent by the Armaments Division.

4. FINDINGS -- SYSTEMS

4.1 BACKGROUND

This chapter presents an analysis of the data pertaining to the Air Force systems that were studied. Twelve systems from four Air Force divisions were included in the analysis. The systems examined were:

- A-10
- B-52 Offensive Avionics System/Cruise Missile Integration (OAS/CMI)
- E-3A
- ECMS (Electronic Countermeasures) AN/ALQ-137
- F-15
- F-16
- F-16 Operational Flight Trainer (OFT)
- GBU-15
- JTIDS
- Laser Guided Bomb (LGB)
- PMALS (Prototype Miniature Air-Launched System)
- SACDIN (SAC Digital Network)

The Air Force divisions provided information on more than twelve systems, but only those mentioning the five components of interest (bearings, castings, connectors, forgings, and integrated circuits) were studied in detail. Figure 4.1-1

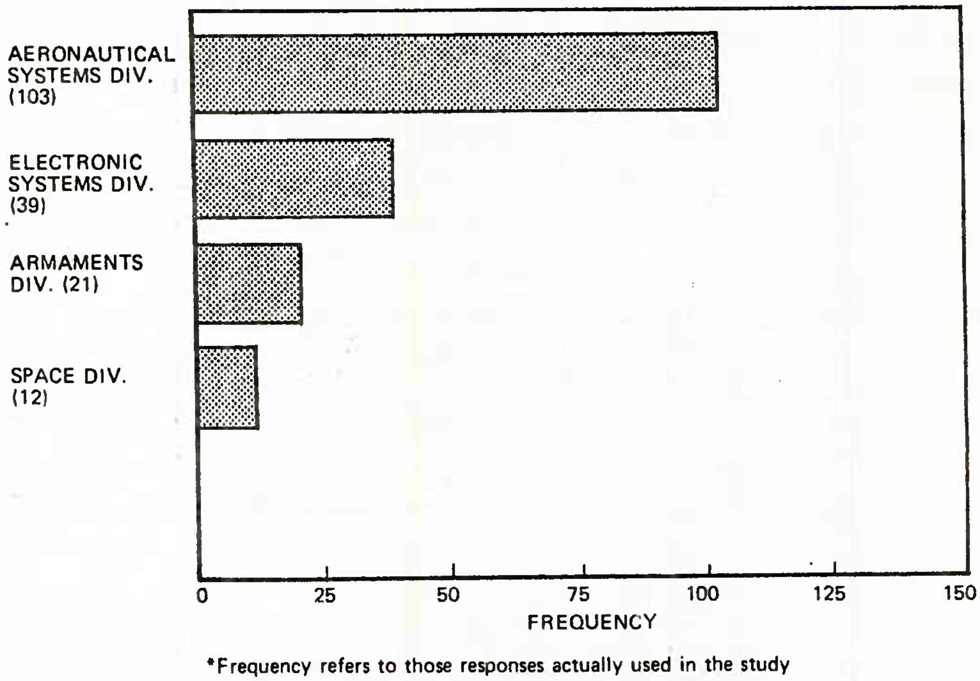


Figure 4.1-1 Distribution of Responses by Air Force Division

gives the frequency of utilized responses by Air Force Division, and shows that the majority of the data comes from the Aeronautical Systems Division. Figure 4.1-2 presents the frequency of utilized responses by system, with the F-16 providing the most data on the components selected for detailed study and the ECMS the least.

System lead times for 1980 have increased on the average by approximately ten months since 1977. For example, the average system lead time in 1977 was 24.37 months, as compared to 34.31 months in 1980. This lead time increase has been driven by similar increases in subsytem and component lead times. Subsystem lead times have increased by approximately six months between 1977 and 1980, and component lead times show approximately a five month increase for the same time frame.

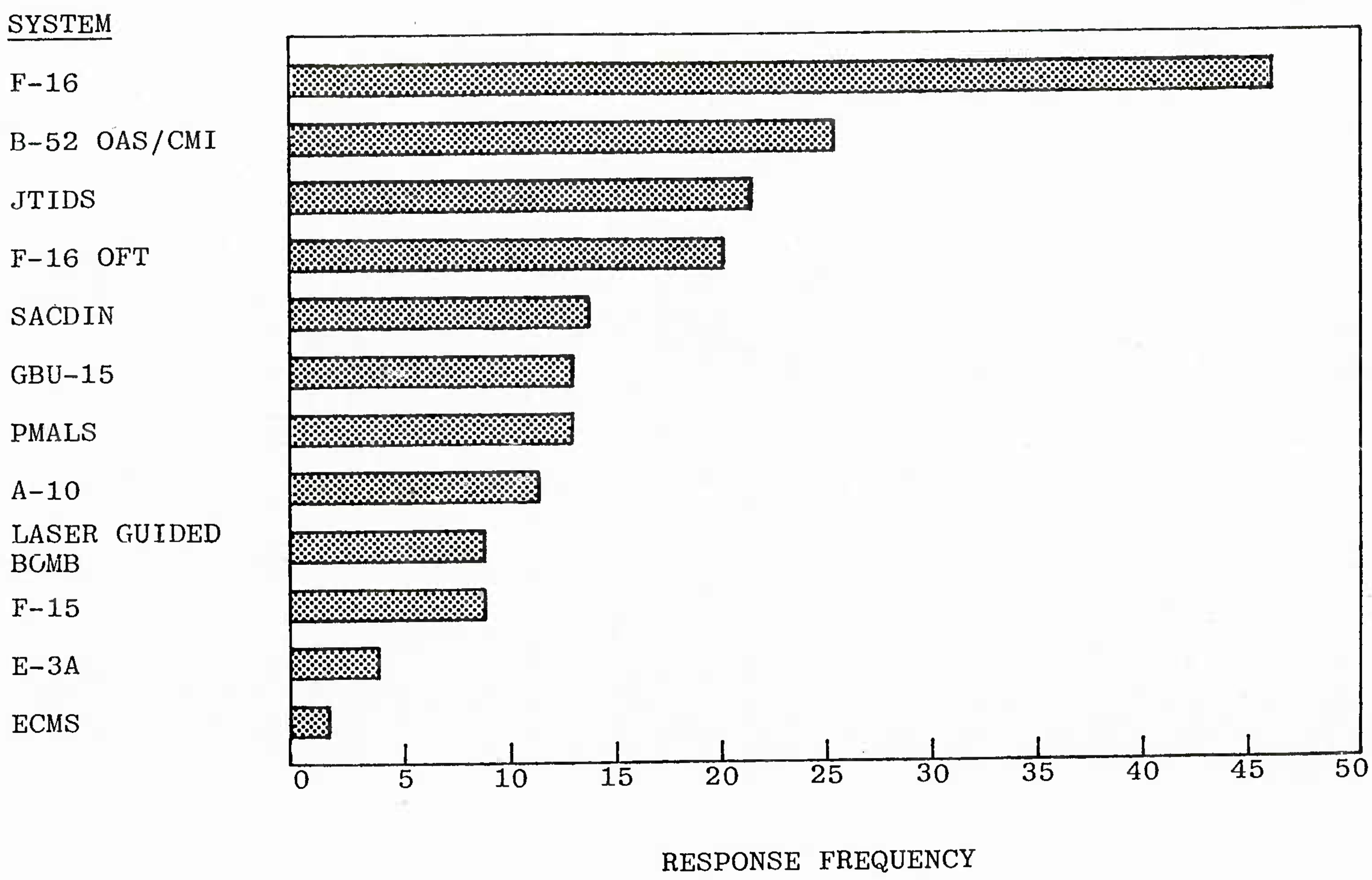


Figure 4.1-2 Response Frequency by System

The statistical results presented in Table 4.1-1 show a significant correlation between the system, subsystem, and component lead times.

TABLE 4.1-1

LEAD TIME PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR SYSTEM, SUBSYSTEM AND COMPONENT, 1980

System/Subsystem	0.76368
System/Component	0.50110
Subsystem/Component	0.83732

The strongest correlation is found between subsystems and components, where approximately 70 percent of the subsystem lead time may be explained by the component lead time. The relationship between system and subsystem lead times is somewhat lower, yet still shows that approximately 60 percent of the system lead time may be explained by the subsystem lead time. These figures verify what has been intuitively believed throughout the study -- that component lead times directly impact the ability of the Air Force to deliver systems on time.

Figure 4.1-3 illustrates the relationship between system, subsystem, and component lead times for five of the systems studied. In the A-10 system, for example, it shows that the ability to obtain forgings is driving the landing gear lead time, which in turn drives the overall lead time for the system. It should follow that if component lead times could be reduced, subsystem and system lead times could also be expected to decrease.

The survey respondents were asked to give their impressions of the causes of lead time growth. The responses

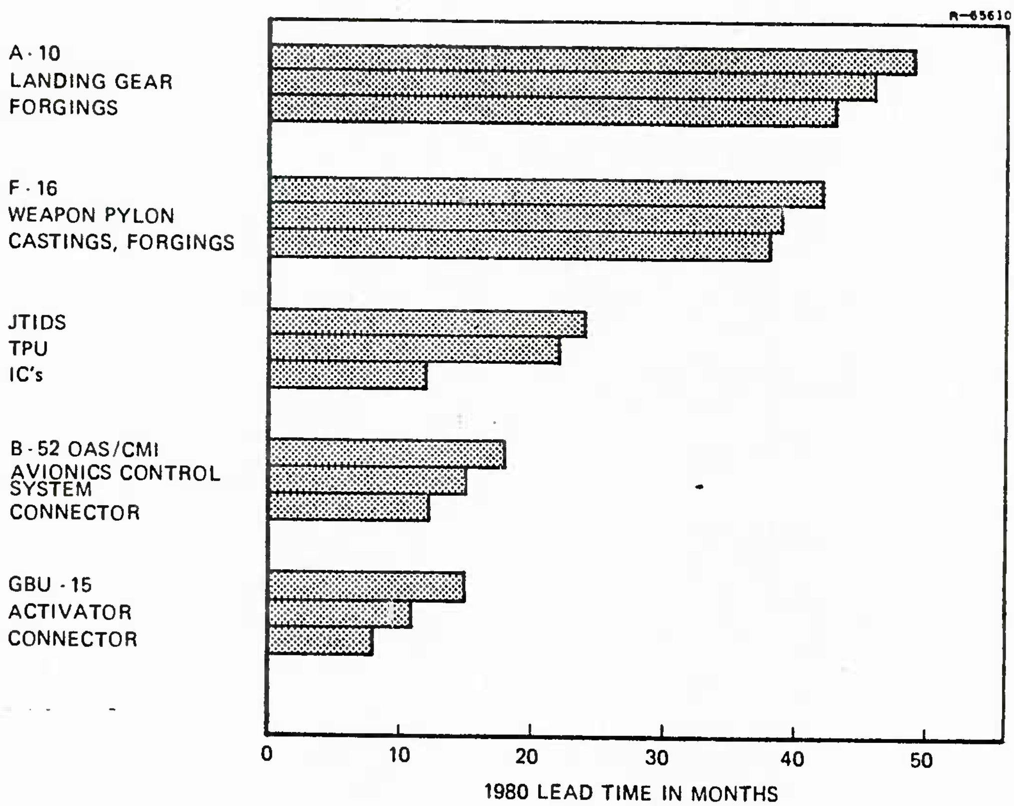


Figure 4.1-3 System-Subsystem-Component Lead Time Relationships

which were general in nature, or which explained overall reasons for system lead time increases are given in Figure 4.1-4. Figure 4.1-5 shows in more detail the types of reasons that were given for system lead time increases. Reasons given for specific component lead time increases were separately coded, and those responses are summarized in Chapter 5, Figure 5.1-4.

High demand was cited most frequently (18%) as the reason for long lead times. Demand coupled with lagging capacity (12%) accounted for 40 percent of the responses. Commercial sector demand for raw materials and machine time, particularly

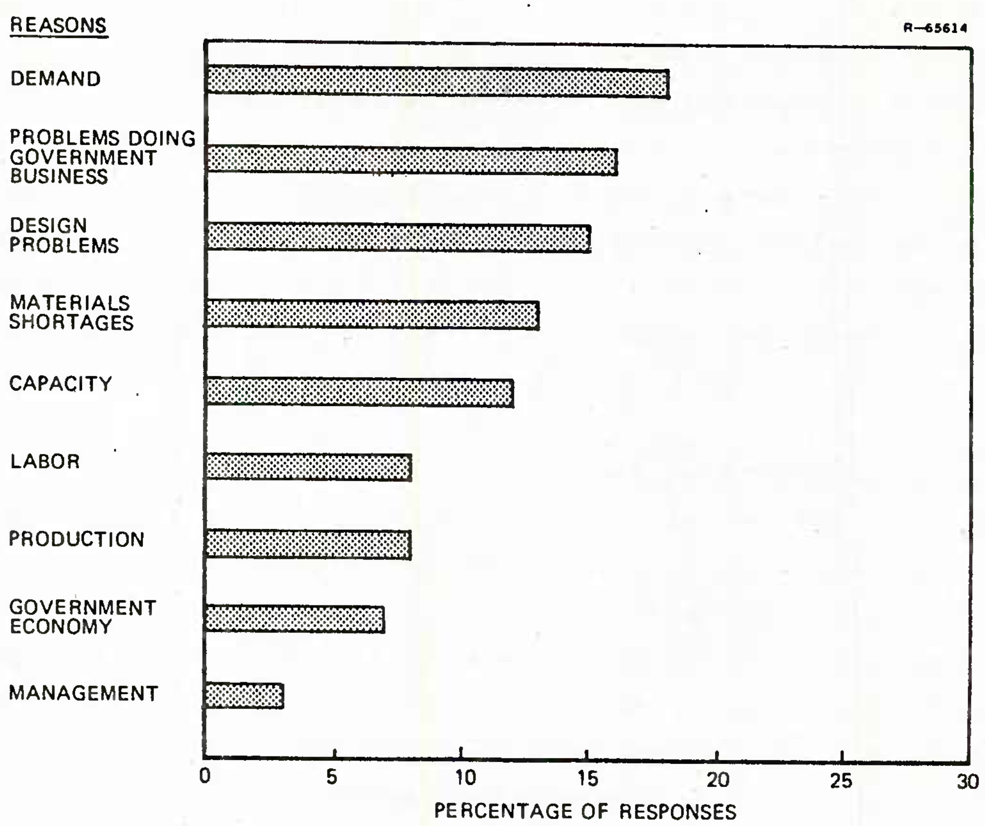


Figure 4.1-4 Reasons Given for System Lead Time

in the automobile and electronic toy industries, was frequently mentioned as a factor affecting the Air Force's lead times.

The dominant theme in the responses was that despite the high demand and limited capacity, which affects government and commercial buyers equally, the Air Force is not in a position to compete equally with the commercial sector because of problems industry has in doing government business. In particular, small volume orders make the Air Force a less attractive customer to industry than the commercial customers with larger and more profitable orders. These small orders are the result of government year-to-year funding procedures, as well

CAPACITY

Capacity Problems
Concentration of Industry in Southern California
Shortage Quality Suppliers
Low Yield Rate
Plant Closings

PROBLEMS WITH GOV'T BUSINESS

Distrust of Gov't Business
Year-to-Year Funding
Patent Rights
Procurement Lead Time
Small Volume Orders
Regulations/Requirements
Sole Sourcing

DESIGN

Changes Made Later
Custom or Special Devices
Higher Quality
Push State-of-the-Art
Technological Change
Variety of Parts

MATERIAL SHORTAGES

Aluminum
Cobalt
Nichrome
Silicon
Titanium
Metals
Materials

LABOR PROBLEMS

Labor Problems
Manpower Shortage
Turnover

ECONOMIC PROBLEMS

Economy in General
Energy
Deferred Investment Incentives
High Capital Costs
Reduced Investments

DEMAND

Increase in A.F. Demand
Commercial Sector Factors
Competition From Other Subs.
Demand at Test Labs
Demand in General
Low Military Demand

MANAGEMENT PROBLEMS

Priority Ratings Failure
Management/Admin. Problems
Variation in Admin. Time

PRODUCTION PROBLEMS

Component Delivery Late
Delivery Late Within Company
Obtaining Tools and Dies
Item Produced Specific #1 Times Per Year
Piece Part Lead Time
Secondary Machinery
Time for Packaging
Tooling Not Available
Transportation Problems
Unique Manufacturing Problems
Variation in Dock Time

Figure 4.1-5 Reasons for Lead Times

as system-specific reliability requirements. Industry is hesitant to expand capacity based on present defense demand because historically the defense business has been so cyclical, and from industry's point of view, offers no long-term guarantee of steady buys. The Defense Priority System (DPS), if used effectively, could improve the status of Air Force orders by requiring industry to fill the defense-related orders prior to the commercial ones. Yet, the DPS does not appear to be followed by industry or actively enforced by the Air Force.

Many government procurement practices were cited by the respondents as aggravating lead time trends. As discussed earlier, year-to-year funding results in small orders and gives industry no assurance of continuing business. Qualification requirements that must be met by companies before they are allowed to produce military components are often very demanding, expensive, and time-consuming especially for small companies to meet. The result is that only a limited number of firms are available to manufacture certain components. In some cases critical parts and components are only available through a sole source contractor, which can significantly reduce the Air Force's options when trying to meet deadlines or adjust time schedules.

Raw material shortages were frequently cited by the Air Force divisions as contributing to long component lead times, which in turn increase system lead times. In particular, limited supplies of aluminum, cobalt, nichrome, silicon, and titanium were mentioned as impacting the lead times of some Air Force systems. As discussed in Chapter 6, capacity in some of these industries is currently expanding to meet increased demand.

Air Force component reliability requirements are generally higher than those for commercial systems. This results in smaller orders and special production runs, which in turn cause lead time increases and make Air Force orders less desirable to industry. Easing of the requirements or designing for more off-the-shelf items would ease the impact on lead times.

Other problems seen as influencing lead time behavior include labor shortages, general economic conditions, unique manufacturing problems, and design changes made after orders have been placed. Labor problems, and in particular the lack of skilled aerospace workers and engineers, impact commercial and military production equally. The overall economic condition of the country was cited as influencing lead times by discouraging capacity expansion, causing high capital costs, and resulting in reduced inventories.

Special manufacturing problems which impact lead times include obtaining specific tools needed for production, tooling no longer being available, and transportation and packaging delays. Changes in design made after an order is placed are more common in military than commercial procurements, due in part to the changes that often take place in specifications during the research or prototype development phases. Year-to-year funding may contribute to design changes in that procurement officers, eager to place an order in a certain year, may be forced to later revise the order after further testing or development.

The remaining sections in this chapter are devoted to the analysis of system lead times. A brief description of each Air Force Division which responded is given, and lead time trends for the twelve systems are analyzed.

4.2 SPACE DIVISION

The military, as a whole, generally needs higher quality components than the commercial sector, and the Space Division's parts demand a greater degree of reliability than those of other military systems. This need for higher reliability is due to the environment in which the systems will operate and the inability, in many cases, to quickly repair or replace a component that has malfunctioned.

The Space Division's lot sizes for these special parts are small in comparison with commercial orders. The result is that industry is often unable or unwilling to produce the orders promptly. The commercial orders involve longer production runs, standardized parts and greater profitability for the contractor. There is, therefore, every incentive for the contractor to fulfill commercial orders before the special defense orders. The Space Division considers these small orders of high reliability parts to be the primary cause of increasing system lead times.

When compared to other systems in this study, Space Division systems are unique in the way schedules are prepared. Schedules are established by working backward in time from an established launch date. As a result, design time is often compressed to meet the launch-drive schedule and purchase orders may be placed before the designs are firm. If engineering changes occur late in the design process, then new part orders must be initiated. The lead times associated with the new procurements can be difficult to accomodate in the launch-driven schedule.

The PMALS (Prototype Miniature Air-Launched System) from the Space Division was analyzed for this study.

4.2.1 PMALS (Prototype Miniature Air-Launched System)

The PMALS is jointly manufactured by Vought Corp. and Boeing, and has a 1980 lead time of 48 months (no 1977 data is available since the prototype is new). The components with the longest lead times are shown in Table 4.2-1, which was prepared by the PMALS project office.

TABLE 4.2-1
PMALS REPRESENTATIVE COMPONENT LEAD TIMES, 1978 and 1980

	Lead Times In Months		
Component	1978	1980	% Change
Microcircuits	5	12	140
Connectors	4	9	125
PROM/RAM	4	19	375
Small Forgings	8	27	238
Bearings	6	14	133

Lead time problems for PMALS are attributed in part to heavy commercial and military demand taxing existing industrial capacity. For example, precision forgings are presently required for the Boeing 757 and 767 aircraft as well as for the F-15, F-16, and F-18. Similarly, microelectronic parts are in heavy demand for both commercial and military systems.

Leadtimes for PMALS components have grown substantially since 1978. The data on these lead times, presented in Table 4.2-1 show lead times growing between 125 percent and 375 percent. However, the PMALS project office notes that current economic conditions do not provide the incentives for facility expansion or modernization. Also, some smaller suppliers are reportedly refusing government business entirely due to difficult regulatory requirements. The shortage of specialty metals and lack of skilled manpower are also factors influencing lead time growth.

The key subsystem producers for the prototype are Hughes, Honeywell, Atlantic Research Corporation, (ARC) Singer, Thiokol, Ball Systems and Hamilton Standard. Of these, both Honeywell and Atlantic Research Corporation are sole source for the roll reference assembly and guidance processor electronics (Honeywell) and maneuver propulsion assembly (ARC). Texas Instruments and National Semiconductor supply integrated chips and semiconductors, while Intersil and Harris supply PROMS, RAM and CMOS devices.

4.3 ARMAMENT DIVISION

The Armament Division systems require parts and materials that compete for industrial capacity with commercial systems. Throughout the Division's systems, castings, forgings, integrated circuits, and connectors are the components with the longest lead times. Material availability, particularly high strength aluminum alloys, is an important factor in lead time growth.

The Laser Guided Bomb (LGB) and GBU-15 were the systems analyzed from this Division.

4.3.1 Laser Guided Bomb

The Laser Guided Bomb is produced by Texas Instruments. The survey responses did not provide lead times for the system as a whole, but the lead times reported for the subsystems range from 10.5 to 11 months (1980). Therefore, it may be assumed that the overall system lead time is comparable or higher than its subsystems.

Lead times for integrated circuits (produced by Texas Instruments, National Semiconductor and Fairchild) are attributed to the tremendous demand for silicon, which exceeds present capacity levels. Forgings and castings are in high demand from both the military and commercial sectors, with lead times further aggravated by material shortages.

Growth in laser guided bomb component lead times between 1978 and 1980 is depicted in Table 4.3-1. The increases, between 13 percent and 70 percent, are considerably less than seen in most of the systems examined.

TABLE 4.3-1
LGB LONGEST COMPONENT LEAD TIMES, 1977 and 1980

	Lead Time in Months		
Component	1977	1980	% Change
Castings	6	9	50
Connectors	6	9	50
Forgings	8	9	13
Integrated Circuits	5	8.5	70

The optical filter included in the DSU-18/B Detector subsystem has shown a decreased lead time since 1977. This is attributed to recent advances in optical coating technology, as well as to the increased availability of glass, the key material in the filter.

4.3.2 GBU-15

The GBU-15 is produced by Rockwell International and has a 1980 lead time of 15 months, an increase of one month since 1978 to 1979. The contractor attributes this lead time growth to the relatively small production quantities that have been required over the lifetime of the system. An example of this problem is the Vidicon subsystem produced by RCA. For this subsystem, the glass melting required for the glass bulb and glass face plate only takes place twice a year and is a sole-source item.

The GBU-15 components with the longest lead times are presented in Table 4.3-2; because no historical information was available only 1980 figures are given.

TABLE 4.3-2
GBU-15 LONGEST COMPONENT LEAD TIMES, 1980

Component	Lead Time In Months 1980
Bearings	6
Castings	5
Connectors	10
Integrated Circuits	7

The Actuator subsystem, produced by AiResearch, has the longest lead time of any of the subsystems at 13 months. The survey response indicated that this lead time is normally 16 months, but that it can be reduced to 13 by offering workers premium pay and (presumably) assigning them to work extra shifts.

4.4 AERONAUTICAL SYSTEMS DIVISION

The Aeronautical Systems Division (ASD) systems often involve components ordered in small lot sizes. Because of changes in procurement funding at the system level, long-term guarantees of order volume cannot be provided. The small lot sizes, combined with uncertainty about sustained ordering, put these systems at a disadvantage when competing with the commercial sector for available industrial capacity. This situation is aggravated by the year-to-year budgeting practices of the government.

Insufficient industrial capacity is also seen as a contributing factor to long lead times. Both low capital investment and manpower shortages are seen as problems. Two reasons cited for the reluctance to expand capacity are the current economic climate and a belief that current demand levels will be short-lived. The suppliers hope to level their production and thereby avoid wide fluctuations in employment levels and the inefficiencies that result. Availability of materials, such as titanium plate, can also be a factor in system lead times.

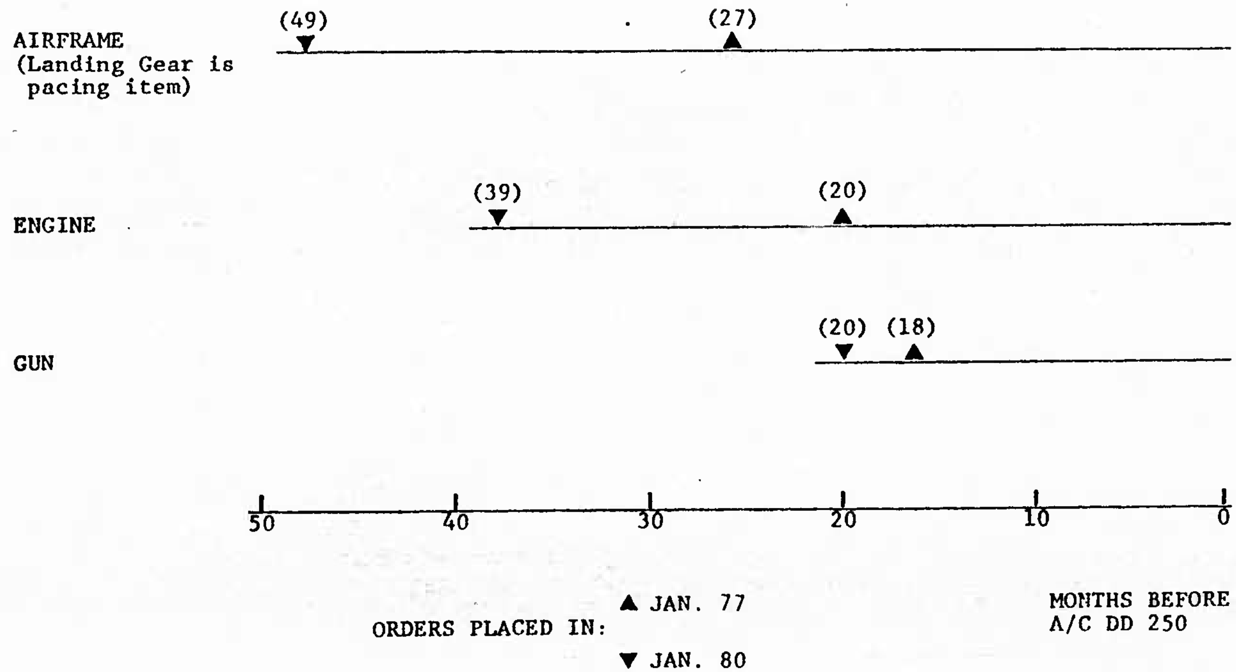
As illustrated in Figure 4.1-1, the largest quantity of data for this study was provided by ASD. The following ASD systems are included in the analysis: A-10 Aircraft, F-15 Aircraft, F-16 Aircraft, B-52 Offensive Avionics System/Cruise Missile Integration (OAS/CMI), ECMS (Electronic Countermeasures) AN/ALQ-137, and F-16 Operational Flight Trainer (OFT) - Simulator. The F100 engine and TF34 engine were treated as subsystems in this analysis.

4.4.1 A-10

The A-10 is produced by Fairchild (FRC) and has a 1980 lead time of 49 months, up 22 months from 1977. Figure 4.4-1, supplied by the program office, illustrates the character of lead times for 1977 and 1980.

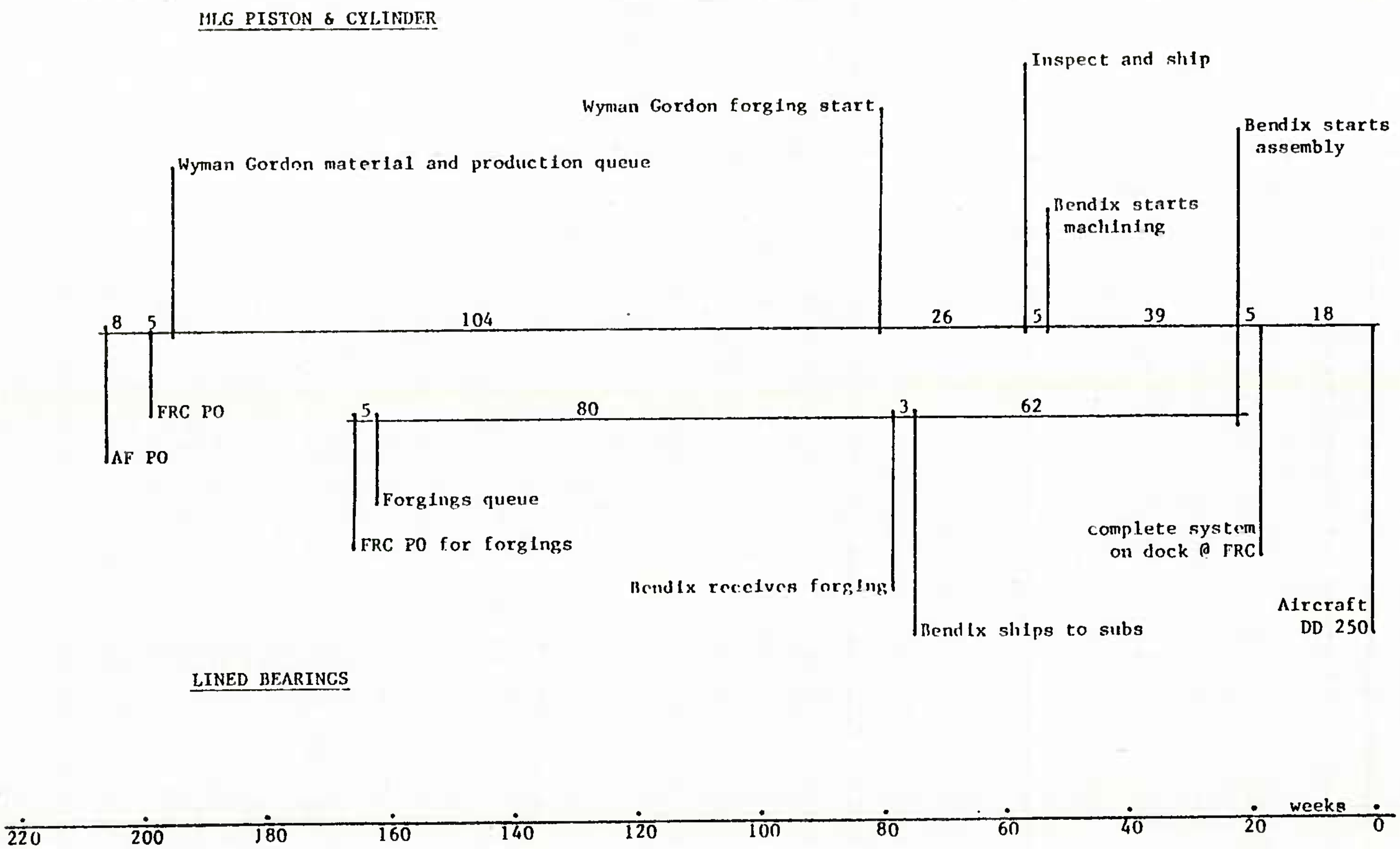
The A-10 landing gear is the longest lead time item on the airframe at 46 months (1980). Fairchild divides purchase of the finished product between Bendix and Menasco on a 50/50 basis, with Fairchild providing both companies with the forgings required to make the landing gear. Capacity is given as the principal cause of this lead time. Wyman-Gordon, the forging supplier, reported at the time of the survey a 139 week (33-month) lead time for any new forging orders. Their workload was reported as 38 percent military and 62 percent commercial at the North Grafton, Massachusetts GOCO (government owned contractor operated) plants. One of the main problems is that Wyman-Gordon schedules both commercial and military orders on a first-come-first-served basis, and the Air Force has not demanded priority scheduling. The actual time for production was 25 to 39 weeks, with queue time accounting for the balance. Bendix, on the other hand, is working at 60 percent capacity, and parts flow time has not changed for several years. Figure 4.4-2, supplied by the A-10 program office, summarizes how time is allocated for producing the landing gear.

The A-10 system lead time is also affected by the shortage of titanium sponge. Because of an overall titanium shortage, mills are not filling total orders, but are apportioning supplies amongst their customers. Also, the mills are reluctant to produce special alloys or grades. As an indication of the tight supply, prices for all grades have tripled or quadrupled in the past year.



Source: A-10 program office

Figure 4.4-1 A-10 Lead Time



Source: A-10 program office

Figure 4.4-2 A-10 System Landing Gear Set Back

Fastener supplies are sold out for the next three years as a result of strong commercial demand, and this is influencing the A-10 lead time. Milspec electrical connectors also have increasing lead times, though manufacturers are increasing capacity and relief is expected in the next few months.

Aluminum plate and extrusions present a problem similar to fasteners for the A-10: suppliers are quoting 70-week production lead times while Fairchild requires the material 52 weeks before deliveries.

Table 4.4-1 presents the longest component lead times for the A-10.

TABLE 4.4-1
A-10 LONGEST COMPONENT LEAD TIMES, 1977 AND 1980

	Lead Times In Months		
Component	1977	1980	% Change
Forging	21	42.5	102
Bearing	--	16	--

4.4.2 F-15

The F-15 is produced by McDonnell-Douglas and has a 1980 lead time of 44 months, an increase of 12 months from 1977. Table 4.4-2 indicates the components with the longest lead times, and the changes in these lead times between 1977 and 1980.

The longest lead time subsystem is the F100 engine at 36 months (domestic) or 41 months (European Participating Industry). This engine, produced by Pratt and Whitney, is also used

TABLE 4.4-2
F-15 LONGEST COMPONENT LEAD TIMES, 1977 AND 1980

Component	Lead Times In Months 1977	1980	% Change
Bearings	8	12	50
Castings	10	12	20
Forgings	12	36	200

in the F-16. The lack of forging capacity is the constraining factor on the engine lead time. Titanium forgings, produced by Wyman-Gordon, Reisner Metals, and Carlton Forge are the pacing components for the engine. Sufficient information was provided on the forging lead-time to further characterize it as follows: queueing -- 21 months; melt -- one month; forging -- 6 months; inspection, packaging, transportation, and administration -- 8 months.

The data provided for the F-15 were scant, making further analysis impossible at this time.

4.4.3 F-16

The F-16 is produced by General Dynamics and has a 1980 lead time of 42 months, up 22 months from 1977. Table 4.4-3 shows the components with the longest lead times and how they have changed since 1977. The F-16 lead time increase is primarily attributed to the lack of forging and casting capacity.

The longest lead time subsystems, at 39 months, are: Weapon Pylon, Fuel Pylon, Centerline Pylon, Conventional Weapons

TABLE 4.4-3
F-16 LONGEST COMPONENT LEAD TIMES, 1977 AND 1980

	1977	1980	% Change
Bearings	16	33	106
Castings	17	39	129
Connectors	10	27	170
Forgings	17	39	129

RIU, Aim 9 Missile RIU, and the Nuclear RIU. For these subsystems, each produced by General Dynamics, castings and forgings have lead times of 38 months.

The Ammunition Handling System (an F-16 subsystem) is currently being produced by Sperry Vickers in Norway, but was previously made by General Electric. The overseas location of this manufacturer has increased the subsystem lead time in that additional transportation time is now required. Machine capacity is also considered limited.

4.4.4. B-52 Offensive Avionics System/Cruise Missile Integration OAS/CMI

The first delivery unit of the B-52 OAS/CMI, produced by Boeing, is scheduled for January 1981. Therefore, no actual production information was reported in the survey; only estimated figures were given. The system is to be delivered in three lots: Lot I is scheduled to have its first unit delivered in January 1981, Lot II in June 1981, and Lot III in May 1982. The estimated lead time for Lot I deliveries is 18 months. In Table 4.4-4, FSED (Full Scale Engineering Development) lead time figures for 1978-79 are included for components,

TABLE 4.4-4
B-52 OAS/CMI LONGEST COMPONENT LEAD TIMES,
1978-9 AND 1980

	Lead Times In Months		
Component	1978-9	1980	% Change
Bearings	6	12	100
Castings	12	12	0
Connectors	8	12	50
Forgings	15	21	40
Integrated Circuits	2	12	500

and these numbers are contrasted with estimated Lot I 1980 figures.

The Data Transfer Unit, produced by Sundstrand, has six digital integrated circuits which influence lead time. These IC's are produced by Texas Instruments (TI), Advanced Micro Devices, National Semiconductor, and Signetics. The estimated lead times for 1980 range from 32 to 50 weeks (7 to 12 months) depending on manufacturer. Projected increases between the 1978-9 experience and Lot I range from 42 weeks on one Texas Instruments IC, to only eight weeks on another.

The Attitude Heading Gyroscope Set produced by Lear Siegler is influenced by bearings, castings, connectors, and ICs. DXA1 ratings are used on all B-52 OAS purchase orders let by Lear Siegler, though the ratings were actually needed only for the delivery of cobalt materials used in laminated rotary components. This particular subsystem is not anticipated to have any lead time growth between that reported in 1978-9 and Lot I in 1980. Lear Siegler attributes this to be the use of multiple source procurements, reserved manufacturing time, and blanket/annual agreement purchase orders.

The Radar Altimeter subsystem, produced by Honeywell, anticipates reduced lead times on Amphenol connectors (from 24 to 12-16 weeks), and no increase on Dolphin casting lead times. These figures are in contrast with those provided by most respondents to the survey.

A great variety of suppliers are used for the B-52 OAS/CMI components so there should be little conflicting demand on the same manufacturer for different components for this system. The main reasons given for increasing lead time for the components are high commercial and military demand, inadequate plant expansion, lack of skilled manpower and processing problems due to the need for high reliability parts.

4.4.5 F-16 Operational Flight Trainer (OFT)

The F-16 OFT is co-produced by Singer/Link and DISA, and has a 36-month 1980 lead time, up 6 months from 1977. The five subsystems discussed in the data are all produced by Singer/Link. The project office reports that connectors, integrated circuits, and aircraft parts have the longest lead times for this system. Table 4.4-5 shows the longest lead time components for the F-16 OFT (historical data was not available).

TABLE 4.4-5
F-16 OFT LONGEST COMPONENT LEAD TIMES, 1980

Component	Lead Time In Months 1980
Connectors	15
Integrated Circuits	9

The automobile and electronic toy markets are again cited as consuming huge amounts of integrated circuits. Both these industries are able to forecast their needs several years in advance and buy larger quantities at one time than the Air Force.

The Student Station has the longest subsystem lead time at 23 months. The aircraft parts supplied by General Dynamics are the constraining factor, at 20 months. Therefore, the same component lead time problems facing the actual F-16 are translated into similar problems for the simulator. The F-16 OFT project office suggests that a possible solution might be to order the required simulator parts along with the parts for the aircraft itself.

4.4.6 ECMS AN/ALQ-137

The EMCS AN/ALQ-137, produced by Sanders Associates, has a 1980 lead time of 16 months, up four months from 1977. Integrated circuits, connectors, and traveling wave tubes (TWT's) are the most troublesome components in the system.

Low power and Schottky ICs produced by various companies are in high commercial demand, with only 15 percent of the work in the industry being done for the government. Commercial companies are able to make three to five year order commitments in contrast to the small quantities procured by the government.

Traveling wave tubes' lead times are increasing (from 20 to 32 weeks in 1977 to 52 to 78 weeks in 1980) due to the rigid performance specifications required. In addition, many of the tubes fail or are rejected. The TWT industry as a whole is declining due to the use of solid state devices, and there has been significant personnel turnover aggravating this trend.

Connectors manufactured by Amphenol have 1980 lead times of 13 months, in contrast to three months in 1977. The surge in commercial demand is again blamed for the lack of capacity in the industry. Government business is estimated at less than 15 percent of the total input of the connector industry.

4.5 ELECTRONIC SYSTEMS DIVISION (ESD)

The ESD E-3A, JTIDS, and SACDIN (SAC Digital Network) systems have been analyzed for this study. Supplier capacity was given as the primary cause of increasing lead times for the Division. These problems are experienced by both commercial and industrial customers, though government procurement practices which result in smaller orders of more specialized components are seen as contributing to the problem.

While significant lead time increases for certain components have impacted ESD programs, the responding office notes that there has not been a corresponding increase in the lead time of most electronic systems. This situation is attributed primarily to the action being taken by prime contractors and higher tier subcontractors to make certain components in-house rather than buying them from suppliers with capacity problems.

4.5.1 SACDIN (SAC Digital Network)

SACDIN is produced by ITT, and has a 1980 lead time of 41 months. The system has only been in existence since 1978, so comparative data were not included. The component data given were not subsystem specific, but instead reflected current ITT general commodity lead time experience. It is interesting to note that component lead time is a problem even in interdivisional transfer/purchases; for example, rack and panel connectors from ITT's Cannon Division take up to 21 weeks for delivery. Table 4.5-1 gives lead times for representative SACDIN components. No historical information was available, so only 1980 figures are presented.

TABLE 4.5-1
SACDIN LONGEST COMPONENT LEAD TIMES, 1980

Component	Lead Time in Months 1980
Bearings	5
Castings	6
Connectors	8
Integrated Circuits	7

4.5.2 JTIDS

JTIDS is produced by Hughes Aircraft and has a 1980 lead time of 24 months, up two months from 1977. The JTIDS program office was not able to supply much commentary due to time constraints, but indicated that capacity, system design changes, and high quality parts all contributed to increased lead times. Table 4.5-2 gives the longest component lead times for JTIDS.

The lead time growth for the JTIDS system is fairly modest in comparison to some areas in ESD, reflecting perhaps the high degree of vertical integration across the spectrum of subsystem-to-system assembly (i.e., Hughes is the contractor for all of the seven subsystems). The principal increases in component lead times have been identified as connectors, chips, captive fasteners, universal modems, teletypewriters, PROMs, ICs,

TABLE 4.5-2

JTIDS LONGEST COMPONENT LEAD TIMES, 1977 AND 1980

Component	Lead Time in Months		
	1977	1980	% Change
Connector	3	10	233
PROM	2	12	500
Integrated Circuits	7	12	71

resistors, hybrid ICs, and rivets. Lead times for some of the component categories vary significantly, both within and across subsystems, which would appear to indicate that the reasons for lead times differ even between generally compatible components.

4.5.3 E-3A

The E-3A is produced by Boeing and has a 1980 lead time of 45 months, up 30 months since 1977.

Data provided for the E-3A can be classified under the rubric of airplane and avionic "systems" (the propulsion system was not included in this study). This division also facilitates the consideration of two major systems that are subject to different sets of industrial constraints, as the E-3A combines a civil airframe (Boeing 707) with an extensive military electronics package. This division of origin would suggest that procurement issues affecting the delivery of the aircraft would reflect conditions affecting the manufacture of civil aircraft in general, while the electronics sytems would represent a competing military interest.

Aircraft - The conditions which significantly affected the lead time growth of the aircraft were primarily a combination of difficulties in obtaining raw materials and the diminishing capacity of the machine tool industry. Both of these problems are critical in the Pacific Northwest, where Boeing maintains main production facilities. In addition to rising energy costs, power shortages and a shortage of electrical assemblers/machinists inhibit aluminum producers from expanding capacity to meet an increased demand from aircraft manufacturers. Other high demand raw materials for aircraft, such as titanium, are in short supply.

Capacity is a serious constraint in the segment of the machine tool industry that fabricates large complex parts for airframes. While the closure of facilities in the Cleveland region has shifted a sizeable burden to other suppliers, there is little incentive to incur the high costs of expanding existing facilities. Data provided by Boeing indicate that requirements for new tooling carry long delivery times.

Avionics - The reasons for growth in the lead times of avionics systems for the E-3A vary somewhat between components but appear in general to be affected by a shortage of industrial capacity devoted to military electronics products.

Several subsystems, particularly identification, communications, and data display, cited strong competition from civilian markets for products with IC technology. Some of the more common reasons for the inferior competitive position of the military have been small batch size and lower profit margins of military runs, excess risk associated with meeting MILSPECS, and constraints on the utilization of productive capacity and skilled personnel.

In addition, some suppliers have cited factors that are external to material and capacity constraints. In the case of the surveillance radar, WECO cited a lack of test equipment to support an increase in production. Other significant time delays result when certain components confront state-of-the-art problems which inhibit delivery of other components in the subsystem as well (e.g., the Hughes TDMA communications computer). Table 4.5-3 gives representative lead times for E-3A components.

TABLE 4.5-3

E-3A LONGEST COMPONENTS LEAD TIMES, 1977 AND 1980

	Lead Times in Months		
Component	1977	1980	% Change
Castings	5	12	140
Forgings	9	17	89
IC Chips	8	11	38

In summary, the project offices responding to this study reported similar overall reasons for lead time increases. At the component level, small Air Force orders and high commercial demand coupled with lagging industrial capacity are cited across all the systems as contributing significantly to longer lead times. In turn, the extended component lead times cause both subsystem and system delays. Chapter 5, which follows, discusses the individual components examined earlier in this study.

5. FINDINGS -- COMPONENTS

5.1 BACKGROUND

The analysis of data pertaining to component-level lead times is presented in this chapter. Though many types of components were included in the original data, the five that were cited most consistently as having long or rapidly growing lead times were analyzed for the study. The components are:

- Bearings
- Castings
- Connectors
- Forgings
- Integrated Circuits.

Figure 5.1-1 shows the response frequency by component. Each time one of the five components was cited in the data a separate coding entry was made. Therefore, the information on these five components is as complete as the data, in contrast to the system-level information which was included only if one of these components were given as influencing system lead time. Bearings have been excluded from some types of analysis because they appear only ten times in the data set.

As discussed in Section 4.1, component lead times drive subsystem lead times, which drive system lead times (see Table 4.4-1 and Figure 4.1-3). Figure 5.1-2 shows the five component lead times for 1977 and 1980. It is significant that 25 percent

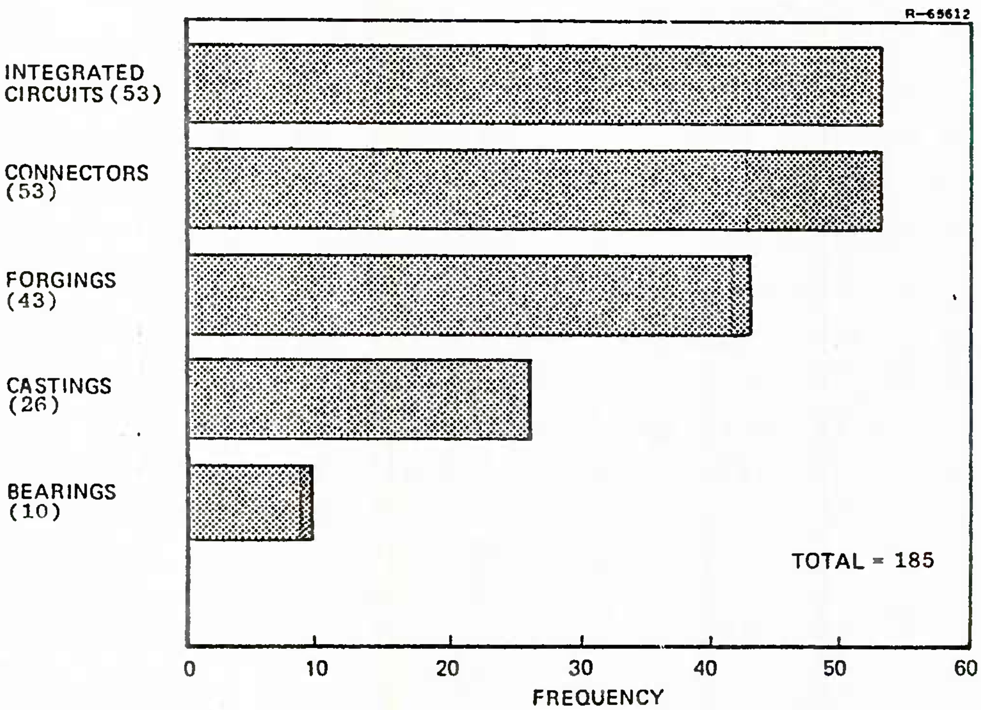


Figure 5.1-1 Frequency* of Response, By Component

of the lead times for 1980 fall into the 20 to 43 month categories, whereas in 1977 only one percent of the lead times were in these categories. In 1977 40 percent of all components' lead times were between two and six months, but by 1980 only 15 percent were in this time frame.

Figure 5.1-3 presents 1980 lead times by component. Each component, except integrated circuits, appears in four categories, which indicates that the Air Force is experiencing not only longer lead times, but also a wide range of component lead times. Integrated circuits and connectors, the components

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*Frequency represents all occurrences of the component within the systems studied.

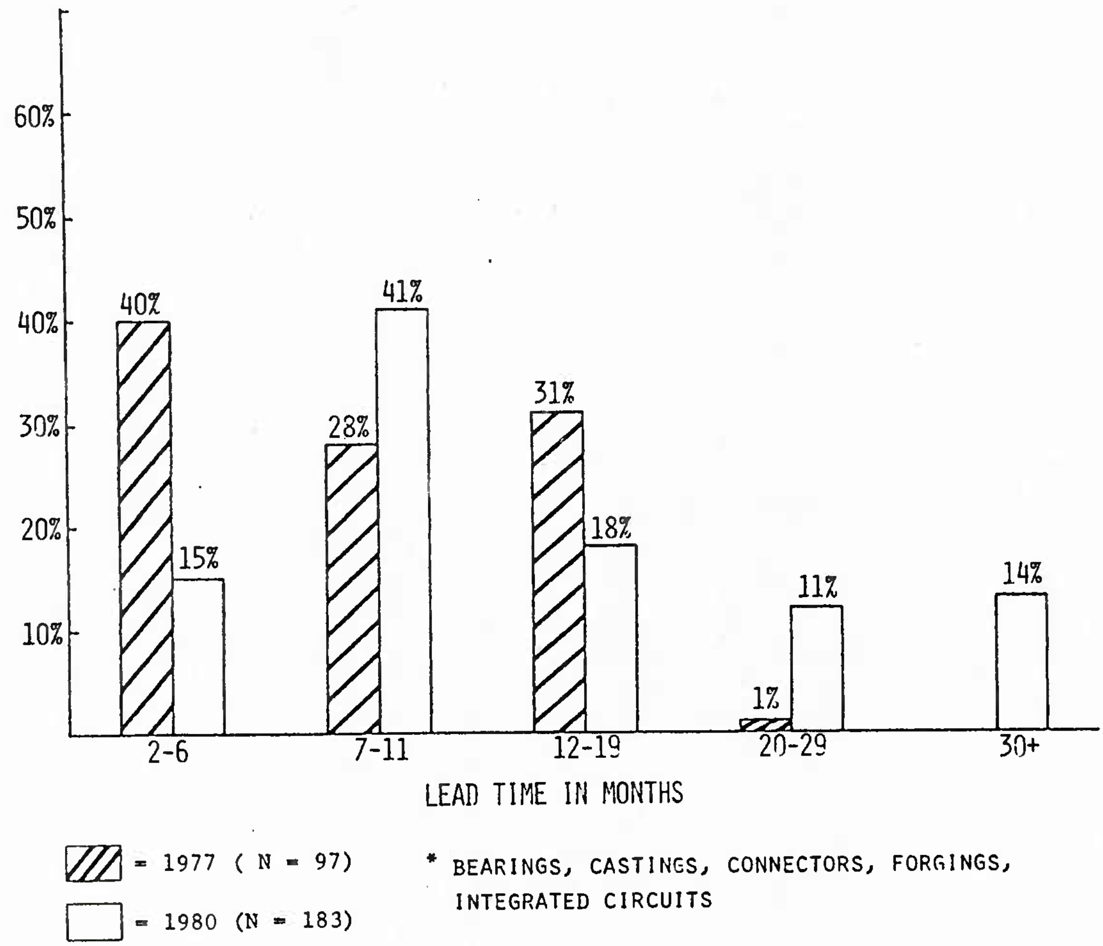

Figure 5.1-2 Lead Times for All Components, 1977 and 1980

in this study which are used most heavily for commercial applications, generally have shorter lead times than the components' suppliers which have a higher proportion of military business. It may be concluded that where commercial demand is high, it is actually helping keep some Air Force lead times down in that those industries are willing to expand capacity for more predictable and steady commercial-military requirements and other

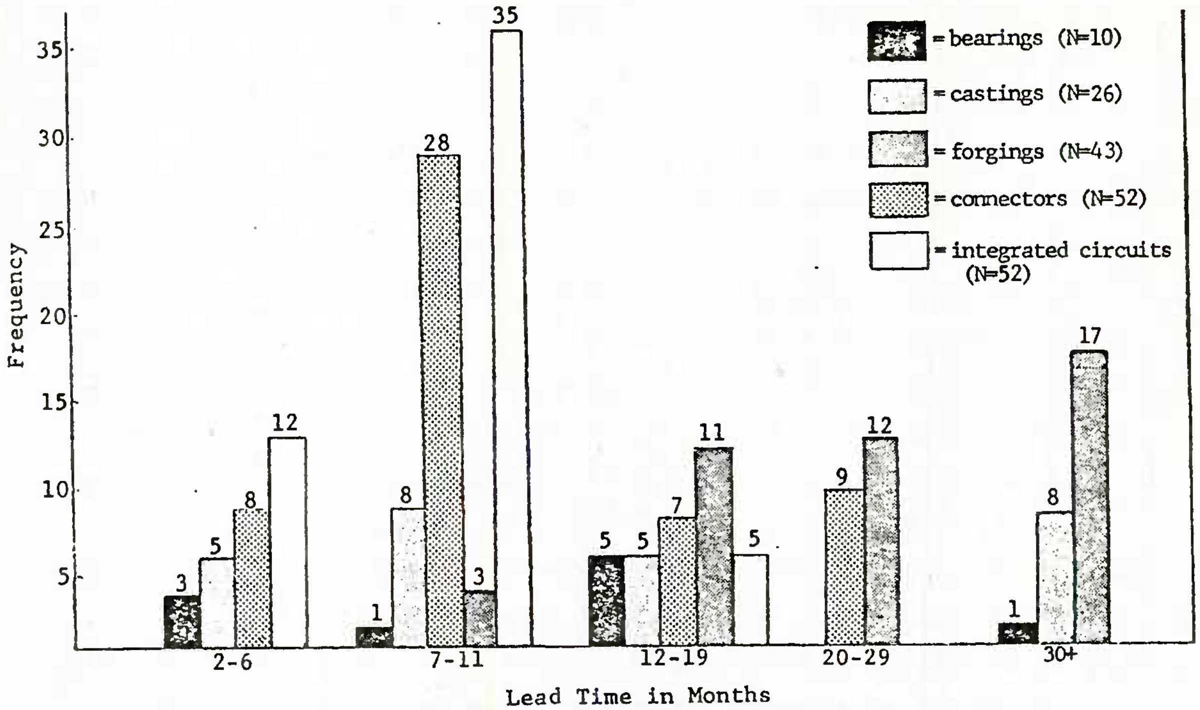

Figure 5.1-3 Distribution of Components By Lead Time, 1980

suppliers are more reluctant to expand when the military is a significant customer, but one periodically affected by large program variations. It should also be noted that integrated circuits and connectors are intrinsically easier products to manufacture than forgings, for example, and this also has an impact on the lead time.

In many cases the survey respondents differentiated between reasons for overall (system) lead time increases, and reasons for component lead time increases. The general reasons are discussed in Section 4.1, and summarized in Figure 4.1-4 and Figure 4.1-5. The reasons given specifically for component lead times were separately coded, and are shown in Figure 5.1-4.

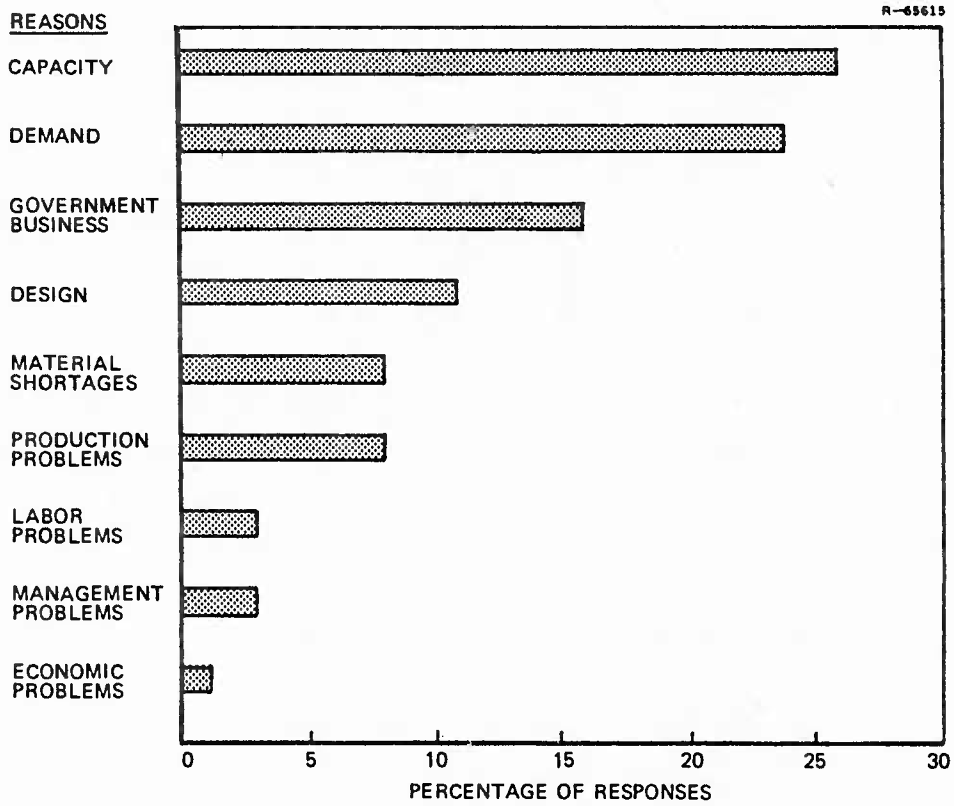

Figure 5.1-4 Reasons Given for Component Lead Times

However, a comparison of Figure 4.1-4 and Figure 5.1-4 (which indicate general and component-specific lead times respectively) shows a strong similarity.

The exception is the category of capacity, which represented 12 percent of the general reasons and 26 percent of the component specific reasons. This indicates that capacity is a greater problem in the component industries than in the subsystem or system integration industries. This, in turn, is due to the higher demand from the commercial sector at the component level, compared to the subsystem and system levels. For example, commercial demand for micro-electronic components places greater stress on the micro-electronics industry than commercial demand does for aircraft assembly on the aircraft industry.

Approximately one-third of the component data may be identified by type of component, such as lined bearings or PROM integrated circuits. When this information was available from the data it was separately coded. Nineteen different types of forgings, fourteen types of integrated circuits, nine types of connectors, eight types of castings, and five types of bearings were mentioned. The hypothesis was that certain types of components may require longer production times than others, and that this might account for one manufacturer showing a wide range of lead times for a component. Table 5.1-1 shows lead times for selected component types. The lead times do not show much variation from type to type (with the exception of bearings), and further data, perhaps coupled with industry interviews or visits, would be needed to fully test the hypothesis.

The components with the longest lead times in any particular system can be seen as driving the system lead times. Table 5.1-2 shows which of the five components have the longest lead times for each system. Forgings are the limiting component for six systems, connectors for four, integrated circuits for three, and castings for two (though in some instances, such as the Laser Guided Bomb, more than one component had the same lead time).

The following sections present an analysis of lead time trends for the five components studied. Background informaton on each of the components is included in the appendices of this report.

TABLE 5.1-1
SELECTED COMPONENT TYPES, BY 1980 LEAD TIME

Bearings		
Ball (2 to 6 months)		
Lined (30 to 43 months)		
Castings		
Aluminum and Fairing (12 to 20 months)		
Forgings		
Bearing Retainer	(2)*	(20 to 30 months)
Body Bolt	(2)	(20 to 30 months)
End Plate	(2)	(20 to 30 months)
Compressor Disk	(2)	(30 to 43 months)
Fan Disk	(2)	(30 to 43 months)
Forward Fan Shaft	(2)	(30 to 43 months)
Forward Spool	(1)	(30 to 43 months)
Front Casing	(2)	(30 to 43 months)
Housing Halfs	(2)	(20 to 30 months)
Large	(2)	(30 to 43 months)
Main Manifold	(2)	(20 to 30 months)
Rotor	(1)	(20 to 30 months)
Small	(3)	(20 to 30 months)
Steel	(4)	(20 to 30 months)
Integrated Circuits		
Digital		(12 to 20 months)
PROMs		(12 to 20 months)

*Frequency

TABLE 5.1-2
LONGEST LEAD COMPONENTS BY SYSTEM, 1980

Component	System												
	A-10	B-52 OAS/CMI	E-3A	ECMS	F-15	F-16	F-16 OFT	GBU-15	JTIDS	LGB	PMALS	SACDIN	TOTALS
Bearings													0
Castings						X (39)				X (9)			2
Connectors							X (15)	X (10)		X (9)		X (8)	4
Forgings	X (43)	X (21)	X (17)		X (36)	X (39)				X (9)			6
Integrated circuits				X (15)					X (12)		X (11)		3

( )=lead time in months

5.2 BEARINGS

Mentioned only ten times in the survey, it is difficult to draw significant conclusions concerning bearing lead times. In 1977 the mean lead time was 11 months, and in 1980 it was 13 months. Table 5.2-1 shows bearing lead times by manufacturer. (The total is only seven instead of ten in this table because some entries in the data gave no specific manufacturer.)

TABLE 5.2-1
BEARING LEAD TIMES BY MANUFACTURER, 1980

	Lead Time In Months				
Manufacturer	2-6	7-11	12-19	20-29	30+
Astro			1		
Barden			1		
Fafnir			2		1
Minimum Precision			1		
Specline		1			
Totals (N=7)		1	5		1

Capacity was cited most often as the reason for bearing lead time increases. This may be attributed to a shortage of qualified suppliers as well as to the high reliability required for Air Force applications, which makes capacity expansion more difficult. Though not specifically cited in the data, Fafnir experienced protracted labor strikes in 1979 which impacted lead times.

5.3 CASTINGS

The lead time for castings has risen from an average of 14 months in 1977 to 18 months in 1980. Figure 5.3-1 shows comparative casting lead times for 1977 and 1980. It is significant that 31 percent of the 1980 lead times fall in the 30+ month category, whereas in 1977 there were no lead times greater than 19 months.

Table 5.3-1 presents casting lead times for 1980 by manufacturer. The data used in this table only reflects those responses where a specific manufacturer was given. Capacity was mentioned most frequently as the cause for long lead times. Aluminum shortages were also seen as aggravating lead times.

5.4 CONNECTORS

Connector lead times have shown a dramatic increase since 1977. The 1977 mean lead time for connectors was seven months, while the 1980 lead time was 12 months. Figure 5.4-1 shows comparative 1977 and 1980 lead times. In 1977, 57 percent of connectors fell within the two to six month lead time range, contrasted with only 15 percent in this range for 1980. Thirty percent of the 1980 lead times were in the 12-29 month range, versus nine percent for 1977.

Table 5.4-1 presents 1980 connector lead times by manufacturer. Again, only that data which specified a manufacturer can be included in this table. Amphenol stands out

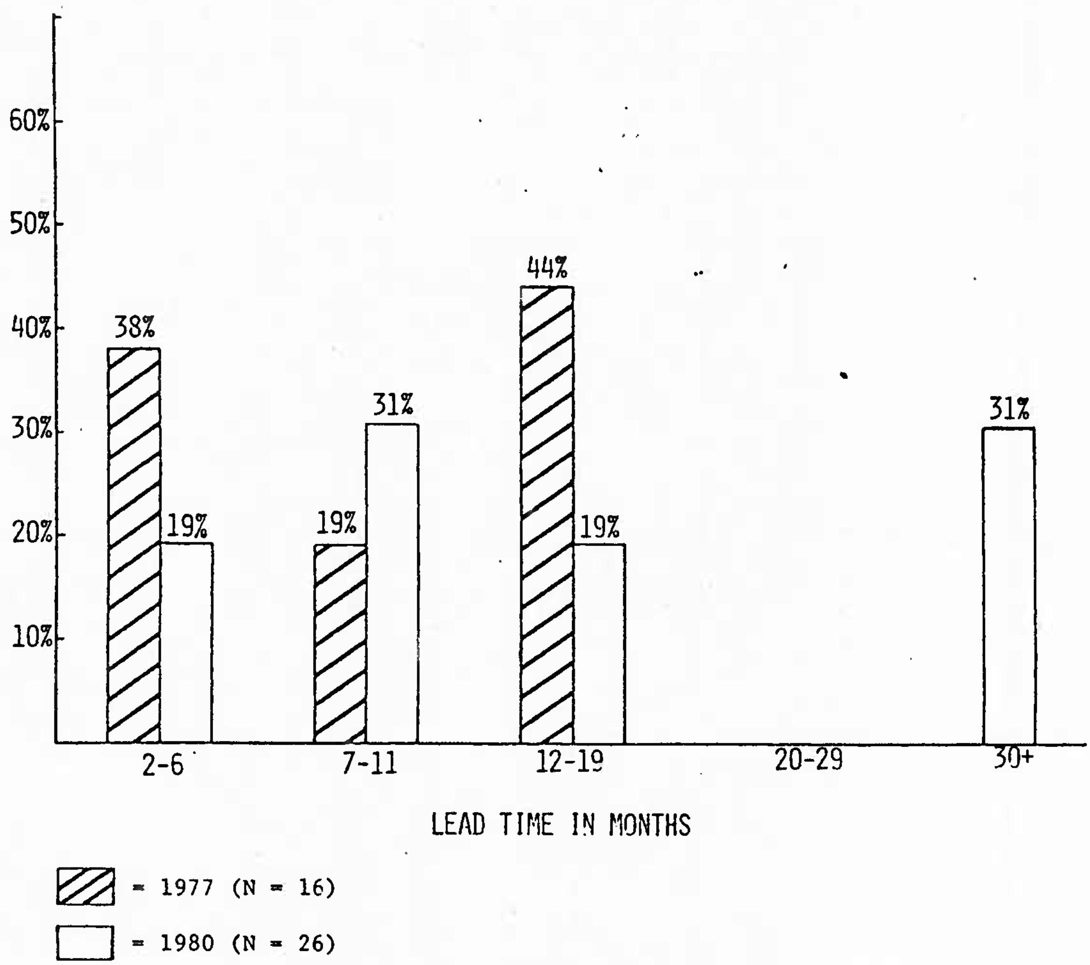

Figure 5.3-1 Casting Lead Times, 1977 and 1980

TABLE 5.3-1
CASTING LEAD TIMES BY MANUFACTURER, 1980

Manufacturer	Lead Time In Months				
	2-6	7-11	12-19	20-29	30+
Alcoa					2
Alloy Die		1			
Altamil					6
Cercast		2	1		
Dean Castings	1				
Dolphin			1		
General Semi		1			
Hyatt		1			
Pico		2			
Rex Precision Product		2			
Shellcast	1		1		
Smithford		1			
V&W		1			
Totals (N=24)	2	11	3		8

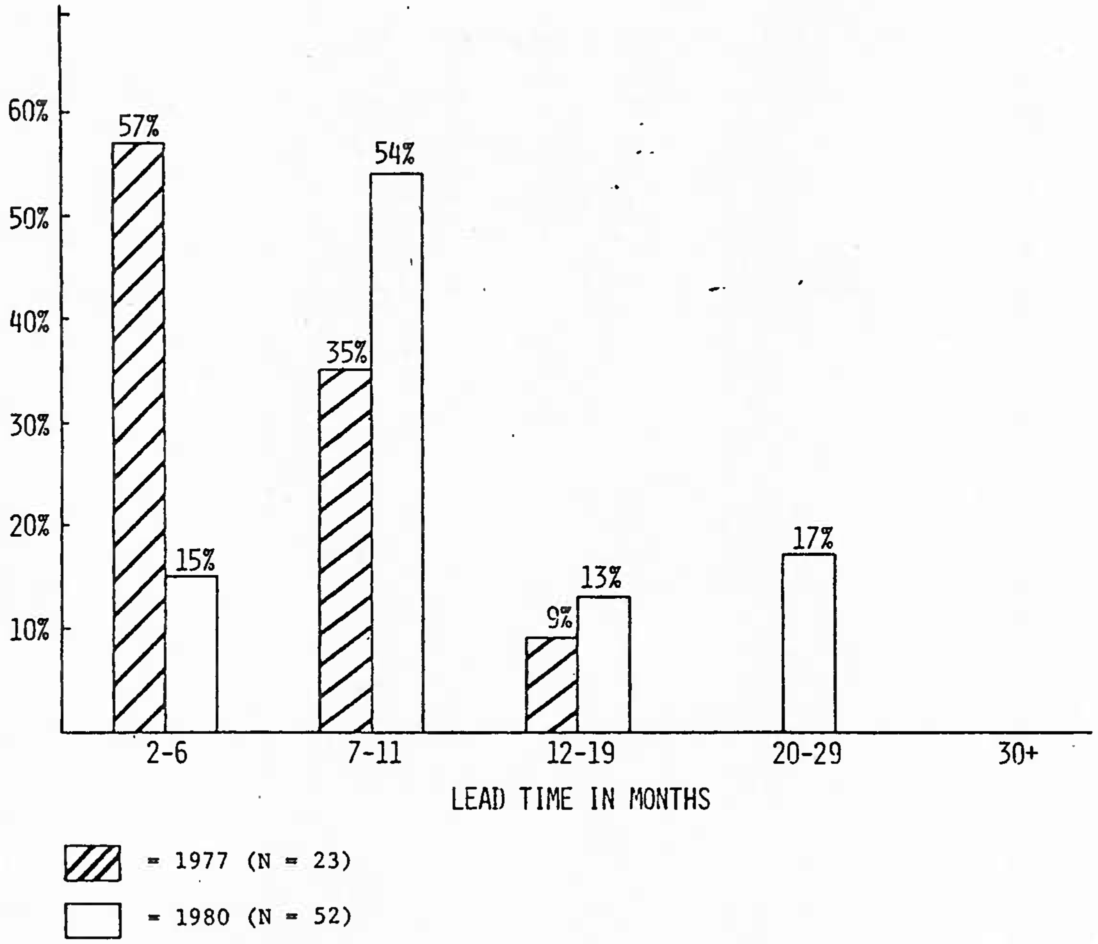

Figure 5.4-1 Connector Lead Times, 1977 and 1980

TABLE 5.4-1
CONNECTOR LEAD TIMES BY MANUFACTURER, 1980

Manufacturer	Lead Time In Months				
	2-6	7-11	12-19	20-29	30+
Amphenol	1	1	1	8	
Bendix		14	1		
Berg Electronics		1			
Burndy		2			
Cannon		5			
Cercast		1			
Dursch				1	
ITT		1			
Omnispec		1			
OSM	1	3			
Time			5		
Totals (N=47)	2	29	7	9	

in this table as having connectors in four different lead time categories. Yet a closer examination of the data yields no explanation since the type of connector was not specified.

The sharp increase in commercial demand for connectors, particularly in the automobile and electronic toy industries, is the main cause for long lead times. Government business is estimated to be less than 15 percent of the total connector market, and with small orders and uncertainty concerning future government volume, industry has been more attracted to the big commercial orders.

5.5 FORGINGS

Forging lead times have more than doubled in the last three years, from an average of 11 months in 1977 to 26 months in 1980. In this study, forgings have had much longer lead times than the other components. Figure 5.5-1 shows comparative forging lead times for 1977 and 1980. Sixty-seven percent of the 1980 forging lead times are greater than 20 months, whereas in 1977 only three percent fell in this range. While 28 percent of the 1977 lead times were between two and six months, no 1980 lead times are reported less than seven months (an examination of the actual data shows nine months to be the lowest forging lead time for 1980).

Table 5.5-1 shows 1980 forging lead times by manufacturer. The main reason cited for long forging lead times is lack of capacity. It is interesting that demand is not seen as an important factor, and commercial demand in particular is not as strong for forgings as for components such as integrated circuits and connectors. It may be concluded that the forging industry is more reluctant to expand capacity than the more commercially-oriented industries because of their particular

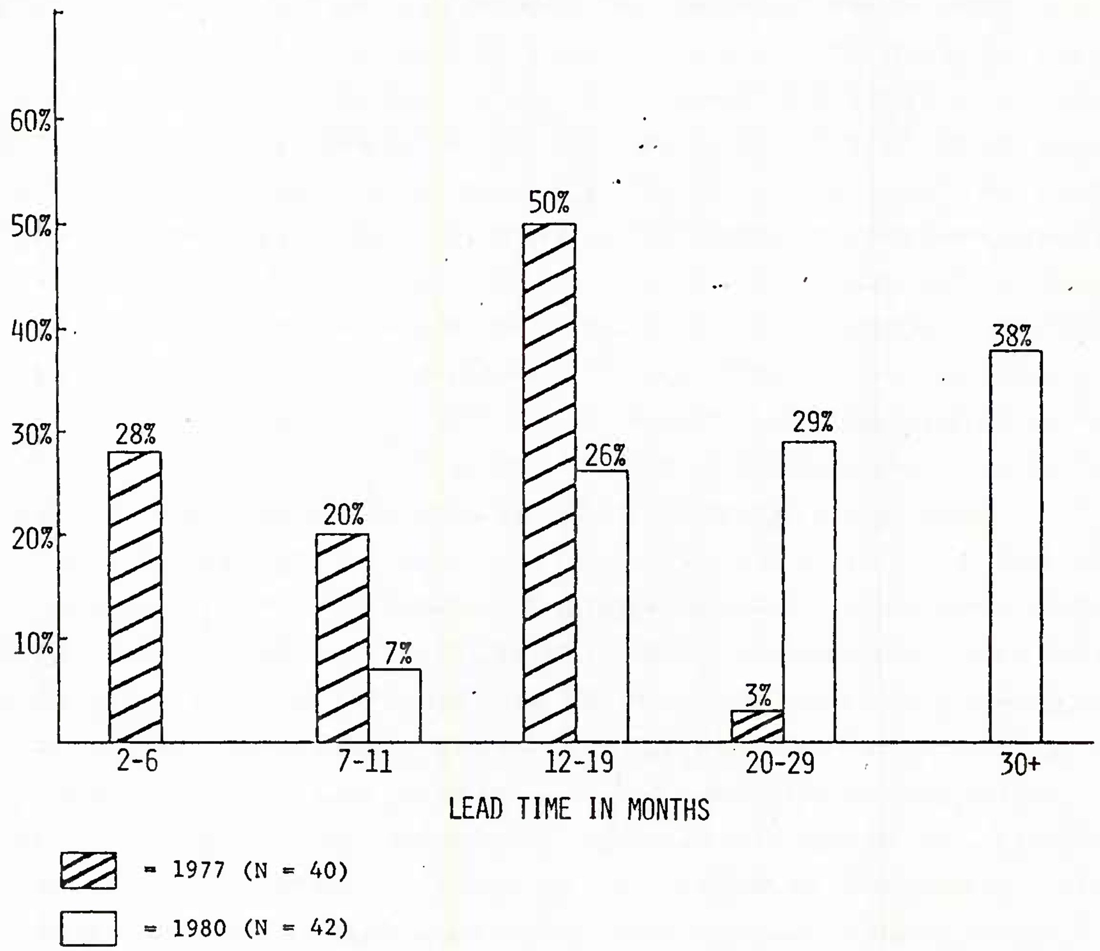

Figure 5.5-1 Forging Lead Times, 1977 and 1980

TABLE 5.5-1
FORGING LEAD TIMES BY MANUFACTURER, 1980

Manufacturer	Lead Time In Months				
	2-6	7-11	12-19	20-29	30+
Alcoa		2	1		
Aluminum Forge				1	
Bergman		2			
Carlton Forge					1
Consolidated				2	
Kaiser					8
Kropp				1	
Ladish Pacific			2		1
Martin Marietta			6		
Park Drop Forge				2	
Patty Precision				1	
Reisner Metals					2
Schultz				1	
Steel Imprv. & Forgings Co.			1		
Thiokol		1			
Wyman-Gordon				3	3
Totals (N=41)		5	10	11	15

vulnerability to government spending cuts. The forgings industry is also constrained by OSHA and EPA regulations, which have driven some small companies out of business. As with castings, materials shortages are also driving longer forging lead times.

5.6 INTEGRATED CIRCUITS (ICs)

Lead times for integrated circuits have risen from an average of five months in 1977 to eight months in 1980. Figure 5.6-1 presents comparative 1977 and 1980 lead times. The range of possible lead times expanded during 1980 to include three of the categories, where in 1977 the lead times were more concentrated. Nevertheless, integrated circuits show less variation in lead time range than the other four components.

Table 5.6-1 shows integrated circuit lead times by manufacturer. Both Fairchild and Texas Instruments have integrated circuits in each of the three categories. An examination of component type data yields no explanation for this. For instance, the one Fairchild IC in the two to six month range is a PROM, but two of the nine in the seven to 11 month range are also PROM's. Seven of the 13 Texas Instruments ICs in the seven to 11 month category are special types (Chips, MOS Devices, Digital IC's, and Microprocessor ICs).

Commercial sector demand for integrated circuits, particularly from the automobile and toy industries is cited as being the cause for increased lead times. Various materials shortages, silicon in particular, are also seen as aggravating the problem.

The shortage of skilled labor is also having a strong impact on the IC industry. Manufacturers treat the high reliability parts required by the military as special transactions,

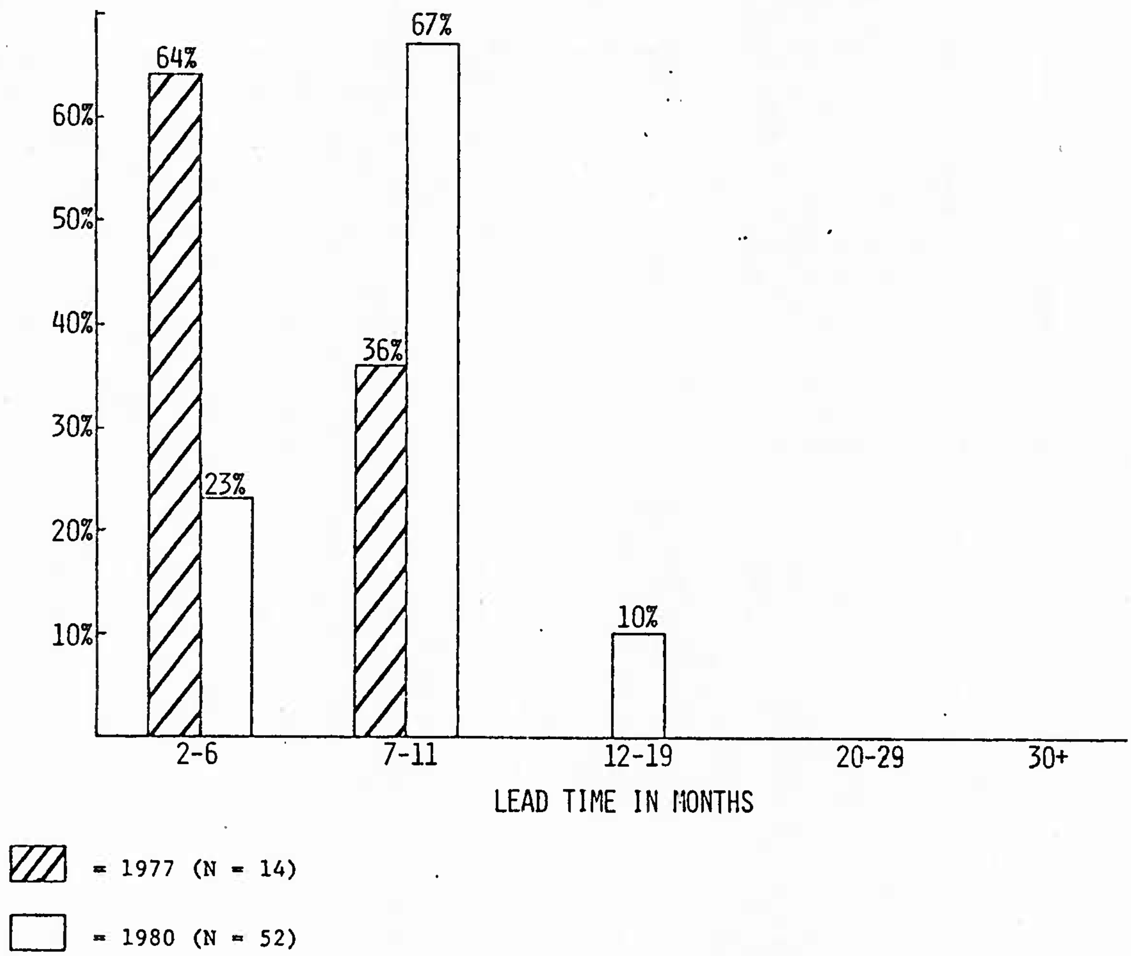

Figure 5.6-1 Integrated Circuit Lead Times, 1977 and 1980

TABLE 5.6-1
INTEGRATED CIRCUIT LEAD TIMES BY MANUFACTURER, 1980

Manufacturer	Lead Time In Months				
	2-6	7-11	12-19	20-29	30+
Advance Micro Devices	1				
AIL		1			
Beckman Instruments	1				
Bendix	1				
Fairchild	1	9	3		
Harris Semiconductor	1	3			
Intersil		4			
Motorola		3			
National Semiconductor		8			
Plessy		1			
Republic			1		
Signetics		2			
Singer	1				
Texas Instruments	2	13	2		
Totals (N=58)*	7	45	6		

*N in some instances reflects multiple manufacturers for one IC.

and would rather utilize their skilled personnel on product lines with higher profit margins. The labor shortage is resulting in lower yields as well as quality problems in the IC industry. Military demand constitutes a very small (approximately 7%) proportion of overall IC demand (with a decline to 3% projected by 1987). Military IC orders are generally smaller and require higher reliability IC's than commercial orders. As seen with the other components, these factors tend to make military orders less desirable and profitable for manufacturers.

5.7 AREAS FOR FURTHER RESEARCH

Tha analysis of the survey data identified a number of lead time issues which could be pursued in further research. For instance, the data could not be used to specifically identify sole source suppliers. In a future effort it would be beneficial to gather this type of information and compare the lead times of sole source versus multiple source procurements. In a check of the existing data, no lead time trends for multiple versus single manufacturers could be detected (a single manufacturer was not necessarily regarded as a sole source in this study).

Another question that could be pursued is the impact on lead times of the subsystem and components' manufacturer being the same (that is, a particular subsystem manufacturer using its own components). For instance, the JTIDS system produced by Hughes lists seven driving subsystems, also produced by Hughes. Since the present data were collected by requesting information on only the longest lead subsystems and components, this question cannot be adequately answered. Further study using data for an entire system and covering all lead times, for example, could show the influence of a subsystem and component manufacturer being the same.

One of the most intriguing questions raised in the analysis is why certain manufacturers show a variety of lead times for the same component, and why there is such a range of lead times between manufacturers for the same component. One possible reason for this could be that the components are actually different types, yet the present data could only identify type for approximately a third of the components. Further study regarding the impact of specific component types on lead time would be beneficial. Case studies or interviews with industry could also help identify reasons for lead time differences such as transportation problems, problems associated with small versus large firms, or administrative delays.

6. SUPPLIER CAPACITY AND MATERIAL SHORTAGES

6.1 SUPPLIER CAPACITY

One of the most frequent reasons cited in this study for increasing lead times is that supplier capacity is insufficient, particularly in the forging and casting industries. If supplier capacity is insufficient to meet the demand, long lead times result as materials and items wait to be processed and manufactured. This reason is cited so often that some further investigation of the facts seemed warranted. In this chapter capacity issues impacting Air Force lead times are discussed. In particular, the forging and casting industries' plans for expansion are examined. This expansion, in turn, is dependent upon the availability of certain raw materials, As an example, capacity in the aluminum and titanium industries is examined. Under current conditions, many subcontractors do not feel confident enough in a high level of future military sales to take the risk of investing capital in new or improved capacity, thereby creating a cycle of insufficient capacity and longer lead times in periods of high military demand.

6.1.1 Forging Industry Capacity

Reports on the capacity situation from industry associations and individual suppliers conflicted with the Air Force explanation of capacity shortages. A report from the Forgings Industry Association in September 1980, for example, said that there was "no capacity problem" in forgings houses. In order to try and establish a better understanding of both procurement and supplier perspectives, several suppliers were asked for information on capacity, capacity utilization rates and any recent adjustments to capacity, as well as for general comments on where and why bottlenecks occurred and the breakdown of "a typical lead time." Since, according to our data analysis, forgings seemed to have the consistently longest lead times of any of the components, most attention was directed to this industry.

The Forgings Industry Association undertook a survey of its members in August 1980 to: "(1) develop facts relating to alleged shortages of forging capacity, and (2) convey study results to the various forging industry publics so that factual perspectives on the availability of forging capacity could be made known." Forty aerospace forging producers participated in the survey. Results showed that only half of the total forging capacity measured in hours of aerospace forging producers was actually used in 1979, and one-third of the actual aggregate forging hours was used to produce military forgings. Military aerospace forgings accounted for three-fourths of all the time spent on producing military forgings. The Forgings Industry Association concluded that there was no shortage of forging capacity for military aerospace requirements.

Some of the main forging houses which supply military aerospace forgings confirmed that they had not been working to full capacity even in the period of high demand for military aerospace forgings. Current capacity utilization rates were given ranging between 40 percent and 75 percent and normal capacity utilization rates as between 50 percent and 80 percent. None of the forging houses contacted said that they were more than 50 percent dependent on military business, and some were considerably less dependent.

However, this report on forging capacity presents only a partial view of the situation with regard to aerospace forgings. The spare capacity available in the forging industry does not represent capacity which can be used for large-scale military specification aerospace forgings. Currently the Air Force owns the only forging facilities capable of this work. For example, Alcoa operates Air Force Plant 47 at Cleveland comprising 50,000 ton and 35,000 ton presses and auxiliaries; similar equipment is located at Air Force Plant 63 operated by Wyman-Gordon in North Grafton, Massachusetts. The theoretical maximum capacity of these presses is three shifts a day, but due to an imbalance among auxiliary equipment (such as stock heaters, die heaters, heat-treat furnaces and manipulators) practical capacity is one to two shifts per day. With additional investment in auxiliary equipment, floor space to set down in process inventory, and industrial engineering the practical capacity level could be raised. Given a long-term demand for the type of forgings pressed at these Air Force plants, a closer examination of ways in which capacity could be increased at low cost would be desirable. The operating companies, however, are unlikely to undertake any investment themselves for reasons of uncertainty of demand as previously stated in this report.

Though the forging industry has indicated its desire to expand, this will not be achieved without some problems (see Iron Age, April 2, 1979, p. 55+). Energy supply is crucial to the forging industry's capacity expansion. Some companies in the Ohio area have responded by drilling for gas on their own property, and some northeast companies are switching from electricity to fuel oil or gas.

Another persistent problem in the industry, which may inhibit expansion, is that of acquiring, training, and keeping talented employees. There is presently a shortage of skilled workers in the manufacturing and manufacturing management areas.

Most forging employees learn their skills on the job, and it can take several years of in-house apprenticeship including four years of classroom instruction to achieve such ranks as hammer-smith, heavy press operator, or heat treater. Yet, and it is a matter of growing national concern particularly in the area of defense preparedness, the apprentice system may soon become extinct. The result will be a shortage of skilled workers in many areas critical to the U.S. defense industrial base, including the forging industry.

As has been discussed earlier in this report, small lot size and specialized forging orders coupled with the generally low percentage of military ordering, gives industry less incentive to expand capacity for this particular market. For example, DOD shipments for iron and steel forgings (SIC 3362) comprised only 2.5 percent of the entire shipments for this industry in 1977. A more detailed examination of the forging industry is included in Appendix B of this report.

6.1.2 Casting Industry Capacity

Recent trends indicate that casting lead times are declining for the first time in many years.* The shortened lead times are attributed to a sharp decline in demand for steel castings (especially small castings) caused by the current economic conditions. Energy-related casting markets remain strong, but deterioration is occurring for railroad freight car builders, manufacturers of mining and heavy construction equipment, large materials handling units, marine equipment, and pressure vessel fabrication units. Lead times for large castings, such as those used by the military, are declining also but the trend is not so distinct as that for the small castings.

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*Purchasing, August, 7, 1980, p. 73.

Due to the drop in casting demand, the projected production for 1980 has been revised by the Steel Founders Society from 2,050,000 tons to 1,800,000 tons. Industry capacity is currently rated at 2,500,000 tons. Yet despite any current lead time and capacity relief, it may still be difficult to expand the production of large steel castings, such as those required by the Air Force. These castings, as discussed in this report, are usually bought in relatively small lot sizes. As a result, the foundry experiences frequent downtime for changing molds or steel grades in order to produce the next customer's order. These conditions also do not lend themselves to the incorporation of more efficient automated machinery.

The overall casting industry market, as noted earlier with forgings, is not heavily influenced by DOD orders. DOD shipments from steel improvement foundries (SIC 3324), for example, comprise only 1.8 percent of the total for that industry, and only 1.4 percent for aluminum foundries (SIC 3361). Further discussion of the casting industry is included in Appendix B.

6.2 MATERIAL SHORTAGES

A preliminary attempt was made to break down and analyze the different component sections of "lead times." Some of the original data collected in the AFSC survey did split lead time (receipt of order to delivery time) into queuing time and manufacturing, but these were the exception rather than the rule (see Table 6.2-1). However, these breakdowns did show that in most cases queuing time, rather than the actual production time, was mainly responsible for long lead times. This queuing time was not clearly defined by the respondents, but may be understood to mean all the stages <u>before</u> actual production, i.e., processing of orders, ordering of materials and any special tooling, set-up time, etc. Several forgings houses were

TABLE 6.2-1

EXAMPLES OF 1980 QUEUING AND PRODUCTION TIME, IN MONTHS

Component	Component Manuf.	Subsystem	System	Queue Time	Queue as % of Total	Manuf. Time	Manuf. Time as % of Total	TOTAL Lead Time
Forging	Wyman-Gordon	Landing Gear	A-10	26	(79)	7	(21)	33
Light Press Extrusions & Aluminum Plate	-	ACES II Seat	A-10	17	(59)	12	(41)	29
Titanium Forgings	Wyman-Cordon Carlton Forge Reisner Metals	TF34-100 Engine	A-10	20	(74)	7	(26)	27
Standard Forgings	Wyman-Gordon Carlton Forge Reisner Metals	TF34-100 Engine	A-10	17	(65)	9	(35)	26
Connector	Time	Visual System (& Others)	F-16 OFT	12	(80)	3	(20)	15
Casting	Surcast	Radar	F-16	1	(8)	11	(92)	12
Casting	Shellcast	Radar	F-16	1	(8)	11	(92)	12
Connector	Cannon	Visual System (& others)	F-16 OFT	7	(70)	3	(30)	10
Integrated Circuits	Fairchild, Texas Instruments	Computational System	F-16 OFT	1	(11)	8	(89)	9
Connector	Bendix	Visual System (& others)	F-16 OFT	5	(63)	3	(37)	8

asked in follow-up interviews what a typical lead time breakdown would be. For military steel forgings, normal lead times of between six and twelve months were quoted, and somewhat longer lead times were quoted on titanium forgings, depending on material availability. In general, the forging houses account for approximately 50 percent of the quoted lead time in the actual forging processes including forging machinery and any specialized processing that needs to be done before actual shipment. Before entering the forging process, approximately 50 percent of the lead time is accounted for by processing of the order, ordering and waiting for materials and any set-up that needs to be done before forging can take place. Unlike the materials used in commercial types of forgings, materials used in military aerospace forgings are usually of a specialized nature -- extremely high alloy steel or a particular grade of titanium, for example -- and therefore the forgings houses do not keep this material in stock.

One way in which the Air Force could dramatically reduce lead times for forgings, therefore, would be to ensure material availability. This could be done through a variety of means. Advance orders and payments for materials ahead of ordering the actual system, subsystem and component would ensure a reduction in queuing time. Material availability could also be ensured through releases from the government stockpile or extension of the defense materials system (DMS) to materials which are the cause of bottlenecks. Other areas where improvements might be possible, but where information was beyond the scope of this study, are the time needed between an Air Force decision to order a system/subsystem/component and the time the order is received or acted upon by the supplier. Similarly, there may be opportunities for improvement between the time when the item is ready for shipment and delivery to its destination. The Air Force could undertake a case study of the critical items for a system and subsystem and trace the time needed for each part of the procurement cycle in order to understand where and why delays occur and then take some corrective action.

The ability of the forging and casting industries to expand will depend partly upon their ability to obtain certain critical raw materials, such as aluminum and titanium. Aluminum production, especially for sheet and plate, has been limited in recent years by th lack of capacity. The Aluminum Association projects, a small increase in production from 5,312,600 short tons in 1980 to 5,574,600 sheet tons in 1983.

Alcoa is one of the first aluminum manufacturers to recently expand capacity, adding increased heat-treating facilities in Davenport, Iowa, expanding the continuous casting and cold rolling mill at Lebanon, Pennsylvania, expanding rolling facilities in Alcoa, Tennessee, and constructing a new sheet mill in Wales, U.K. Martin Marietta plans to increase production in mid-1982 and Alumax plans an increase from 218,700 short tons to 415,700 short tons by the end of 1980. Kaiser has recently spent $200 million to modernize aluminum sheet facilities in Trentwood, Washington and Ravenswood, West Virginia. Reynolds has constructed a new continuous casting and cold rolling plant in Arkansas, and has spent $70 million to expand the McCook, Illinois sheet and plate plant.

Yet, according to a recent article in Business Week* the most significant growth in the U.S. aluminum industry is overseas. Most of the U.S. capital expansion is taking place in Brazil and Australia. Both countries have plentiful supplies of bauxite, the raw material from which alumina is refined

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*"For Aluminum, A Shift Overseas," Business Week, December 8, 1980.

and then electrolytically reduced to aluminum. Australia and Brazil are considered safe countries for business, and also offer the advantage of cheap energy (if compared with U.S. costs).

The high price and undependable supply of energy in the U.S. is contributing to the aluminum industry's trend to move overseas. The energy problem is most severe in the Pacific Northwest, where approximately 30 percent of the nation's aluminum is produced. Because uninterruptible sources of power could not be guaranteed by the Bonneville Power Administration in the Pacific Northwest, and because other power suppliers were charging as much as ten times Bonneville's price, some aluminum manufacturers in the area have decreased production. Alcoa, for example, has shut one and a half potlines with an annual capacity of 54,000 tons, and Reynolds has cut production by approximately 10 percent, or 34,000 tons.

Capacity utilization in the U.S. aluminum industry is expected to be approximately 94 percent in 1981. Industry analysts predict that by 1982 or 1983 European demand for aluminum will rise, and shortages may develop.

Titanium capacity is particularly constrained due to the small number of domestic firms producing titanium sponge: Timet, RMI, and Oregon Metallurgical Company.[*] Industry capacity for titanium sponge is estimated at 24,500 tons per year. RMI has recently completed a $3.5 million expansion of its Ashtabula, Ohio plant, which was heralded as "the titanium industry's first major capital expenditure since 1968."[†]

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[*] Journal of Metals, May 1979, p. 22.

[†] The Wall Street Journal, July 23, 1980.

Oregon Metallurgical Corp is planning to complete its mill products plant by late this year, and boost its current sponge capacity of six million pounds a year by 50 percent in 1981. The company also plans to add melting capacity in 1982. Titanium Metals Corp. expects to expand sponge production to 32 million pounds in 1984 from the current 28 million.

Two Japanese sponge producers, Toho Titanium and Osaka Titanium are expanding their plants. The USSR is planning to expand titanium sponge capacity by 25 percent, or an estimated 15,000,000 pounds. A fourth U.S. firm is expected to open a plant in 1982 in Texas. It will be called D-H Titanium Company, and is a joint venture between Dow Chemical and Howmet Corporation.

Non-military sector consumption of titanium sponge has increased dramatically in recent years. In 1972 only five percent of the titanium sponge used domestically went for products other than aircraft, where in 1979, 30 percent went to non-aircraft customers. This trend away from dependence on the military market is encouraging titanium producers to expand. Yet, due to the large percent of titanium sponge which is still used for aerospace applications (about 70% in 1979), the planned increases in existing plant capacity as well as the addition of D-H Titanium should in the future serve to improve sponge lead times for Air Force systems.

When asked what impact the DMS and DPS systems had on lead times the contractors questioned replied that either the systems worked or they had little impact. Several contractors mentioned that they would like to see government action to ensure greater availability of parts or materials through, perhaps, incentives to industry. On the whole, however, industry suppliers wish to run their own business with minimal government oversight or control.

In sum, the main bottlenecks as far as aerospace forgings are concerned seem to be the timely supply of specialized materials such as titanium. Some suppliers said that they had to wait two years for their orders of titanium. Others maintained that the allocation system was providing some materials but stretching lead times further than normal. The difficulty of receiving an adequate supply of cobalt (from Zaire) was also mentioned as a factor contributing to long lead times. Suggested solutions to these bottlenecks included government incentives to industry such as more rapid depreciation allowances and an updated and replenished stockpile to include the needs of modern aerospace production.

7. RECOMMENDATIONS

7.1 RECOMMENDATIONS FROM SURVEY

In providing lead time data on systems, subsystems and components, some program offices also supplied recommendations on ways in which government procurement practices from primes (and subcontractors) could be changed to improve lead times. Many of these recommendations could apply to government procurement other than Air Force systems. Apart from these general recommendations, however, some recommendations which more specifically refer to the nature of contracting for the Air Force were mentioned.

Table 7.1-1 shows the number of recommendations provided by each program office. Most recommendations were given only once although many of them tend to overlap in their practical implications. Table 7.1-2 gives a breakdown, under group headings, of the types of recommendations received, and frequency cited. The main headings used to group these recommendations are procurement management, ordering, funding, incentives, easing requirements and miscellaneous.

The largest number of these recommendations (35%) fall under the general heading of procurement management. This is perhaps to be expected since procurement offices were the originators of these suggestions and are likely to be more aware of changes they would like to see implemented in their own area of procurement management. Most of the procurement management type of recommendations tended toward greater government control over prime and subcontractors. As far as funding,

TABLE 7.1-1

NUMBER OF RECOMMENDATIONS BY PROGRAM OFFICE

System	# of Recommendations
A-10	26
PMALS	14
Laser Guided Bomb	13
B-52 OAS	7
SACDIN	4
F-16	2
ECMS	2
E-3A	1
F-16 OFLT	1
GBU-15	1
JTIDS	1
F-15	0
TOTAL	72

the next most important group of recommendations (26%) was concerned, there were several suggestions in favor of multi-year program funding. This significant change in procurement practices will be referred to again more fully later in this discussion of recommendations. The recommendations falling under the general heading of "ordering" received 14 percent of all recommendations from the survey, as did the "miscellaneous" group. The former category included such recommendations as combining orders or making advance buys, whereas the latter included a range of suggestions including a government role in expanding industrial capacity where needed and increased supply from government -- owned and controlled sources.

TABLE 7.1-2
RECOMMENDATIONS

Recommendations	A-10	B-52	E-3A	ECMS	F-15	F-16	F-16 OFT	GBU-15	JTIDS	Laser Guided Bomb	PMALS	SACDIN	Total	%
	26	7	1	2	0	2	1	1	1	13	14	4	72	
Procurement Management													N=25	34%
Aggressive Procurement Management	3/12%										2/14%		5	7%
Blanket/Annual Agreement PO's		2/29%											2	3%
Early Planning											3/21%		3	4%
Enforce Priority Ratings	3/12%	1/14%		1/50%									5	7%
Evaluate Contractor's Purchasing Systems	1/ 4%													
Evaluate Subcontractor Lead Times	1/ 4%												1	1%
Frequent Communication with Primes & Subs											3/21%		3	4%
More Active Role in Schedule Negotiation	1/ 4%												1	1%
Reserve Manufacturing Time	1/ 4%	2/29%											3	4%
Use Priority Rating													0	—
Encourage Mills to Make Desired Quantity	1/ 4%												1	1%
Funding													N=19	26%
Five Year Commitment													0	—
Long Lead Procurement Funding	4/15%			1/50%		1/50%							6	8%
Multiple Source Procurements		2/29%											2	3%
Multi-year Program Funding	3/12%		1/100%						1/100%	3/23%	1/ 7%	2/50%	11	15%
Ordering													N=10	14%
Buy Stock, Make Advanced Buys											2/14%	1/25%	3	4%
Combine Orders	1/ 4%												1	1%
Coordinate Procurement of Piece Parts with Subs											1/ 7%		1	1%
Early Buy-outs										1/ 8%			1	1%
Increased Demand										1/ 8%			1	1%
Large Orders											1/ 7%		1	1%
Manual Ordering of Some Critical Parts						1/50%							1	1%
Order Spares with Original Order							1/100%						1	1%
Incentives													N= 4	6%
Better Capital Investment Incentive										2/15%			2	3%
Higher Allowable Profit Margins										1/ 8%			1	1%
Premium Pay								1/100%					1	1%

TABLE 7.1-2 (Continued)

Recommendations	A-10	B-52	E-3A	ECMS	F-15	F-16	F-16 OFT	GBU-15	JTIDS	Laser Guided Bomb	PMALS	SACDIN	Total	%
Easing Requirements													N= 4	6%
Ease Environmental Restrictions													0	—
Ease Degree of Specificity										1/ 8%			1	1%
Use Off-the-Shelf Items	1/ 4%									1/ 8%			2	3%
Substitute Type										1/ 8%			1	1%
Miscellaneous													N=10	14%
Develop New Capacity in Specific Technology	2/ 8%												2	3%
Funding for 2nd Source Qualification										1/ 8%			1	1%
Improve Mill Capacity	2/ 8%									1/ 8%			3	4%
Increase Titanium Sponge Supplies	2/ 8%												2	3%
Manpower Analysis and Training													0	—
Government Supply High Reliability Items											1/ 7%		1	1%
Make Components In-House												1/25%	1	1%

Although these recommendations can in no way be considered a statistically significant sample or distribution (due to the disparity of response frequency and the optional nature of the question), they do at least serve to indicate some directions in which Air Force procurement offices would like to see changes which they believe could favorably affect lead times.

7.2 SUPPLIERS' VIEWPOINT OF SURVEY RECOMMENDATIONS

In order to gauge industry reaction to some of these recommendations and to hear from some Air Force subcontractors, several were telephoned for their views on specific recommendations. In addition, they were asked if they had any further recommendations whose implementation would reduce lead times.*

There was a large degree of agreement and consistency among the responses from the subcontractors, regardless of industry sector. While they agreed that the government could take some steps which would help to reduce lead times, they were generally against any greater government interference in their business. This was indicated by support for early planning, an increase in the size of orders where possible and advance buys on the part of the government (who would have to bear additional inventory storage costs). However, there was little support for any further government evaluation of contractors' purchasing systems or lead time records, or more active role in schedule negotiation. Further, it appears that industry does not want the government to develop new capacity, but would generally be in favor of government incentives (such

*The selected subcontractors who responded with their views were: Alcoa, Bendix, Carlton Forge, Fairchild, General Electric, and Wyman Gordon.

as investment tax credits or depreciation allowances) to industry for defense items.

There was a very strong consensus among those firms questioned that multi-year contracting would aid in decreasing lead times. The reasons for this include the fact that if a firm knows that it has a long-term contract, rather than one which might not be renewed annually, then this is in and of itself an incentive to provide better service to the customer, as well as a basis for better planning and management of their own production flow and also maintain a higher level of production capacity. Some firms said that they have already worked with multi-year contracts with the government for some items and that this had worked well.*

In order for the practice to become more widespread certain existing legislative obstacles would need to be removed, such as the current $5 million ceiling on termination liability. A figure of $100 million has been widely recommended (e.g., by the Defense Science Board) as being more realistic. Congressional approval is also needed to include material and labor for "continuous" production in the cancellation ceiling instead of the one-time start-up cost policy.

Industry representatives were generally in favor of early planning on the part of the government which would in turn enable them to plan their contracts better. It was widely agreed that government incentives to military contractors would result in more timely contract performance and delivery schedules. Specifically, subcontractors would like to see higher

*Multi-year contracts have been awarded for the GAU-8 30mm ammunition used on the A-10 aircraft (three years) which will save an estimated $34 million, and for the AN/ALQ-155 Power Management System used on the B-52 in the electronic countermeasures area which will save an estimated $10.6 million in three years.

depreciation allowances, investment tax credits for their military-related capital investments and perhaps some greater flexibility in profit margins on defense business. There was also a substantial consensus that the ordering of spares together with the original procurement would make good sense and help to decrease lead times. Some concerted action would need to be taken by AFSC and AFLC in order for this to be achieved.

7.3 OTHER RECOMMENDATIONS

7.3.1 Other TASC Studies

In an earlier study for the Office of the Secretary of Defense TASC made several recommendations based on a review of 20 studies of lead time and surge capacity which are believed to still be relevant today and applicable to the Air Force lead time problems. These recommendations were to:

- Establish a pilot program for buying spare parts of components for two to three years usage with the initial production contract
- Establish and monitor a test program for obtaining capacity commitment from suppliers through multi-year contracts
- Develop a program to analyze the effectiveness of the DOD priority and allocation program
- Establish a scenario-independent program (i.e., ask how much the defense indutrial base can produce rather than ask if it can meet certain scenario demands)
- Analyze lead time for high value industrial plant and equipment, and evaluate the viability of reserve equipment.

While not reducing lead times in and of themselves, these recommendations would investigate steps which could be taken toward control of lead times, more effective procurement practices and a basis for evaluation of the industrial base.

The first suggestion, that of buying spare parts with the initial production contract, would require a large capital investment at the outset of the project rather than a flow of funds over several years. This practice would benefit from savings on inflation, but would demand changes in appropriation practices. The benefit from this recommendation would include a greater freedom for suppliers to focus on other products after the initial and spares contract had been fulfilled. For the government, the placing of the spares order early on would save on time-consuming processing of orders, ordering of components, etc. There would also be the advantage of increased sustainability if spares could be deployed with finished products in the field; logistics support could be improved if the right equipment was in the right place at the right time. There would also be lower unit costs because of higher quantities and the supplier would be able to smooth production schedules. However, careful consideration would need to be given to the difficulty of assessing the exact demand for spare parts, where there is danger of over- or underestimation. If insufficient spares are ordered, there would be delay and costs in restarting a "cold" production line as well as the difficulty and frustration of wanting further spare parts. In the case of overestimation money, time and other resources would be wasted. There is also a danger of obsolescence.

The benefits of contractor capacity commitment or multi-year orders would include a certainty of contractor performance for DOD and a certainty of business for the contractor. There would also be secondary benefits of economies in production runs, material or component orders, paper processing, etc. On the other hand, a contractor may be reluctant to tie up production lines for defense and perhaps lose secure commercial business. However, if overall demand is projected to grow, then the contractor would have some basis for long-term planning and capital investment.

The subject of compliance with the priorities and allocations (DO and DX) system is one which has been examined from time to time for its effectiveness. Earlier studies have demonstrated a lack of meaningful or complete data due to industry's reluctance to cooperate without compensation. Any new study would have to contend with or overcome this problem. An analysis of the system could be performed by selecting a few examples for assessment and comparing whether or not greater effectiveness might be attained by a more rigorously selective assignment of DO priorities.

The general question of production machine tools could be addressed by studying the specific example of reserve industrial equipment held by the Defense Industrial Production Equipment Center (DIPEC). It would be beneficial for surge planning to know what the typical lead time experiences were for this equipment. The age, condition and frequency of use of equipment, dispersal and acquisition policies and practices would also be analyzed to determine the efficiency of the equipment in reserve and its useful life. This type of study could either be performed on a case study basis or using a broader, less in-depth approach.

7.3.2 Defense Science Board

In August 1980 a Defense Science Board Task Force on Industrial Responsiveness met to discuss issues relating to the development of a near-term strategy and specific actions for improving the rpesent state of industrial responsiveness. The Task Force was asked to provide specific guidance and to examine actions which could be accomplished within the defense community such as improved cash flow, profit policy implementation, multi-year procurement concepts and advance buy/stock piling of long lead items. The Task Force was also asked to review actions taken since the 1976 Defense Science Board (DSB) sutdy of industrial preparedness plans and programs. Since many of the findings and recommendations of the DSB Task Force are relevant to the subject of lead times and associated costs and inefficiencies, several observations and recommendations are summarized here.

The DSB Task Force found that the main reasons for total acquisition program cost growth were due to the higher rates of actual vs. predicted inflation, optimistic government and industry estimates obtained in early phases under competitive conditions, impact of technical changes and schedule and quantity changes. Productivity was found to be decreasing due to low levels of capital investment and uneconomic buys. Lead times were increasing, causing program stretch-outs and even higher costs in subsequent years. The lower tier suppliers find defense business less and less attractive, and there is a growing dependence on foreign sources for parts and materials.

The Task Force recommended that OSD should modify policies and practices to encourage gerater capital investment by improving cash flow, enhancing the financial stability of the industry, and ensuring that recent profit policy changes are implemented at all levels. The Task Force also recommended that industry and DOD should encourage, request, and support executive and Congressional actions designed to stimulate capital investment e.g., changing tax policies and accounting standards. Similarly, it was recommended that DOD and industry encourage Congressional action to modify legislation currently constraining the use of multi-year contracts. Further, DOD should encourage, through tax and profit policies, contractor ownership and maintenance of modern and efficient machine tools and phase out the obsolete government-owned machine tool base. Title III of the Defense Production Act could be used to provide loans, loan guarantees or subsidies for domestic mineral exploration and development and upgrade the national stockpile. The DSB Task Force also recommended greater education and implementation of the DPS and DMS.

The DSB Task Force included representatives from both industry and government so that there was an opportunity for discussion from different perspectives before agreement on these findings and recommendations was reached. Many of these observations overlap with or are confirmed by findings in this study.

7.4 POTENTIAL INSTITUTIONAL ACTIONS

There are a number of ways in which current legislation permits actions which could favorably influence lead times. These include the defense priorities system, the defense materials system, stockpile releases, expansion of industrial capacity, plant equipment packages and economic incentives.

7.4.1 Defense Priorities System

The Defense Priorities System (DPS) assigns priority ratings (DO, or DX) to important defense procurement, allowing such procurement to receive preferential treatment in terms of access to productive capacity. Slightly over 75 percent of all defense procurement qualifies for Defense Production Act priority ratings. Using the fiscal year 1974 as an example, of defense procurement of $40 billion, some $30 billion worth of contracts and orders were assigned priority ratings in that year. Rating is mandatory for all "authorized" programs and the Department of Defense states that virtually all "qualifying" contracts are so rated. The system is intended to avoid the additional inflationary costs that would be experienced through production delays in the absence of Defense Production Act priorities. This ongoing program is conducted by the Department of Commerce. This system has some potential benefit for lead times when a contractor is faced with rated orders from the Defense Department and non-rated orders from other customers. However, it is extremely difficult to know in practice what the benefits are for defense since this would mean an extraordinary amount of cooperation from contractors. The Department of Commerce is not in a position to carry out surveillance of contractors to ensure implementation of the DPS. When a contractor receives many orders with the same rating then, of course, there is technically no "priority" since they all deserve "priority." When DO and DX orders are received together DX priorities take precedence over DO orders; similarly, DO orders are intended to take precedence over all non-rated orders.

7.4.2 Defense Materials System

The Defense Materials System (DMS), like the DPS, has its origin in the Defense Production Act. The Defense Materials System (DMS) assures the availability of basic materials for defense production through mandatory material set-asides, which at this time apply to nickel, steel, copper, and aluminum, but which can be extended to cover other materials critical to defense production. This allocation mechanism is intended to distribute hardships and stresses more equitably among producers. This program also helps avoid the upward pressure on defense costs that would result from the necessity of acquiring materials without mandatory set-asides for high-priority programs. Since defense contractors have suffered from long lead times for other materials such as titanium and cobalt, there are arguments for extending the DMS to these materials (and perhaps other critical materials) also. An extension of this nature would require legislative action.

7.4.3 Stockpile Releases

Related to the question of materials set-asides is the government stockpile of strategic materials. These materials may, according to the law, be released only for national defense purposes. Since the establishment of the strategic stockpile there have been 20 releases of materials for defense needs. An interagency review process evaluates the need for any release, which must be approved by the President. The current stockpile contains 62 materials and family groups and is worth $14 billion in current market value. There have been no net additions to the stockpile in over two decades despite many unfulfilled goals.

Clearly, the government stockpile has not achieved its goal of providing adequate stockpiles of critical materials for national defense purposes since most of the stated goals for individual materials have not been met. Although the stockpile has been used to provide materials in some cases, the conditions for release and distribution of materials are very stringent, i.e., it has to be shown that the materials are not available from any other sources, and once this has been demonstrated, the President is required to sign an authorization for release of that material. Economic conditions or hardship are not sufficient grounds for a material release. In the case of materials for defense production for the Air Force, therefore, this avenue of possible government action to ease current difficulties would not seem to be a viable one.

7.4.4 Expansion of Industrial Capacity

Pursuant to the Defense Production Act, the government has the authority to expand productive capacity and supply for defense purposes through the use of loans, loan guarantees, and commitments to purchase. Currently each funding proposal must be presented to Congress for approval in an appropriations bill. The DPA was recently amended to provide funding for synthetic fuels. This activity has been more symbolic than effective in recent years. There have been no major projects since 1967 despite a shrinking defense productive base.

7.4.5 Plant Equipment Package (PEP)

The PEP concept provides for the retention and assignment of complete production lines or individual pieces of equipment to designated producers for the manufacture of certain items. This is intended primarily for mobilization purposes, but could potentially be used in other emergencies.

7.4.6 Economic Incentives

A number of economic incentives can facilitate industry's increased production. These include tax write-offs, more rapid depreciation of capital and equipment, increased profit margins, and use of cost plus contract. These measures have been used in various circumstances to stimulate industrial output and expand capacity. Changes in tax law, of course, require legislation, and changes in contracting procedures must take into account Administration and Congressional policies.

7.5 SHORT-TERM AND LONG-TERM RECOMMENDATIONS

7.5.1 Short-Term Recommendations

Although the Air Force does not have the authority to initiate or implement all of the following recommendations, these actions are indicated as areas where change is needed and which could have a beneficial effect on Air Force system lead times.

- Dispose of all equipment (not plants) which use outdated technology (e.g., >20 years old). Use proceeds to improve plant and equipment currently in use
- Improve Defense Priorities System effectiveness
- Monitor procurement cycle to see where improvements might be made and lead times reduced
- Address question of dependency on foreign sources for critical parts and materials
- Address question of dependency on sole source suppliers

Economic incentives are likely to produce the most immediate effect on suppliers' performance and delivery time. Such incentives would include:

- Indexing progress payments to prime interest rate
- Expediting the government paying cycle
- Increasing use of milestone billings and advanced funding
- Enforcing consistent application of tailored economic price adjustment (EPA) clauses
- Ensuring that primes flow down EPA clauses to sub-tiers.

7.5.2 Long-Term Recommendations

The following changes in current practice are offered to the Air Force for consideration as possible solutions to lead time and related problems. Some of these changes require further study or coordination and cooperation with other organizations before actions can be explicitly defined or instituted.

- Extend DMS to include other critical materials such as titanium and cobalt
- Increase stockpile of critical materials in light of current and projected needs for strategic materials. Review conditions for release of materials
- Raise termination liability from $5 million to $100 million to facilitate multi-year funding
- Buy spare parts together with initial procurement
- Encourage industrial expansion of capacity in areas which do not compete heavily with commercial demand and for which there is likely to be a continuing heavy demand for defense purposes through tax incentives, depreciation allowances, etc.
- Introduce the possibility of multi-year funding for systems which are likely to be procured over several years
- Provide investment incentives to industry such as more rapid depreciation, capital investment allowances for defense business, flexibility in profit margins.

DOD, working in conjunction with prime contractors, should adopt policies and practices which ensure appropriate tailoring of subcontractors and supplier purchase orders and greater flow down of favorable contract terms.

- Ensure that national defense needs are properly considered in the application of government regulations (e.g., OSHA, EPA, Tariffs, etc.)

- Utilize Title III of the Defense Production Act to provide loans or loan guarantees, subsidize purchases, or support domestic mineral exploration and development
- Conduct an educational program in industry and DOD on the DPS/DMS systems
- Integrate handling of requests for special priorities assistance
- Reduce paperwork required by government subcontractors
- Multi-year funding for lower-tier suppliers to benefit from economies in production runs where possible
- Combination of orders where possible to benefit from economies of production runs
- Simplification of military specifications where possible
- Greater use of off-the-shelf commercial items where possible (e.g., connectors, integrated circuits)
- Address issue of actual or projected lack of skilled labor in key aerospace industries (such as machinists).

8. DATA/GATHERING FOR A PREDICTIVE SYSTEM

8.1 INTRODUCTION

Lead times for critical parts and materials have increased to the point whereby system production is delayed by many months. The magnitude of these delays is of sufficient importance to necessitate immediate steps towards the reduction of current lead times and to develop an ongoing program to prevent a recurrence of the problem. An ongoing predictive system can be used to provide realistic projections of future lead times for parts and materials to plan new policy strategies and evaluate their impact.

The primary function of the predictive system will be as a decision making tool. The construction of a predictive system is beneficial as it puts many of the uncertainties and complexities associated with the lead times of critical parts and materials into a logical framework amenable to comprehensive analysis. The system will generate a set of defined indicators to provide early warning of possible lead time increases and bottlenecks.

A part or material becomes critical when the lead time between the order and the delivery results in a production delay for the system requiring that part or material. Frequently, there is more than one required part or material which can be designated as critical, therefore a reduction in system lead time will require a concerted policy change, rather than a piecemeal attack on individual problem parts and materials.

The predictive system will generate indicators of future problems as output. These indicators will function as an early warning, and will be associated with increased lead times for parts and materials that have not reached the critical stage. The warning is to indicate to the decision maker that corrective or preventative intervention is necessary to avert a future lead time problem. The decision maker can then address alternative interventions and evaluate their anticipated effects on the problem.

8.2 PREDICTIVE SYSTEM

The predictive system will be based on statistical analysis of the information and data collected and systems analysis methods. This systems approach will allow exploration of the interaction of different variables, e.g., supply, demand, capacity, and profit in order to project future lead times using an analytic based methodology. The relationships among these variables will be estimated using existing knowledge and past and present data. From these relationships, future trends will be extrapolated and lead times will be predicted. Figure 8.2-1 depicts a systems perspective for Air Force part and material lead times. The key feature of the approach is the computation of the interaction between commercial and defense demand with the available supply, as well as the estimation of the parameters reflecting firm capacity: labor, materials machinery, and profit measures. Analytical techniques such as regression and network theory will be used to define the set of early warning indicators.

The data base will be used to generate warning indicators as output for the following components of increased lead times for parts and materials:

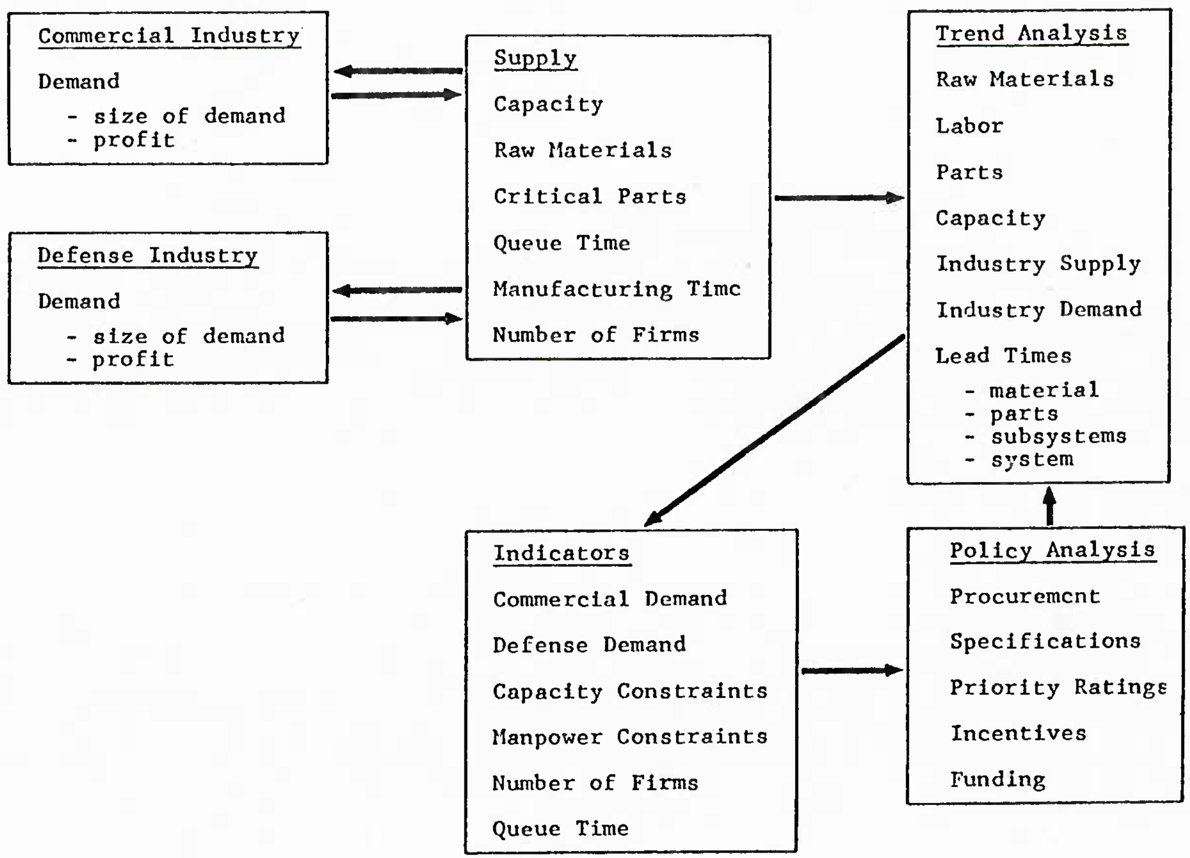

Figure 8.2-1 Systems Model of Aircraft Industry

- Commercial demand
- Defense demand
- Capacity constraints
- Manpower constraints
- Number of firms
- Queue time
- Manufacturing time.

These output indicators will be used to select from the identified alternative policy actions, and in the evaluation of the impact of the actions on the indicators. The policy areas as follows:

- Procurement
- Specifications
- Priority ratings
- Incentives
- Funding.

The data gathering and predictive system will be executed in a manner such that future phases can add other critical aircraft parts and materials, as well as critical parts and materials for other Air Force programs.

8.3 DATA NEEDS AND SOURCES

A data acquisition plan is necessary to provide information to estimate the system parameters. Lead time data already collected will be supplemented by an additional data collection effort. This new effort will revolve around the estimation of the basic subsystem parameters for the commercial industry demand, defense industry demand, firm level supply and the effects of policy changes.

Aspects of commercial demand will be estimated with FAA forecasts, Commerce Department (Bureau of the Census) collection of aggregate industry statistics. Defense industry demand will be estimated using DOD forecasts, and Air Force projections. Firm specific data reflecting capacity, material availability, queue time, manufacturing time and profit measures will be collected through firm level interviews and questionnaires, as well as from Air Force data.

8.4 TECHNICAL ASPECTS

An initial interactive Fortran computer model with detailed specifications to forecast trends for lead times of selected critical parts and materials will be developed. The specifications will be clearly documented and will include definitions of all relevant industry variables, diagrams reflecting the flow of information through the model, equations, programming language, and data base structure and information specifications. Potential problem areas will be explored through the use of sensitivity analysis.

APPENDIX A
BALL AND ROLLER BEARING INDUSTRY PROFILE (SIC 3562)

A.1 INTRODUCTION

A ball or roller bearing (also known as an anti-friction bearing) is a machine element that permits free motion between moving and fixed parts. Bearings are essential to mechanical equipment; they hold or guide moving machine parts and minimize friction and wear. Ball bearings consist of balls running in grooves in inner and outer races, and roller bearings are essentially the same with rollers replacing the balls.

Anti-friction bearings have existed since ancient times. Egyptian engineers used a type of roller bearing to transport blocks of stone from the quarry to the building site of a pyramid. The Egyptians also used bearings in chariot wheels. Bearings have been made from wood, stone, leather, bone, and later of metal. Lubrication is crucial to the functioning of a bearing, and petroleum oils and grease fortified with chemical additives are generally used for this purpose. The first major application of anti-friction bearings was for use in bicycles, just before the year 1900.*

The bearings industry began sometime after 1907, when the crucial bearing patent was awarded to Mr. Conrad. This patent established the first complete and practical bearing, one combining the rolling element, races, and cage. It was

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*McGraw-Hill Encyclopedia of Science and Technology, 1977.

only after this point that control over bearing accuracy could be achieved, since prior to this time rolling elements were supplied to a manufacturer who would then fabricate his own races and cage. Mr. James Whitsett, President of the Anti-Friction Bearing Manufacturers Association, could not identify the exact date of the first bearing company (it was probably shortly after 1907), though he indicated that it was a hotly debated subject in the industry!*

Shipments for the industry are expected to increase nine percent in 1980, to more than $3.5 billion, following expansion in the aircraft, mining and oil field machinery industries, and the continuing, though slower growth in construction machinery, agricultural machinery and most other industrial equipment markets. As in 1979, the primary negative influence on sales in 1980 will be the decline in automotive production. Several of the major bearing manufacturers completed difficult labor contract settlements in 1979.†

A.2 THE PRODUCT

A.2.1 Materials

When bearings are needed to withstand high stress and temperature, they are composed of a low chrome alloy steel, or as in the case of aircraft, of a tungsten alloy.

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*Telephone conversation with Mr. Whitsett, 8/7/80.

†Department of Commerce, 1980 U.S. Industrial Outlook, GPO, January 1980.

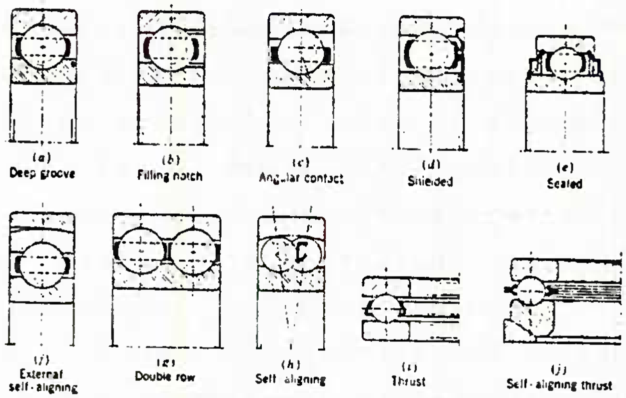
A.2.2 Production Process

There are three parts to a bearing: the races (or rings), which contain the balls or rolling elements, and the cage which holds everything in place. The rings are forged or cut from tubing, and then heated and ground to the final configuration. The rolling elements are formed in a cold header and then ground, heated, and ground again. The cage is stamped from sheet steel. The manufacture of bearings involves many technologies and sophisticated engineering expertise. The production process is highly automated though less than 12 types of bearings (out of thousands) are made in a large enough quantity to allow total automation. Figure A.2-1 shows the various types of anti-friction bearings that are produced.

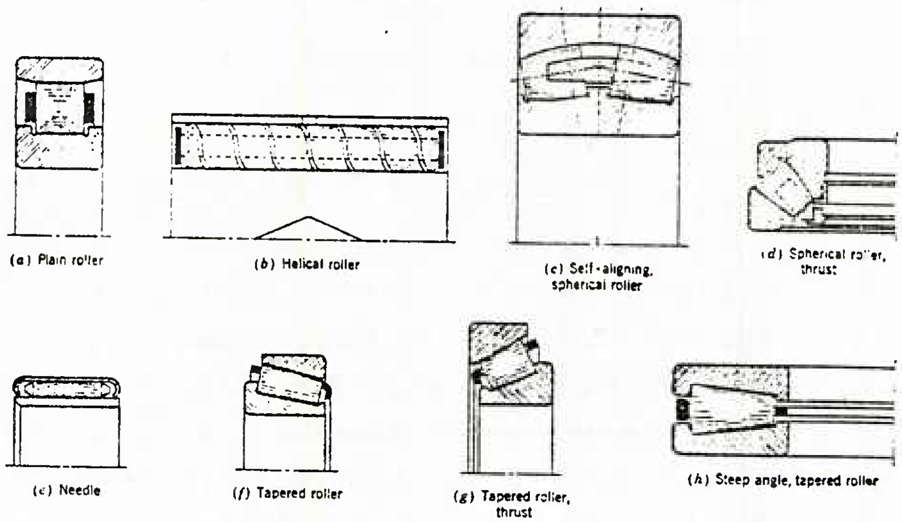
A.3 MARKET ANALYSIS

A.3.1 Structure

The anti-friction bearing industry is mature, stable, and highly technical. There were 153 ball and roller bearing firms reported in the 1977 Census of Manufacturers, with 107 of the firms having 20 or more employees. In the 1972 Census there were 135 firms, in 1967 there were 124, 125 in 1963, and 107 in 1958. The bearing firms are mainly located in the Northeast and North Central states. In 1977 Pennsylvania had the greatest number of bearing firms (19), Indiana was second with 11 firms, and South Carolina was third with nine. Though South Carolina is third in number of firms, it is ranked first in number of employees, value of shipments, new capital expenditures, value added by manufacture, and cost of materials. This is in contrast to the 1972 Census where South Carolina ranked third in employees and value added by manufacture.



Ball Bearings



Roller Bearings

(Courtesy of the Timken Roller Bearing Company.)

Figure A.2-1   Types of Anti-Friction Bearings

South Carolina employment in the industry rose 56 percent between 1972 and 1977.*

The Department of Commerce projects a compound average annual growth rate for the industry of 29 percent per year through 1984. Because the bearings industry serves such a wide range of manufacturing markets, it remains dependent on the expansion and contraction of end-user production. After 1980 automotive sales are expected to climb for several years, and most other major industrial equipment markets are expected to grow through 1984, but at a slightly slower rate than during the last several years.†

The ball and roller bearings industry is fairly concentrated, and has shown little change in concentration since the 1940s (see Table A.3-1).

A.3.2 Performance

Inventory data for the industry are given in Figure A.3-1.

Capacity utilization figures, derived from the Department of commerce Survey of Plant Capacity (for several years) are given in Table A.3-2.

The NAs (not available) above are due to inconsistencies in the Department of Commerce data collections in this area.

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*Dept. of Commerce, 1977 Census of Manufacturers, "Ball and Roller Bearings," Preliminary Report, April 1979.

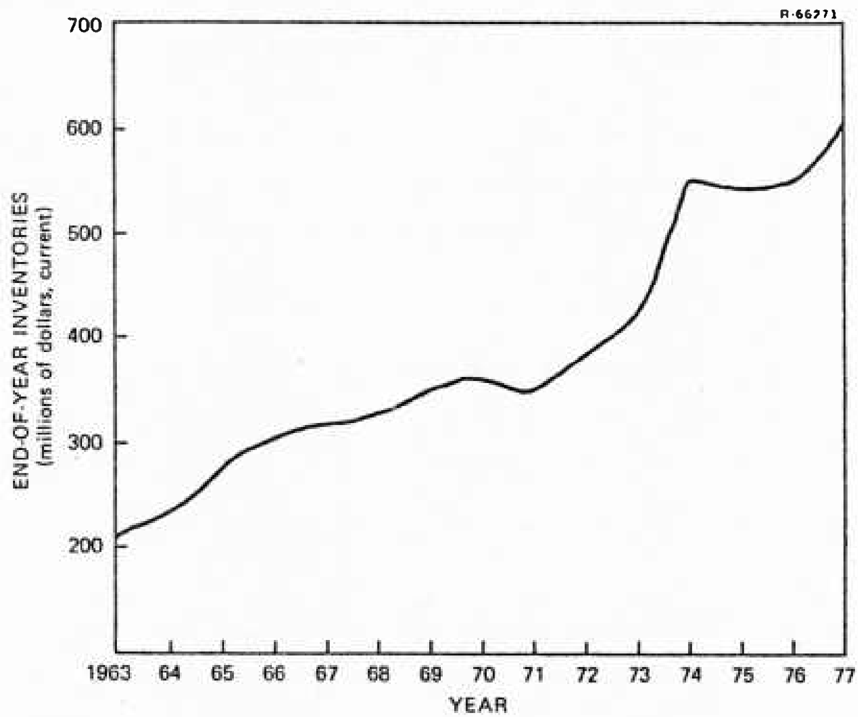
†U.S. Industrial Outlook.

TABLE A.3-1

SHARE OF VALUE OF SHIPMENTS ACCOUNTED FOR BY THE 4, 8, 20, AND 50 LARGEST COMPANIES (CONCENTRATION)

	# Comp.	Total $ Million	4 Larg. Comp.	8 Larg. Comp.	20 Larg. Comp.	50 Larg. Comp.
1972	99	1,530.5	53	73	89	99
1970	NA	1,314.6	54	74	NA	NA
1967	85	1,328.5	54	73	90	99
1966	NA	1,398.9	56	74	NA	NA
1963	93	998.8	57	76	91	99
1958	85	638.9	57	77	92	99
1954	83	537.2	60	79	92	NA
1947	78	365.6	62	79	93	NA

Source: 1972 Census of Manufacturers.



Source: 1977 CENSUS OF MANUFACTURERS, PRELIMINARY REPORT, BALL AND ROLLER BEARINGS, APRIL 1979.

Figure A.3-1 Bearing Industry End-of-Year Inventories, 1963-1977

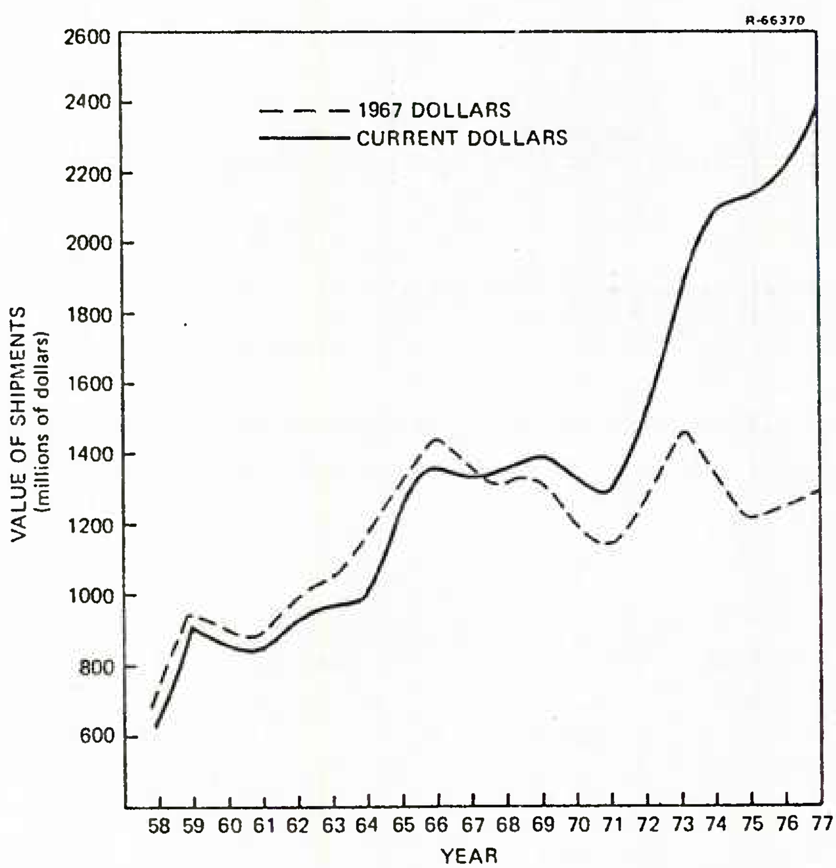
TABLE A.3-2

BEARING INDUSTRY CAPACITY

	Preferred Rate	Practical Rate
1977	89	78
1976	NA	80
1975	82	75
1974	NA	86

Figure A.3-2 shows the value of shipments for the industry in current and 1967 dollars. A new series of the Census Bureau's Current Industrial Reports has been started on anti-friction bearings (the first issue was for 1978, dated November 1979, Number MA-35Q(78)-1). This publication gives quantity data that cannot be found in as complete a form elsewhere. In 1978, 447,735,000 bearings were shipped by U.S. manufacturers.

Values for imports and exports are given below in Table A.3-3. Imports increased 17 percent in 1979, following a 43 percent jump in 1978. Rapid growth in domestic bearings



Source: 1972 CENSUS OF MANUFACTURERS, and 1977 CENSUS OF MANUFACTURERS, PRELIMINARY REPORT, 1979

Figure A.3-2 Bearing Industry Value of Shipments, 1958-1977

TABLE A.3-3

VALUE OF IMPORTS/EXPORTS IN CURRENT $ MILLIONS

	1974	1975	1976	1977	1978	1979(Est.)	1980(Est.)
Exports	195	209	194	236	290	290	290
Imports	234	207	221	277	398	466	530

consuming markets, coupled with the phasing-out of special tariff duties on selected ball bearings groups in May 1978 were major contributing factors to the growth in imports in the 1978-79 period. Japan was the leading source of imports in 1979, sending 42 percent of the total. Other suppliers include West Germany (21%) and Canada (12%). Singapore and Romania are beginning to influence the U.S. market considerably as imports from each grew from a small amount in 1978, to $12 to $14 million in 1979 (3% of the total market).* From 1978 to 1979, Romanian imports to the U.S. increased by 82 percent,† and Romania is seeking special tariff treatment from the U.S. in order to further increase its sales. The dramatic increase in imports is of great concern to U.S. manufacturers.

Exports of bearings and parts increased 14 percent in 1979 to approximately $270 million (with roller bearings 66 percent of the total). Thirty-one percent of U.S. export shipments go to Canada, and 16 percent to Mexico. Other major and expanding markets are the United Kingdom, West Germany, and Australia.‡

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*U.S. Industrial Outlook, 1980.

†Phone conversation with Mr. Whitsett.

‡U.S. Industrial Outlook, 1980.

A.3.3 Operation

Bearings are usually sold either directly to original equipment manufacturers (OEM) or through distributors (though OEM sales are by far the largest). Prices of bearings sold to OEM accounts are generally negotiated, sometimes at fixed prices over periods as long as a year.* Prices of bearings have generally followed inflation trends with the exception of 1974.

Price index figures for the industry are given in Table A.3-4.

TABLE A.3-4

YEAR-TO-YEAR PERCENT CHANGE IN PRODUCERS PRICE INDEX

1974	1975	1976	1977	1978
29.6	5.3	8.7	7.2	7.8

In January 1980 the average lead time for anti-friction bearings was 10.8 weeks, versus 9.1 weeks in January, 1979.†

Since 1963 employment has ranged from approximately 61,000 (in 1966) to 49,000 (in 1976). The years in the early 1970s through the present show a decline, probably due to a

*U.S. Tariff Commission, Anti-friction Balls and Ball Bearings, Including Ball Bearings with Integral Shafts, and Parts Thereof, July 1973.

†Purchasing, January 17, 1980.

decreased defense market near the end of the Vietnam conflict, and the recession at that time. Production workers have comprised 80 to 81 percent of the work force since the early 1960s.

Employment levels are shown in Figure A.3-3.

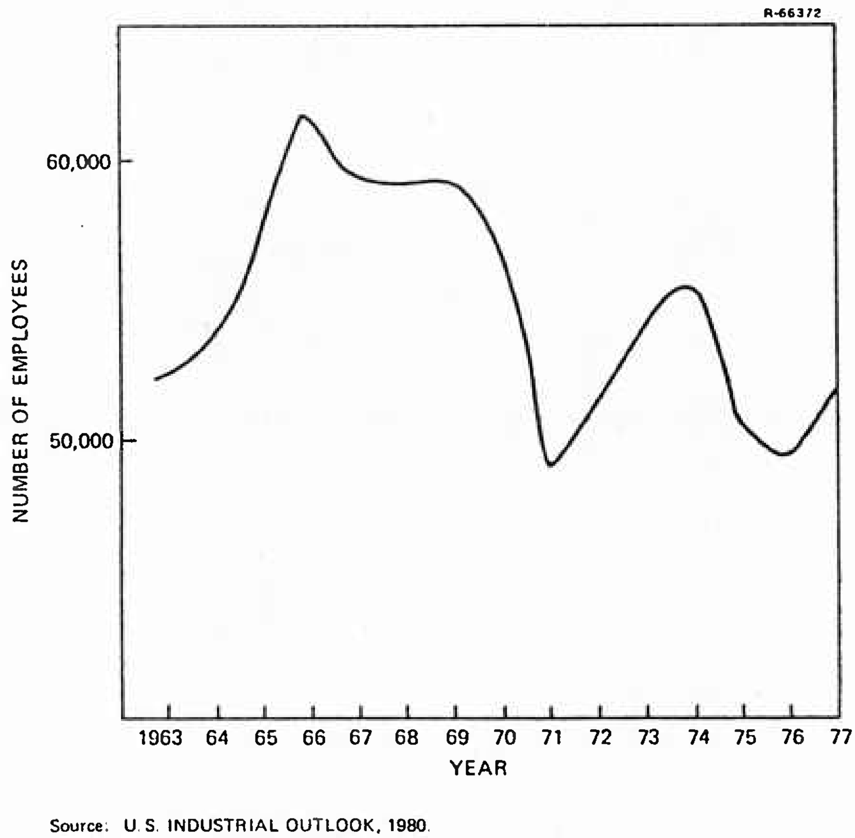

Figure A.3-3 Bearing Industry Employment, 1963-1977

A.3.4 Customer Base

The automobile market is the single most important user of bearings, with 16 to 18 percent of total sales.

Construction machinery takes eight percent of sales, general industrial machinery six percent, farm machinery five percent, aircraft four percent, and metal working machinery equipment three percent each.

Table A.3-5 shows the percent of all ball and roller bearing industry shipments that go to DOD, and also gives the percent of government sales that are for DOD.

TABLE A.3-5

VALUE OF SHIPMENTS OF DOD - RELATED BALL AND ROLLER BEARING ACTIVITIES (In $ Millions)

Year	Total DOD	% DOD of Government Shipments	% DOD of All Shipments
1972	20.2	35.2	1.4
1973	16.4	27.6	.9
1974	14.4	23.2	.7
1975	20.7	26.3	1.0
1976	24.3	27.5	1.1
1977	24.3	27.3	1.0
1978	22.9	26.0	.8

Source: U.S. Department of Commerce, Bureau of the Census, Shipments to Federal Government Agencies, 1978, MA-175

APPENDIX B
FORGING AND CASTING INDUSTRY PROFILE (SIC 3324, 3325, 3361, 3462, 3463)

B.1 INTRODUCTION

Forgings and castings are essential to almost all military systems, and especially aerospace systems. The performance of modern aircraft often demand combinations of one or more characteristics such as high strength to weight ratios, intricate shapes and/or exotic alloys to meet temperature or other special requirements. The process of making a forging, simply stated, is to form a shape from a billet of metal which has been heated to the point of plasticity. The hot billet is usually shaped by pounding or squeezing between two dies which give the forging its final shape. Forgings may be steel, aluminum, titanium or other metal alloys. Usually the selection of forging as the process of manufacture is made on the basis of strength requirements such as the landing gear struts, wing spars or bulkheads.

Forgings, like castings, are generally not used without some subsequent machining. In extreme cases, for example, a titanium forging may weigh 1,000 lbs. before machining and 110 lbs. after machining.

Castings are made from different alloys ranging from various grades of cast iron, steel alloys, aluminum, bronze, stellite, and others. Several casting processes are utilized, depending on the requirements of the part. These range from relatively crude sand castings to more precise plaster mold castings, die castings and investment castings.

B.2 MARKET

B.2.1 Structure

Table B.2-1 shows the number of forging and casting establishments from 1963 to 1977. More current information will not be available until the next Census of Manufacturers in 1981. The number of establishments in the categories of gray iron foundries has declined since 1963, though the other categories show moderate increases. Reportedly, OSHA requirements have contributed to the decline in the number of establishments in the castings industry.

B.2.2 Geographic Regions

In general, the forging and casting industry tends to be concentrated in areas of heavy industry. These are the east, north central, and mid-Atlantic regions. Ferrous forging and casting production is most numerous in these regions. The non-ferrous (in particular aluminum forging industry) tends to be more widely distributed with the majority centers of production located in the following states: New York, Pennsylvania, Ohio, Illinois, Michigan, Wisconsin, Missouri, and Texas. A good deal of production occurs in various other states and regions.

B.2.3 Product Description and Substitutability

Forgings and castings are used in the production of capital equipment to form frames of equipment such as manifolds, and engines. Differences in castings are a result of the type of metal and the type of process used (i.e., sand, permanent or investment). Forgings are differentiated by type of metal, size, and process. They are classified as either large or small forgings as well as closed and open-die, cold forgings, and ring rolling.

TABLE B.2-1

NUMBER OF FORGING/CASTING ESTABLISHMENTS, 1963-1977

Type	1963	% with 20 employees or more	1967	% with 20 employees or more	1972	% with 20 employees or more	1977	% with 20 employees or more
Gray Iron Foundries (SIC 3321)	1139	(67)	1061	(73)	993	(73)	984	(69)
Malleable Iron Foundries (SIC 3322)	81	(88)	81	(93)	73	(88)	66	(80)
Steel Investment Foundries (SIC 3324)	n.a.		n.a.		74	(84)	92	(74)
Steel Foundries, N.E.C. (SIC 3325)	n.a.		n.a.		260	(77)	323	(71)
Aluminum Foundries (SIC 3361)	954	(34)	922	(45)	1005	(43)	1038	(44)
Iron and Steel Forgings (SIC 3462)	272	(69)	272	(69)	280	(64)	358	(65)
Nonferrous Forgings (SIC 3463)	34	(56)	41	(76)	46	(72)	47	(66)

Source: 1977 Census of Manufacturers

The degree of substitutability tends to be fairly limited, particularly in high performance aircraft parts. Once a part has been designed as a forging it is not likely that a casting can be used instead. Forgings are generally used for parts subjected to higher stress than castings. On the other hand, some high strength materials such as stellite are more suitable for castings. In general industrial applications there has been a significant trend to design parts, such as machinery frames, to utilize welded steel instead of castings. This has come about because of increased cost and lead time of obtaining castings.

B.2.4 Growth of the Industry

Production in both iron and steel foundries and non-ferrous foundries grew substantially between 1961 and 1966 (see Table B.2-2), and this growth was at a faster rate than all manufacturing industries. Two recessions (1969-1971 and 1974-1975) resulted in significant decreases in production in all foundries. In both cases the impact on the forging and casting industries was greater than that on manufacturing as a whole.

Value of shipment figures may indicate growth in the forging and casting industry. Table B.2-3 shows value of shipments from 1972 to 1977. The period of decline is reflected a year later with the value of shipments data. This is probably caused by backlog orders from 1973 appearing in this data.

In the high inflation period of 1974 and 1975, all categories of forgings and castings except Steel Foundries N.E.C. (SIC 3325) show a decline in value of shipments. By 1977 malleable iron foundries (SIC 3322) and steel investment foundries (SIC 3324) had still not recovered to 1974 levels, though all others had.

TABLE B.2-2

ANNUAL INDEX OF INDUSTRIAL PRODUCTION,
IRON & STEEL FOUNDRIES, NON-FERROUS FOUNDRIES,
ALL MANUFACTURING, (1961-78)
(1967=100)

YEAR	Iron & Steel Foundries SIC 332	Non-Ferrous Foundries SIC 336	All Manufacturing
1961	65.6	55.1	65.6
1962	73.7	72.2	71.4
1963	82.3	74.6	75.8
1964	93.9	80.8	81.2
1965	105.0	88.8	89.1
1966	110.4	106.9	98.3
1967	100.0	100.0	100.0
1968	103.0	106.4	105.7
1969	111.2	108.4	110.5
1970	97.7	94.9	105.2
1971	96.7	91.6	105.2
1972	107.1	100.9	114.0
1973	110.1	110.8	125.1
1974	113.0	96.7	124.4
1975	91.9	77.3	112.2
1976	102.5	99.5	130.3
1977	110.2	106.2	138.4
1978	111.9	101.3	146.8

Source: Board of Governors of the Federal Reserve System, Industrial Production, 1976, Table A-11, and Industrial Production, January 1976 - December 1978, Table 4-A.

TABLE B.2-3

VALUE OF SHIPMENTS FOR FORGINGS AND CASTINGS, 1972-1977
(IN MILLIONS OF 1972 DOLLARS)

Category	1972	1973	1974	1975	1976	1977
Gray Iron Foundries (SIC 3321)	3876.5	4528.2	4988.5	4586.4	4934.5	5214.3
Malleable Iron Foundries (SIC 3322)	507.9	540.9	564.4	465.6	516.8	509.4
Steel Investment Foundries (SIC 3324)	262.2	268.9	351.7	296.2	295.6	287.6
Steel Foundries N.E.C. (SIC 3325)	1067.4	1143.8	1453.2	1631.6	1573.2	1631.7
Aluminum Foundries (SIC 3361	1269.9	1439.3	1605.5	1316.3	1572.4	1735.4
Iron and Steel Forgings (SIC 3462)	1416.1	1625.9	1814.9	1729.9	1760.3	1972.0
Nonferrous Forgings (SIC 3463)	222.5	267.5	305.5	303.9	300.2	322.3

Source: 1977 Census of Manufacturers. Deflator taken from Economic Report of the President, January 1980, p. 206.

Table B.2-4 shows more current data on ferrous castings shipments by weight.

Table B.2-5 shows quantity of shipments figures for castings and forgings for 1972 to 1977.

B.3 INDUSTRY CONDUCT

B.3.1 Price Trends

Data on wholesale price indexes was available for ferrous castings, however, it was not readily available for non-ferrous castings or forgings. Wholesale price indexes are listed under a different schedule by the Bureau of Census, and the Department of Labor. As illustrated in Table B.3-1, from 1972 to 1979 there has been a steady increase in the price of ferrous castings. This is compared with the price index change in primary metals industries for the same period. In 1974, prices rose dramatically across-the-board probably reflecting general economic conditions and higher energy costs.

B.3.2 Innovation

Technical improvements have been developed in both the forging and casting industry. In the casting industry, these changes have increased productivity and the size of casts. They resulted in an overall decline in the number of workers with a three percent decrease in production workers expected between 1979 and 1980. Table B.3-2 shows production employment and total employment for the ferrous castings industry. The steel investment casting industry is one which is marked by a high rate of automation. According to Iron Age, "the industry has moved into automation, robotics, and sophisticated material

TABLE B.2-4

FERROUS CASTINGS SHIPMENTS
(MILLIONS OF TONS)

	Gray Iron	Ductile Iron	Malleable	Steel	Total
1979	11,899,000	2,694,000	724,000	2,025,000	17,342,000
1978	12,417,000	2,896,000	803,160	1,829,670	17,945,830
1977	12,295,000	2,694,000	828,000	1,718,000	17,535,000
1976	11,045,568	1,887,460	847,612	1,802,340	15,582,980
1975	10,621,700	1,824,500	730,700	1,938,000	15,114,900
1974	13,488,900	2,202,300	914,300	2,090,300	18,695,800

Source: Department of Commerce and Iron Age, April 7, 1980.

TABLE B.2-5

QUANTITY OF SHIPMENTS (1972-1977) CONSTANT 1972 DOLLARS
(IN MILLIONS OF DOLLARS)

Year	Steel Investment Foundries 3324	Iron & Steel Forgings 3462	Non-Ferrous Forgings 3463
1972	262.2	1416.1	222.5
1973	279.7	1691.4	278.7
1974	371.9	1927.9	324.5
1975	299.0	1746.4	306.7
1976	296.9	1768.2	301.5
1977	287.6	1973.0	322.3

Source: Department of Commerce, Annual Survey of Manufacturers, 1976, and 1977 Census of Manufacturers.

TABLE B.3-1

YEAR-TO-YEAR PERCENT CHANGE IN PRODUCERS PRICE INDEX (DECEMBER - DECEMBER)

	1974	1975	1976	1977	1978	1979
Primary Metals Industries (SIC 33)	32	2	9	6	10	17
Ferrous Castings (SIC's 3321, 3322, 3324, 3325)	32.9	10.8	9.9	7.2	8.6	9.8

Source: 1980 U.S. Industrial Outlook, pp. 177 and 169

*Dec. 1967 is the base year for Producers Price Index.

handling equipment...the process...is based upon the...fact: no machinery or very little and ergo no need for skilled machinists."*

B.3.3 Performance

Inventory and Capacity Utilization Rates - Two measures of the rate of capacity utilization are used. The first is measured by pratical capacity which is defined as the greatest level of output which a plant could achieve within the framework of a realistic work pattern. The second rate is measured by the preferred level which is defined as the intermediate level of operations which the manufacturer would prefer not to exceed due to cost or other considerations. Data on

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* *Iron Age*, February 26, 1979, p. 36-38.

TABLE B.3-2

TOTAL EMPLOYMENT AND NUMBER OF PRODUCTION WORKERS*
FOR THE FERROUS CASTING INDUSTRY, 1974-1980

	1974	1975	1976	1977	1978	1979	1980 **
Total Employment (000)	239	221	216	223.5	237.1	249.4	244.4
Production Workers (000)	203	184	179	184.4	193.8	204.5	198.4

*for SIC codes 3321, 3322, 3324, 3325
**forecast

Source: 1980 U.S. Industrial Outlook, p. 176.

practical rates as a percent of actual operations for SIC four digit industry levels are available only from 1974. No pattern emerges when figures for practical capacity rates are put into a time series. Rates for preferred capacity were generally high, between 90 to 100 percent in 1976 and 1977. The 1975 figures were much lower with steel investment foundries having the lowest level (66%).

Inventory figures demonstrated a cyclical pattern between 1972 and 1977. Aggregate figures for the forging and casting industry (SIC 3321, 3322, 3324, 3325, 3361, 3462, 3463) are given in Table B.3-3. The peak year for inventories for most forging and casting industry classifications was 1974.

B.3.4 Government Regulation

Since 1976, OSHA (Occupational Safety and Health Administration) has moved to tighten safety standards in the casting

TABLE B.3-3

FORGING AND CASTING INVENTORIES, 1972-1977
(IN CONSTANT 1972 $ MILLIONS)

1972	951.3
1973	1,125.6
1974	1,504.2
1975	1,246.0
1976	1,283.7
1977	1,331.6

Source: U.S. Department of Commerce, 1976 Survey of Manufacturers, and 1977 Census of Manufacturers.

industry. New standards were established to limit exposure to toxic chemicals, such as arsenic lead, asbestos, sulfur dioxide, ketones, berllium, and toluene. Standards also prohibit excessive noise levels. In 1976, Purchasing reported that 300 foundries had been closed due to OSHA restrictions.* OSHA requirements have generally affected smaller foundries most severely as larger firms are more able to afford the adjustment of facilities to the new standards.

B.4 THE MILITARY MARKET

Forgings and castings are critical components for military systems. Every major aerospace system is dependent on the output of the forging industry. The Air Force maintains a heavy

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*Purchasing, February 10, 1976, p. 32.

press program which includes facilities in the possession of eight contractors. The acquisition cost of these facilities was approximately $180 million, but the replacement cost is an estimated $700 million and would require 4 to 5 years to re-establish. The eight contractors are Wyman-Gordon, Alcoa, Curtis-Wright, Kaiser, Martin Marietta, Kropp, Arcturus and Ladish. The first four contractors operate government plants whereas the other companies operate contractor-owned plants.

Government influence is extensive in the U.S. heavy press and heavy hammer forging industry. The government (Air Force) owns 80 percent of closed die hydraulic presses (over 20,000 tons), 60 percent of extrusion presses over 7,000 tons, and 30 percent of hammers over 35,000 pounds. In castings, Iron Age reports that nearly half of the annual receipts for investment castings come from the aerospace industry.* Data on DOD activities in the forging and casting industry are reported by the Department of Commerce in its Current Industrial Reports, Shipments of Defense Oriented Industries (series MA-175). These figures show that large contracts ($25-100 million) were awarded to, at most, three establishments. However, over half the establishments were awarded smaller contracts. In 1977, out of 274 establishments, only 111 reported no shipments to the government. Further data reveals that non-ferrous forgings had the highest percentage of shipments to the government of its total annual shipments than any other industry group. Table B.4-1 shows the number of forging and casting establishments reporting government business. Table B.4-2 shows the value of DOD shipments, and compares DOD volume with the total industry, and with the government shipments.

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*Iron Age, February 26, 1979, p. 36.

TABLE B.4-1

NUMBER OF ESTABLISHMENTS REPORTING GOVERNMENT SHIPMENTS, 1972-1977 (IN $ MILLIONS)

Category	Year	TOTAL # Establish-ments	over $100	$50-$100	$25-$49	$ 5-$24	$1-$4	Under $1	NONE
SIC 3324	1972	16				1	6	9	
	1973	15				2	3	10	
Steel	1974	25				3	6	7	9
Investment	1975	23				4	2	6	11
Foundries	1976	22				4	4	7	7
	1977	21				3	2	9	7
SIC 3325	1972	94				1	6	87	
	1973	98				1	5	92	
Steel	1974	76					5	41	30
Foundries	1975	76				1	5	33	37
N.E.C.	1976	80				1	11	37	30
	1977	78		1		3	9	36	29
SIC 3361	1972	69				2	6	61	
	1973	67				2	5	60	
Aluminum	1974	100				4	5	40	51
Foundries	1975	95				4	6	34	51
	1976	95				3	8	36	48
	1977	95				2	9	36	48
SIC 3462	1972	75			1	2	12	60	
	1973	75			1	2	11	61	
Iron & Steel	1974	72			1	6	10	36	19
Forgings	1975	70			2	6	11	28	23
	1976	66		1	1	3	9	29	23
	1977	68		1	1	2	13	26	25
SIC 3463	1972	10				3	5	2	
	1973	11				4	2	5	
Non-Ferrous	1974	13			1	4	3	1	4
Forgings	1975	14		1	1	3	2		7
	1976	13		1	1	4	1	3	3
	1977	12			2	3	1	4	2

Source: Department of Commerce. MA-175, Shipments of Defense-Oriented Industries.

TABLE B.4-2

VALUE OF SHIPMENTS OF DOD-RELATED ACTIVITIES (IN $ MILLIONS)

Category	Year	TOTAL DOD	% DOD of Gov't Shipments	% DOD of all shipments
SIC 3324 Steel Investment Foundries	1972	19.7*	85.3	10.0
	1973	18.5*	59.5	10.7
	1974	36.0	49.7	8.3
	1975	13.5	27.2	2.9
	1976	32.1	43.1	8.0
	1977	6.6	17.4	1.8
	1978	21.6	48.2	4.0
SIC 3325 Steel Foundries N.E.C.	1972	2.6	9.0	.3
	1973	6.3	20.3	.6
	1974	2.8	13.0	.2
	1975	4.2	15.0	.2
	1976	25.1	23.4	1.2
	1977	69.5	43.9	3.3
	1978	86.3	46.4	3.0
SIC 3361 Aluminum Foundries	1972	6.1	18.5	.9
	1973	5.7	20.3	.7
	1974	24.4	32.4	1.4
	1975	16.7	18.9	.9
	1976	32.9	33.2	1.7
	1977	31.9	32.3	1.4
	1978	54.5	43.2	1.9
SIC 3462 Iron & Steel Forgings	1972	22.9	28.8	2.0
	1973	30.2	32.0	2.3
	1974	75.0*	48.0	3.9
	1975	70.3	37.7	3.4
	1976	64.4	38.8	3.5
	1977	50.3	30.8	2.5
	1978	74.1	27.8	2.1
SIC 3463 Non-Ferrous Forgings	1972	20.9	34.9	12.1
	1973	19.4	30.5	9.0
	1974	36.7	32.7	9.9
	1975	49.9	33.2	12.3
	1976	155.2	70.4	32.5
	1977	144.7	73.1	26.1
	1978	84.9	87.5	15.0

*Estimate (actual numbers not available in order to protect individual firms)

Source: Department of Commerce, MA-175, Shipments of Defense-Oriented Industries.

B.5 SUMMARY

Like the manufacturing sector as a whole, the forgings and castings industry seems to be sensitive to business cycles. Cyclical behavior is apparent in value of shipments, inventory, and production data. Although smaller firms are leaving the market, production in the steel casting industry is continuing to gradually increase.

Prices have been steadily increasing. In 1974, prices rose dramatically while production declined. However, price indexes for ferrous castings closely resemble those for manufacturing as a whole.

Technology and innovation have contributed to a declining number of firms in the market as well as a declining number of production workers. OSHA requirements have also forced many small firms out of the market.

Data was scarce on imports and exports. Imports seemed to be increasing for ferrous casting and ferrous forgings. This trend, while it is still a minute proportion of domestic production, may continue as foreign producers compete with lower prices.

Government involvement in certain parts of the the forging and casting industry is substantial, particularly in the more exotic categories such as large forgings and high performance alloys. The Air Force maintains a heavy press program by which the government owns a significant amount of U.S. heavy equipment capacity. Shipments to the government as a percentage of total annual shipments were high in the non-ferrous forging classification. This classification included aluminum forging firms which are essential to the aerospace industry. While the government has contracts with over half the establishments in the forging and casting industry, only three were awarded contracts between $25 and $100 million.

APPENDIX C
INTEGRATED CIRCUITS INDUSTRY

C.1 PRODUCT DEFINITION

An integrated circuit is an electronic device in which the function of several discrete devices are preformed within a single piece of semiconductor material. Semiconductors are electronic components made from elements such as silicon, germanium and gallium arsenide, that are neither good electrical conductors nor good insulators. They can amplify, switch or rectify electric current.

Integrated circuits are a class of products related to the transistor innovation of the late 1940s. They are currently used in virtually all military electronic systems as well as in a broad and growing array of commercial and industrial goods. From the early days of integrated circuit production to the present the complexity and number of circuits upon a single piece of semiconductor material has increased. Successive generations of ICs have been described in this dimension with reference to scale. Medium scale integration (MSI) refers to integrated circuits with from 50 to 100 gates or logic elements. Large scale integrated circuits (LSI) have 100 or more gates. Very large scale integrated (VLSI), the industry's current technical frontier, could include single chips with as many as 100,000 gates. Additional division of IC type may be made according to type of manufacturing process, whether the IC is produced as a single unit or has discrete elements grafted to it, whether the circuit is a low volume custom product or a high volume item, the circuit's function and whether the circuit is qualified to function in high stress environments.

C.2 INDUSTRY GROWTH

The growth of integrated circuit and the entire semiconductor industry's shipments has been explosive. Table C.2-1 presents the Semiconductor Industry Association's data series on domestic shipments from the early 1950s through 1978.* Growth has occurred both within product lines and in the number of product types. It should be noted that the dollar shipment growth measure, although presented in current dollars, understates the magnitude of industry growth when measures of quantity or device quality are considered. Throughout the time period per unit prices have fallen, while device capability has improved.

Most predictions of the electronics industry's final goods markets foresee a continuation of growth far exceeding other sectors and the U.S. economy as a whole. For example, Gnostic Concepts projects a near tripling of the electronics industry's sales volume by 1987, with the strongest market growth in communications, computers and business segments (see Table C.2-2). Such a projection implies continuing growth for the integrated circuit market. However, the data shows a continuation of the decline of the military share of the total market (Table C.2-3).

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*Sales and shipment data for the semiconductor industry, in the aggregate or by product lines is obtainable from several sources, including: the Bureau of Domestic Commerce of the U.S. Commerce Department, the Census Bureau, and the Semiconductor Industry Association. Unfortunately, discrepancies among these sources exist, largely because of their inclusion or exclusion of the captive production of integrated firms.

TABLE C.2-1

U.S. BASED SEMICONDUCTOR COMPANIES DOMESTIC SHIPMENTS (DOLLARS IN MILLIONS)

	TRANSISTORS	RECTIFIERS AND DIODES	THYRISTORS	OTHER	OPTO	TOTAL DISCRETE	BIPOLAR	MOS	LINEAR	TOTAL	TOTAL SEMICONDUCTORS
1954	5.1					5.1					5.1
1955	12.3					12.3					12.3
1956	37.4					37.4					37.4
1957	67.7	73.2		31.6		172.5					172.5
1958	109.7	95.4		20.4		225.5					225.5
1959	217.2	143.9		28.4		389.6					389.6
1960	293.6	203.1		24.9		521.6					521.6
1961	278.6	109.4		37.6		434.6					434.6
1962	278.1	180.7		49.7		508.5					508.5
1963	287.3	178.5		49.0		514.8					514.8
1964	311.7	216.6	26.2	35.2		589.7	34.7		6.0	40.7	630.4
1965	377.2	256.2	30.1	37.6		701.1	60.9		13.5	74.4	775.5
1966	443.1	315.8	46.0	48.9		853.8	107.7		28.3	136.	989.8
1967	370.5	271.9	46.3	48.9		737.6	161.6		40.7	202.3	939.9
1968	345.2	267.9	48.8	45.7		707.6	224.1		53.6	277.7	985.3
1969	368.3	313.0	52.7	48.0		782.0	294.6		64.2	358.8	1140.8
1970	296.4	261.5	47.0	41.7		646.6	295.8		68.9	364.7	1011.3
1971	267.3	171.3	43.5	36.3	36.0	554.4	298.1		78.1	376.9	931.3
1972	319.7	192.0	53.2	41.1	70.0	676.0	417.8		113.7	531.5	1207.5
1973	408.3	276.2	72.8	51.8	90.3	899.4	495.2	303.8	204.8	1003.8	1903.2
1974	408.5	292.9	75.4	53.9	91.4	922.1	528.9	432.8	237.8	1199.5	2121.6
1975	332.1	222.5	57.2	48.7	99.9	760.4	348.5	427.6	197.8	973.9	1734.3
1976	392.1	257.2	78.9	51.0	140.0	919.2	465.8	635.9	270.1	1371.8	2291.0
1977	389.6	257.4	99.4	47.6	94.2	888.2	558.1	777.3	349.0	1684.4	2572.6
1978	407.3	275.4	105.6	53.8	129.1	971.2	681.9	1045.3	424.3	2151.5	3122.7

Source: Semiconductor Industry Handbook, 1979, p. 9.

TABLE C.2-2

PROJECTIONS OF THE FINAL GOODS MARKET FOR ELECTRONICS, 1978 TO 1987
(Billions of Current Dollars)

	1978	1987
Total	77	191
Business	5 (6.4%)	15 (7.8%)
Communications	13 (16.8%)	32 (16.8%)
Consumer	8 (10.3%)	14 (7.3%)
Computer	23 (29.8%)	63 (32.9%)
Government/Military	16 (20.8%)	34 (12.8%)
Industrial	6 (7.8%)	14 (7.3%)
Instruments	6 (7.8%)	16 (8.3%)

Source: Handel H. Jones, "Forecast of VHSIC/VLSI Markets," VHSIC Conference, (San Francisco, May 1980).

TABLE C.2-3

MILITARY SEMICONDUCTOR AND INTEGRATED CIRCUIT MARKET PROJECTIONS

	1978	1982	1987
Total Semiconductor Market	$ 8.4 B	$17.3 B	$43.1 B
Military Semiconductor Market	$563 M	$878 M	$1.4 B
Military as a % of Total	7%	5%	3%
MIL-M-38510 ICs	$ 15.8 M	$ 57 M	$ 145 M
MIL-M-38510 as a % of Mil. Total	2.8%	6.5%	10.2%

Source: Martin, Jim, "Military IC Standardization: Bedrock or Boondoggle?," Military Electronics/Countermeasures, December 1979, p. 49.

C.3 LEADING FIRMS AND DEGREE OF COMPETITION

The rapid growth of semiconductor and integrated circuit markets and the rapid pace of technological change have created an industry structure characterized by dynamic instability. Growth and technical change have provided new firms with ample opportunities to enter the industry and at the same time have created an atmosphere in which existing firms cannot take continuing leadership for granted.

Tables C.3-1 and C.3-2 present domestic shipment concentration ratios for the whole semiconductor industry and integrated circuits only. Both register moderate concentration figures, with the ratio declining for integrated circuits, which is predictable for a young product market experiencing high rates of market growth and rapid technical change. The concentration ratio data suggests that these larger markets (semiconductors and ICs) are competitive.

This view is reinforced when the shifts in leading firms over time is examined. Tables C.3-3 and C.3-4 show leading firms in semiconductor production overtime. While Texas Instruments has maintained its position as the industry's leading producer, shifts among other industry leaders are evident. Thus, changes in industry market share also reinforce the view that the integrated circuit industry is essentially competitive.

C.4 PRICING STRATEGY

Competition to introduce new devices (product innovation) or to quickly imitate the innovations of other firms and to then build market share by quickly moving down the learning curve, is an essential element of corporate strategy in the

TABLE C.3-1

CONCENTRATION OF U.S. SEMICONDUCTOR SHIPMENTS

Number of Companies	1957	1965	1972	1978
	Percent of Total Shipments			
4 Largest Companies	51	50	50	46
8 Largest Companies	71	77	66	64
20 Largest Companies	97	90	81	84
50 Largest Companies	100	96	96	96
All Companies	100	100	100	100

Source: William Finan, Draft Memo on VHSIC's Industry Impact, Technecon, Philadelphia, Pennsylvania, July 1980.

TABLE C.3-2

CONCENTRATION OF U.S. INTEGRATED CIRCUIT SHIPMENTS

Number of Companies	1965	1972	1978
	Percent of Total Shipments		
4 Largest Companies	69	53	49
8 Largest Companies	91	67	70
20 Largest Companies	99	94	90
50 Largest Companies	100	100	100
All Companies	100	100	100

Source: William Finan, Draft Memo on VHSIC's Industry Impact, Technecon, Philadelphia, Pennsylvania, July 1980.

TABLE C.3-3

RANKING OF U.S. FIRMS BY TOTAL SEMICONDUCTOR SHIPMENTS

1955 TRANSISTORS	1960 SEMICONDUCTORS	1965 SEMICONDUCTORS	1973 SEMICONDUCTORS	1978 SEMICONDUCTORS
Hughes	Texas Instruments	Texas Instruments	Texas Instruments	Texas Instruments
Transitron	Transitron	Motorola	Motorola	Motorola
Philco	Philco	Fairchild	Fairchild	National
Sylvania	RCA	General Instruments	National	Fairchild
Texas Instruments	Motorola	RCA	RCA	Intel
RCA	Clevite	Sprague	ITT	RCA
Westinghouse	Fairchild	Philco/Ford	GE	Signetics
Motorola	Hughes	Transitron	Signetics	ITT
Clevite	Sylvania	Raytheon	Intel	AMD
			AMI	GE

Source: I.M. Mackintosh, "Large Scale Integration: International Aspects," *IEEE Spectrum*, June 1978, p. 54.

TABLE C.3-4

RANKING OF U.S. FIRMS BY TOTAL INTEGRATED CIRCUIT SHIPMENTS

	1973	1975	1978
1.	Texas Instruments	Texas Instruments	Texas Instruments
2.	Fairchild	Fairchild	National
3.	Motorola	National	Motorola
4.	National	Intel	Intel
5.	Signetics	Motorola	Fairchild
6.	RCA	Rockwell	Signetics
7.	Intel	General Instruments	AMD
8.	AMI	RCA	RCA
9.	ITT	Signetics	Mostek
10.	Rockwell	AMI	Harris

integrated circuits industry. Recent pricing data (Table C.4-1 and Figure C.4-1) on integrated circuits illustrates the presence of learning curve pricing. A very recent fall in demand for 16K RAMs, attributable to the 1980 recession, would seem to indicate the attendant problems of this strategy still plague the industry. As firms implement their learning curve pricing policies a softening of demand leaves only one recourse -- further price competition. As per unit prices fall profit margins are squeezed.

Research and development expenditures continue at their historic rate, with six to ten percent of sales an often quoted figure. The International Trade Commission (ITC) sample of integrated circuit producers recorded a much higher figure,

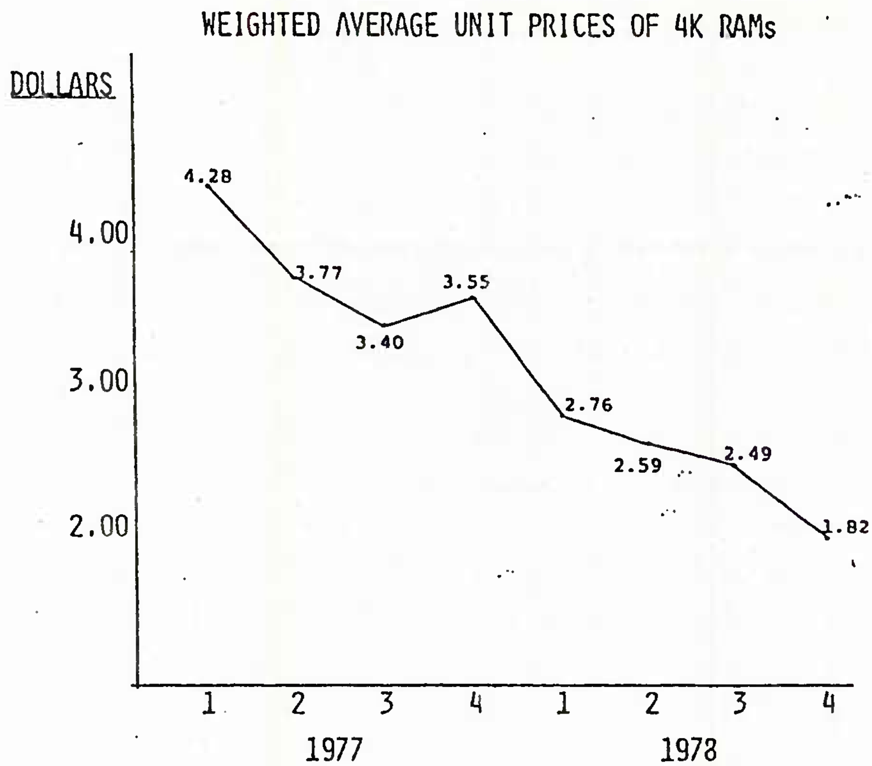
TABLE C.4-1

INTEGRATED CIRCUITS -- INDEXES OF WEIGHTED AVERAGE UNIT PRICES OF SELECTED TYPES OF INTEGRATED CIRCUITS PRODUCED BY U.S. FIRMS, BY QUARTER, 1977 AND 1978

T-4369

PERIOD	LINEAR CIRCUITS	DIGITAL	DIGITAL MOS CIRCUITS	
			4K RAM	OTHER MOS
1977:				
January to March	100.0	100.0	100.0	100.0
April to June	101.2	102.8	88.9	88.8
July to September	89.6	83.7	80.2	88.2
October to December	87.5	76.1	77.8	79.4
1978:				
January to March	78.7	67.7	62.5	68.9
April to June	84.2	59.2	57.1	61.8
July to September	88.8	49.7	53.9	45.8
October to December	72.1	53.1	39.9	41.5

Source: U.S. International Trade Commission, "Competitive Factors Influencing World Trade in Integrated Circuits," (Washington, ITC, November 1979) p. 19.



Source: U.S. International Trade Commission, "Competitive Factors Influencing World Trade in Integrated Circuits," (Washington, ITC, November 1979) p. 80.

Figure C.4-1 Learning Curve Pricing Continues for High Volume Circuits

as shown in Table C.4-2 with worldwide R&D expenditures of U.S. producers exceeding 20 percent of total domestic shipments and exports for the years 1974 through 1978. The discrepancy is difficult to identify given the restraints upon disclosure of sensitive data binding the ITC report. Nevertheless, there seems to be little doubt that research and development continue to play a key role in semiconductor competition.

TABLE C.4-2

INTEGRATED CIRCUITS: WORLDWIDE EXPENDITURES FOR RESEARCH AND DEVELOPMENT BY U.S. FIRMS AND THEIR FOREIGN SUBSIDIARIES, 1974-1978
(Thousands of $)

1974	329,897
1975	422,488
1976	422,292
1977	465,633
1978	529,651

Source: U.S. International Trade Commission, "Competitive Factors Influencing World Trade in Integrated Circuits," (Washington, ITC, November 1979) p. 102.

C.5 INTERNATIONAL COMPETITION, TRADE AND INVESTMENT

The pervasiveness of semiconductor technology and the worldwide perception of electronics as an industry of the future has led to the emergence of significant international competitors to challenge the dominance of the U.S. industry's leadership. This significant structural change affects the U.S. industry in several dimensions:

- Heightened technical competition as Japanese firms in particular seek to leapfrog the U.S. industry into the next generation of integrated circuitry, VLSI
- Increasing price competition as foreign firms attempt to penetrate the U.S. market in state-of-the-arts circuitry such as dynamic 16K RAMs

- Several aspects of the organization of foreign competitors have caused the U.S. industry to push for trade and industrial policy cnages in the U.S.

U.S. technology and markets continue to be of the greatest importance to the world industry. In order to gain access, foreign firms have stressed penetration of the U.S. market by two means -- acquisition and exports. An International Trade Commission survey registered a growing negative balance of trade since 1974 in integrated circuits (see Table C.5-1). However, a strong U.S. position in older discrete devices bolstered the trade balance for all components, allowing the U.S. to maintain a trade surplus for the industry as a whole, at least through 1977. For state-of-the-art devices, 16K RAMs, for example, the 35 percent share of the U.S. market held by Japanese producers also indicates the extent of penetration.

Acquisition is a second way to penetrate the U.S.market, and more importantly to gain access to U.S. technology. As indicated by Table C.5-2, this form of activity has been extensive in the late 1970s, and was certainly made easier by the dollar's decline in value from 1977 through November of 1979. As is well known at this point, these acquisitions have by no means been trivial or restricted to small firms, e.g. Fairchild and Signetics. A significant effect of these developments on the U.S. industry has been to accentuate technology and price competition in the U.S. market.

The vertically integrated form of foreign competition exerts pressures upon the U.S. industry to follow suit, thus complementing other trends discussed. Julian Gresser of Harvard, recently a consultant to the State Department, has stated:

TABLE C.5-1

INTEGRATED CIRCUITS: U.S. BALANCE OF TRADE 1974-1978
(THOUSANDS OF DOLLARS)

	ADJUSTED IMPORTS*	EXPORTS	BALANCE
1974	413,125	217,642	-195,501
1975	359,710	170,017	-189,693
1976	466,339	210,831	-255,508
1977	536,787	216,694	-320,093
1978	643,752	294,658	-349,094

*Adjusted for 806.30 and 807.

Source: U.S. International Trade Commission, "Competitive Factors Influencing World Trade in Integrated Circuits," (Washington, ITC, November 1979), p. 98.

TABLE C.5-2

FOREIGN INVESTMENT (ACQUISITIONS, MERGERS, AND EQUITY INCREASES) IN THE U.S. ELECTRONICS INDUSTRY

T-4368

SOURCE COUNTRY	FOREIGN FIRM	U.S. FIRM	YEAR OF INVESTMENT	% EQUITY ACQUIRED	TRANSACTION COST ($ MILLIONS)
Japan	Nippon	Electronics Arrays	1978	100	8.9 acquisition/merger
	Mansei Kogyo	Maruman	1976	60	3
	Toshiba	Toshiba-America	1978		8.3 new plant
	Fujitsu (with Nixdorf, Germany)	Amdahl	1976	29	
	Tokyo Print Industry,	Tokyo Print Industry	1978		3.0 new plant
	Mitsubishi	Optel	1975		2.5 acquisition
	Sony Corporation	Sony Magnetic Products			12.0 plant expansion
	Toyo	Exar	1972	53	1
	Hitachi Limited	Hitachi Semiconductor America	1978		0.5 new plant/new sub.
	Hatori (Seiko)	Micropower Systems	1971	77	3
	TDK	TDK Electronics	1978		50.0 new plant
Germany	Siemens	Microwave Semiconductor	1979		25
	Seimens	Orbis Systems	1979		
	VDO	Solid State Scientific	1979	25	5
	Robert Bosch	Millenium Systems	1978		Acquisition/merger
	Robert Bosch	American Microsystems	1977	25	14
	Siemens	Advanced Micro Devices	1977 1978	20	26.7 1.0 new plant
	Siemens	Litronix	1977	80	7.5 acquisition
	Siemens	Advanced Microcomputers	1977		3.0 joint venture
	AEG Telefunction	AEG Power Tool	1978		New plant
	Siemens	Seimens Corporation	1978		Plant expansion
	Stettner	Dielectric Laboratories	1977		Acquisition

TABLE C.5-2

FOREIGN INVESTMENT (ACQUISITIONS, MERGERS, AND EQUITY INCREASES) IN THE U.S. ELECTRONICS INDUSTRY (Continued)

T-4368a

SOURCE COUNTRY	FOREIGN FIRM	U.S. FIRM	YEAR OF INVESTMENT	% EQUITY ACQUIRED	TRANSACTION COST ($ MILLIONS)
Germany (Cont.)	Rosenthal	Metalized Ceramics	1977		5.3 acquisition
	Ernst Roederstein	Entron	1976		Joint venture
	Nixdorf (with Fujitsu, Japan)	Amdahl	1972	5	
United Kingdom	National Enterprise Board	Inmos	1979		Plant construction
	Lucas Industries	Siliconix	1978	24	6.1 acquisition
	Ferranti	Inter Design	1977	100	3 acquisition
	English Electric Valve	Microwave Associates (Relmag Division)	1977		Acquisition
	General Cable Conn. (20% owned by British Insulated Calendars Cables)	Sprague Electric	1976	100	68
	EMI	Electronic Technology	1975		0.6 acquisition
	General Electric, Ltd. U.K.	Modular Computer Systems	1978		Acquisition
Netherlands	Akzo	General Circuits	1979		
	Philips	General Electric's Capacitor	1977		10.0 acquisition
	Philips	Signetics	1975	100	49 acquisition
	Akzo	Burndy Corporation's Tape Cable Product Line	1974		Acquisition
	Philips	National Components Industries	1974		5.9 acquisition
France	Thomson-Brandt	Solid State Scientific	1979	100	
	Schlumberger	Fairchild	1979	100	397
	Schlumberger	Unitrode	1979	14	10
	Generale d'Electricite, CIE-CGE	Sensor Technology	1979		Joint venture

TABLE C.5-2

FOREIGN INVESTMENT (ACQUISITIONS, MERGERS, AND EQUITY INCREASES) IN THE U.S. ELECTRONICS INDUSTRY (Continued)

T-4368h

SOURCE COUNTRY	FOREIGN FIRM	U.S. FIRM	YEAR OF INVESTMENT	% EQUITY ACQUIRED	TRANSACTION COST ($ MILLIONS)
Canada	Bell Telphone of Canada	Northern Telecom	1979		
	Northern Telecom	Intersil	1977	24	10.7 acquisition
	Bell Telephone of Canada	AVM Flordia's Circuit Board Operations	1979		0.6 acquisition
	Northern Telecom Ltd.	Monolithic Memories	1969	12	0.3
	C Tech Ltd.	C. Tech Inc.	1979		0.4 new plant
Switzerland	ASUAG Group	Statek	1979		
	Oberlikon-Buhrle Holding	Balzers	1979		
	ASU	Centre Engineering	1977		Acquisition
Bahamas	Commodore	Frontier	1976	100	10 acquisition
	Commodore	MOS Technology	1976	99	1
	Anglo Company Limited	Printex Corporation	1974		1.9 acquisition
Greece	Petronome Group	Thermo Electron	1976		3.4 acquisition
	Suliman S. Olayan		1976		1.1 acquisition
Sweden	Bofors	BBF Group	1976		15.0 acquisition
Hong Kong	Hong Kong Investors	Supertex	1976	10	

Source: Hearing before the Committee on Commerce, Science and Transportation, U.S. Senate -- On Government Policy and Innovation in the Semiconductor Computer Industries (95th Congress, Second Session), Serial No. 95-138, 1978, pp. 96-97.

U.S. Department of Commerce, Industry and Trade Administration, Foreign Direct Investment in the United States, December 1977 and list for first half of 1979.

> "Japan's industrial policies are reinforced by the vertical integration of the Japanese semiconductor, computer, and telecommunications industry. Although there is a trend toward vertical integration in the United States, semiconductors, computers, and telecommunications still remain separate industries, dominated by a single firm (e.g., Texas Instruments, IBM, ATT). Vertical integration will help Japanese firms establish powerful enclaves in the U.S. and world markets. For example, if NEC increases its share of the U.S. telecommunications market, it simultaneously also increases its market share in computers and semiconductors, (and so forth up and down the industrial pyramid) because it will supply most of its own requirements. Finally, because of the opportunities for internal financing, vertical integration increases the leverage such firms have from favorable tax treatment, governmental guarantees, loans, subsidies, access to low cost capital at preferential rates, and the Japanese investor's tolerance of low profit margins."

The strategies of European firms, Siemens and Phillips, have been similar and exert complementary pressure.

C.6 HISTORICAL BACKGROUND: THE INTERFACE BETWEEN THE INDUSTRY AND THE MILITARY CUSTOMER

The sequential emergence of semiconductor industry market segments highlights the role of the military in development of the market not only for particular devices, but for the entire market. As indicated in Table C.6-1 the significance of the military buyer in the semiconductor market has declined over time. Table C.6-2 is as instructive, showing the military role for particular semiconductor technologies. The military played the role of an ideal and unique first user in this early period of the industry's growth, preferring device performance and reliability characteristics to price. In the context of a device product life cycle, military demand

TABLE C.6-1

U.S. PRODUCTION (OR SHIPMENTS) OF SEMICONDUCTORS FOR DEFENSE CONSUMPTION

T-4356

YEAR	TOTAL[1,2]	DEFENSE[1,2]	DEFENSE AS PERCENT[2] OF TOTAL
1955	40	15	38
1956	90	32	36
1957	151	54	36
1958	210	81	39
1959	396	180	45
1960	542	258	39
1961	565	222	39
1962	571	219	38
1963	594 (600)[3]	196 (213)[3]	33 (36)[3]
1964	635	157	25
1965	805 (879)	190 (194)	24 (22)
1966	975 (1,055)	219 (254)	22 (24)
1967	879 (1,074)	205 (297)	23 (28)
1968	847 (1,189)	179 (274)	21 (23)
1969	1,457	247	17
1970	1,337	275	21
1971	1,519	193	13
1972	1,912	228	12
1973	3,458	201	6
1974	3,916	344	9
1975	3,001	239	8
1976	4,968	480	10
1977	4,583	536	12

[1]Millions of dollars.

[2]Shipment rather than production data: ( )1963, 1965-1968; 1969-1979 (rounded).

[3]Data variation in parentheses.

Source: Charles River Associates, Innovation Competition and Government Policy in the Semiconductor Industry, Boston, March 1980, p. 6-10.

provided the initial push down the learning curve allowing cost to fall. In a competitive market, prices fall and price elastic market segments grow, leading to further cost and price reductions, and yet more market growth.

The role of the military as a supporter of integrated circuits development and as its first user is the extreme case of the military affecting the industry. This impact included

TABLE C.6-2

ROLE OF THE DEFENSE MARKET FOR MAJOR SEMICONDUCTOR PRODUCT GROUPS

Defense as a percentage ...			
(YEAR) OF DISCRETE DEVICES SALES		(YEAR) OF INTEGRATED CIRCUITS SHIPMENTS	
1952	59%	1962	100%
1953	57%	1963	94%
1954	55%	1964	45%
1955	38%	1965	72%
1956	36%	1966	53%
1957	36%	1967	43%
1958	39%	1968	38%
1959	45%	1969	24%
1960	48%	1970	21%
1961	39%	1971	19%

Source: John Tilton, International Diffusion of Technology: The Case of Semiconductors, (Washington, Brooking, 1971) p. 90-91.

accelerating technical change, drawing resources, generating commercial spillover, contributing to the rise and decline of individual firms, enhancing the industry manpower pool, and, indirectly, introducing society to a vast array of new, better and cheaper products. Military involvement in integrated circuits began with research and development support. In retrospect the large expenditures made by the military throughout the 1950s certainly provided a strong market signal to the industry that the device characteristics eventually incorporated in the integrated circuit were highly desirable. Table C.6-3 provides a Department of Commerce estimate of annual government R&D support from 1955 through 1961. A host of development projects -- Tinkertoy, molecular electronics, micro-module -- while unsuccessful in and of themselves, certainly established

TABLE C.6-3

ESTIMATED U.S. GOVERNMENT DIRECT FUNDING FOR SEMICONDUCTOR RESEARCH, DEVELOPMENT AND PRODUCTION REFINEMENT PROJECTS, 1955-1961 (Millions of Dollars)

	1955	1956	1957	1958	1959	1960	1961	SUBTOTALS
Research and Development	3.2	4.1	3.8	4.0	6.3	6.8	11.0	39.3
Industrial Preparedness Studies: Transistors	2.7	14.0		1.9	1.0		1.7	21.3
Industrial Preparedness Studies: Diodes and Rectifiers	2.2	0.8	0.5	0.2		1.1	0.8	5.6
SUBTOTALS	8.1	18.9	4.3	6.1	7.3	7.9	13.5	66.1

Source: U.S. Department of Commerce, Semiconductors: U.S. Production and Trade, Washington, D.C., 1961, p. 13.

the nature of DOD needs. While neither Jack Kilby's integrated circuit nor Robert Noyce's planary process were directly supported by the military, it played the first user role following their introduction. This role was broader than simple purchases of finished circuits, it also included the development of manufacturing methods, in some cases the financing of pilot line capabilities and, as importantly, demonstrating the usefulness of the integrated circuit to other markets. Subsequently, military and space demand accounted for the bulk of the integrated circuits produced through the mid-1960s. Firms moved down their learning curves, eventually reducing costs sufficiently to open the market to more price elastic market segments. In turn, not only did the industry grow, but a number of new firms, products and processes may at least indirectly be viewed as outcomes of the military industry interface.

The general impacts of the military-industry interaction preceding and through the early phases of the integrated circuit's development were then:

- Market signaling, DOD in its R&D funding made clear its general devices requirements and broad classes of application
- Process and pilot line development, affecting not only integrated circuit production, but also discrete devices
- Early purchases at premium prices initiating the learning curve growth dynamic
- Less directly, providing a smooth entry and rapid growth for newer firms, e.g., Fairchild and Motorola.

C.7 CURRENT STATUS OF THE MILITARY MARKET

Tables C.7-1 and C.7-2 provide sufficient data for only a partial analysis of the current status of the military integrated circuits market. The data presented is incomplete. It includes neither market share information nor a detailed breakdown of number of suppliers of specific products. As importantly, the data set probably excludes a significant number of military qualified integrated circuit suppliers, such as IBM and Westinghouse, which have captive production facilities and thus in producing finished electronics systems for the military market also indirectly supply integrated circuits.

Table C.7-1 indicates a significant number of qualified suppliers for most types of integrated circuits, ranging from 23 different suppliers for linear integrated circuits to five suppliers for Bipolar ECL circuits. At least at the level of aggregation for which data is available the large number of suppliers indicates the presence of a market structure where

TABLE C.7-1

NUMBER OF FIRMS SUPPLYING MILITARY STANDARD* INTEGRATED CIRCUIT TYPES

Circuit Type	Number of Suppliers
Linear	23
Hybrid	22
Interface	18
Arrays	12
Memory	
Bipolar	12
CMOS	10
MOS	12
Erasable	10
Logic	
Bipolar TTL	8
Bipolar Schottky	11
Bipolar ECL	5
CMOS	11
Other	3

*JAN and/or MIL-STD 883 B Devices

Source: "Military Integrated Circuit Directory," Military Electronics/Countermeasures, August 1980.

competitive conditions may be exploitable by the military to secure lower cost and shorter lead times. These conditions, however, must be balanced against other factors pushing in the opposite direction such as the relatively low volume of military IC purchases and the relatively low profitability of the military market, particularly when prices are being driven up in the commercial and industrial market segments due to insufficient production capacity.

Table C.7-2 provides data showing the breadth of particular firms' product type offerings to the military market. Seven of the top ten firms in this category are also among the top ten sales leaders for the entire market. This correlation would suggest product line breadth is also indicative of military sales volume.

TABLE C.7-2

RANK ORDERINGS OF MILITARY STANDARD INTEGRATED CIRCUIT* SUPPLIERS BY NUMBER OF CIRCUIT TYPES SUPPLIED

Firm	Number of Circuit Types
Fairchild†	11
Motorola	10
National	10
Harris	9
Hughes	9
Advanced Micro Devices†	7
Texas Instruments	7
Intersil†	6
Plessey Semiconductors†	6
Signetics†	6
Applied Micro Circuits	5
Raytheon	5
Beckman Instruments	4
Interdesign†	4
Silicon General	4
American Microsystems†	3
Burr-Brown Research	3
Intel	3
Micro Power Systems	3
Nitron	3
Analog Devices	2

TABLE C.7-2 (Continued)

Firm	Number of Circuit Types
General Electric‡	2
Hybrid Systems	2
Monolithic Memories	2
Mostek	2
Siliconix†	2
Standard Microsystems	2
Circuit Technologies	1
Countermeasure Systems	1
Datel-Intersil Systems	1
Environmental Communications	1
Hycomp	1
Integrated Circuits	1
Micro Networks	1
Precision Monolithics	1
Solitron Devices	1
Teledyne	1

Notes:

*Jan and/or MIL-STD 883B.

†Foreign owndership (20% or more).

‡Merger pending.

Source: "Military Integrated Circuit Directory, 7th Edition," Military Electronics/Countermeasures, August 1980.

APPENDIX D

AFSC QUESTIONNAIRE

This appendix comprises a copy of the original survey distributed by the AFSC.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE, DC 20334

REPLY TO ATTN OF: PMD

20 March 1980

SUBJECT: Detailed Lead Time Growth Analysis

TO: AD/PMD ASD/PMD BMO/PMD ESD/TOM SD/PMD

1. The AFSC Manufacturing Staff would like to thank everyone in the buying divisions, program offices and AFPRO's who supported our recent requests for industrial base data. The information was of significant value in helping to prepare testimony for HQ USAF. The data was also used in preparing General Slay for Corona South.

2. The short suspense required by the HQ AFSC/PM and HQ USAF/RDC messages severely limited the time and the degree of analysis that could be applied to the requested information. The importance of the industrial base issues dictates that we follow through with more detailed analysis.

3. Attachment 1 outlines the programs for each buying division that an in-depth analysis is requested. Should you feel that other programs warrant analysis, please add them to the programs requested.

4. Attachment 2 outlines the desired format suggested for use in completing the in-depth analysis.

5. The respective buying division manufacturing offices are requested to review all program office responses for the purpose of providing a consolidated analysis which will:

a. Determine whether generic problems (bottlenecks) exist, vis-a-vis program specific problems.

b. Determine whether these problems are due to capacity constraints, material shortages, skilled labor shortages, etc.

c. Recommend solutions. If technological or MANTECH solutions are proposed, consult with the AFWAL ad hoc Strategic Materials Committee focal point, Mr. H. Johnson, AUTOVON 785-4623.

6. Request that the program office data and buying division analysis with recommendations be forwarded to AFSC/PMD by 30 May 1980.

7. The focal points are Major Peter C. Giusti, HQ AFSC/PMD, AUTOVON 858-7291 and Mr. Robert Fabrie, AUTOVON 858-6540.

FOR THE COMMANDER

JOSEPH B. ANDERSON
Director of Manufacturing
DCS/Contracting & Manufacturing

2 Atch
1. Programs to be Analyzed
2. Analysis Format

Cy to: AFCMD/PD

PROGRAMS TO BE ANALYZED

ASD	AD	SD
A-10	AMMRAM	NAVSTAR
F-15	LASER GUIDED BOMB	AFSATCOM
F-16	WAAM	DSCS II/III
F100 Engine	HARM	SPACE DEFENSE SYSTEMS
TF34 Engine	AIM-7	

A representative system from each of the following: Strategic Systems, Simulators, Electronic Warfare Program Office. (ASD only)

ESD	BMO
JTIDS	Any data available on MX
SEEK IGLOO	
SAC DIN	
JSS	
E-34	

LEAD TIME TRENDS

				1977	1980	LEAD TIME GROWTH
1.0	SYSTEM:	(a)		(b)	(c)	(d)

	PRINCIPAL INFLUENCING SUBSYSTEMS	MANUFACTURER(S)			
1.1	(e)	(f)	(g)	(h)	(i)
1.2					
1.3					
1.4					
1.5					
1.6					
1.7					
1.8					
1.9					
1.10					

INSTRUCTIONS FOR COMPLETING SYSTEM LEVEL FORM

THE FOLLOWING DATA IS REQUIRED FOR EACH SYSTEM LEVEL ANALYSIS

a. System name
b. 1977 lead time for system
c. Current lead time for system (as of Jan 80)
d. Lead time growth for system (c-b)
e. Ten principal influencing subsystem (nomenclature)
f. Manufacturer for each subsystem
g. 1977 lead time for each subsystem
h. Current lead time (Jan 80) for each subsystem
i. Lead time growth for each subsystem (h-g)

LEAD TIME TRENDS

				1977	1980	LEAD TIME GROWTH
1.0	SYSTEM:	(a)		(b)	(c)	(d)
	PRINCIPAL INFLUENCING SUBSYSTEMS		MANUFACTURER(S)			
1.1	(e)		(f)	(g)	(h)	(i)
1.2						
1.3						
1.4						
1.5						
1.6						
1.7						
1.8						
1.9						
1.10						

NOTE: Instructions attached

LEAD TIME TRENDS

			1977	1980	LEAD TIME GROWTH
1.1	SUBSYSTEM:	(a)	(b)	(c)	(d)
	PRINCIPAL INFLUENCING COMPONENTS	SUPPLIER(S)			
1.1.1	(e)	(f)	(g)	(h)	(i)
1.1.2					
1.1.3					
1.1.4					
1.1.5					

*NARRATIVE: (j)

INSTRUCTIONS FOR COMPLETING SUBSYSTEM LEVEL FORM

THE FOLLOWING DATA IS REQUIRED FOR EACH SUBSYSTEM LEVEL ANALYSIS:

a. Subsystem nomenclature
b. 1977 lead time for subsystem
c. Current lead time for subsystem
d. Lead time growth (c-h) for subsystem
e. Five principal influencing components (nomenclature)
f. Supplier of each component
g. 1977 lead time for each component
h. Current lead time (Jan 80) for each component
i. Lead time growth (h-g) for each component
* If the major constraint is due to the subsystem contractor rather than component supplier, please orient your analysis to subsystem contractor.

j. Discuss the causes of the lead time growth for the three longest lead components of each subsystem. Try to segregate process time from queue (waiting) time. Be sure to segregate the ultimate causes into the following: lack of skilled manpower, machining capacity, tooling, and material. Discuss these causes in depth. If there are other causes, please identify and discuss them. Try to isolate the impact of commercial work. Quantify commercial and defense workloads as percentages of total workload. Be as specific as possible. Do not hesitate to elaborate.

NOTE: FULLY EXPLAIN LEAD TIME GROWTH FOR THE THREE LONGEST LEAD COMPONENTS.

[illegible] required

LEAD TIME TRENDS

			1977	1980	LEAD TIME GROWTH
1.1	SUBSYSTEM:	(a)	(b)	(c)	(d)
	PRINCIPAL INFLUENCING COMPONENTS	SUPPLIER(S)			
1.1.1	(e)	(f)	(g)	(h)	(i)
1.1.2					
1.1.3					
1.1.4					
1.1.5					

*NARRATIVE: (j)

*NOTE: Fully expalin lead time growth for the three longest lead components.

Use as many additional sheets as required.

Instructions attached

APPENDIX E

CODEBOOK FOR LEAD TIME STUDY

	I	1-4	1D	
COMP	I	5	Principal Influencing Components 1. Bearings 2. Castings 3. Connectors 4. Forgings 5. Integrated Circuits	NO ANS 0
AFDIV	I	6	Air Force Division 1. Space 2. Electronic Systems 3. Aeronautical Systems 4. Armaments	
SYSTEM	I	7-8	System Name (See system list)	NO ANS 00
SYSMAN1	I	9-11	Manufacturer of System (1)	NO ANS 000
SYSMAN2	I	12-14	Manufacturer of System (2) (See manufacturer list)	999=fewer named than allowed
SYSLED77	I	15-16	1977 Lead Time for System (months) (If range is given code mid-point and round to nearest month.)	NO ANS 00
SYSLED80	I	17-18	1980 Lead Time for Sys- (If range is given code mid-point and round to nearest month.)	NO ANS 00

SUBSYS	I	19-20	Subsystem name (See subsystem list)	NO ANS 00
SUBMAN1	I	21-23	Manufacturer subsystem (1)	NO ANS 000
SUBMAN2	I	24-26	Manufacturer subsystem (2) (See manufacturer list)	999=fewer named than allowed
SUBLED77	I	27-28	1977 Lead Time for Subsystem (months) (If range is given code mid-point and round to nearest month.)	NO ANS 00
SUBLED80	I	29-30	1980 Lead Time for Subsystem (months) (If range is given code mid-point and round to nearest month.)	NO ANS 00
TYCOMP	I	31-32	Type of Component (See component list)	NO ANS 00
COMPMAN1	I	33-35	Manufacturer of Component (1)	
COMPMAN2	I	36-38	Manufacturer of Component (2)	NO ANS 000
COMPMAN3	I	39-41	Manufacturer of Component (3)	
COMPMAN4	I	42-44	Manufacturer of Component (4)	
COMPMAN5	I	45-47	Manufacturer of Component (5) (See manufacturer list)	
COMLED77	I	48-49	1977 Lead Time for Component (months) (If range is given code mid-point and round to nearest month.)	NO ANS 00
COMLED80	I	50-51	1980 Lead Time for Component (months) (If range is given code mid-point and round to nearest month)	NO ANS 00
REASONC1	I	52-53	Reasons for Component Lead Time (1)	
REASONC2	I	54-55	Reasons (2)	NO ANS 00

REASONC3	I	56-57	Reasons	(3)	
REASONC4	I	58-59	Reasons	(4)	999 Already given
REASONC5	I	60-61	Reasons (See reasons list)	(5)	
CBLAME	I	62	Was component blamed for sub-system or system lead time? 1. No 2. Yes, subsystem 3. Yes, system 4. Yes, system and subsystem		NO ANS 0
RECMEN1	I	63-64	Recommendations for reducing lead time	(1)	999 Already given
RECMEN2	I	65-66	Recommendations	(2)	
RECMEN3	I	67-68	Recommendations	(3)	
RECMEN4	I	69-70	Recommendations	(4)	
RECMEN5	I	71-72	Recommendations	(5)	
RECMEN6	I	73-74	Recommendations	(6)	
RECMEN7	I	75-76	Recommendations	(7)	
RECMEN8	I	77-78	Recommendations	(8)	NO ANS 00
			(79=blank)		
	I	80=1			
	II	1-4	ID		
RECMEN9	I	5-6	Recommendations	(9)	
RECMEN10	II	7-8	Recommendations	(10)	
RESLED1	II	9-10	Any reason given for lead time	(1)	
RESLED2	II	11-12	"	(2)	
RESLED3	II	13-14	"	(3)	999 reasons already noted
RESLED4	II	15-16	"	(4)	

RESLED5	II	17-18	"	(5)	NO ANS 00
RESLED6	II	19-20	"	(6)	
RESLED7	II	21-22	"	(7)	
RESLED8	II	23-24	"	(8)	
RESLED9	II	25-26	"	(9)	
RESLED10	II	27-28	"	(10)	
RESLED11	II	29-30	"	(11)	
RESLED12	II	31-32	"	(12)	
RESLED13	II	33-34	"	(13)	
RESLED14	II	35-36	"	(14)	
RESLED15	II	37-38	"	(15)	
SYSQU	II	39-40	Queue time for system (in months)		
SUBQU	II	41-42	Queue time for subsystem (in months)		
COMPQU	II	43-44	Queue time for component (in months)		
	II	80=2			

MANUFACTURERS

001	Advanced Micro Devices
002	AIL
003	AiResearch
004	Alcoa
005	Alloy Die
006	Aluminum Forge
007	Amphenol
008	Ansco
009	Arkwin
010	Astro
011	Barden
012	Beckman Instruments
013	Bendix
014	Berg Electronics
015	Bergman
016	Biometrics
017	Boeing
018	Burndy
019	Cannon
020	Carlton Forge
021	Cercast
022	Chalco Eng.

023	Consolidated
024	Courter
025	Dean Castings
026	Decko Engineering
027	Delco
028	DISA (Denmark)
029	Dolphin
030	Dursch
031	Fafnir
032	Fairchild
033	General Dynamics
034	General Electric
035	General Semi
036	Goodyear Aerospace
037	Hamilton Avnet
038	Harris Semiconductor
039	Honeywell
040	Hughes
041	Hyatt
042	Hydro-Forming
043	IBM
044	Intersil
045	ITT
046	Kaiser
047	Kropp
048	Ladish Pacific

049	Lear Siegler
050	Martin Marietta
051	McDonnell Douglas
052	Menasco
053	Minimum Precision
054	Motorola
055	National Semiconductor
056	National Waterlift
057	Specline
058	Norden
059	Omni Spec
060	OSM
061	Park Drop Forge
062	Pico
063	Plessy
064	Pratt & Whitney
065	Raytheon
066	RCA
067	Reisner Metals
068	Republic
069	Rex Precision Product
070	Rockwell
071	Sanders Associates
072	Schavitz
073	Schultz
074	Shellcast

075	Signetics
076	Singer
077	Singer Kearfott
078	Singer/Link
079	Smithford
080	Specline
081	Steel Improvement and Forgings Company
082	Sundstrand
083	Teledyne
084	Tennant
085	Texas Instruments
086	Thiokol
087	Time
088	Wyman-Gordon
089	V&W
090	Vought
091	Yardney
092	Patty Precision
093	Altamil

SYSTEMS

01	A-10
02	AIM-7
03	B-52 OAS/CMI
04	E-3A
05	ECMS AN/ALQ-137
06	F-15
07	F-16
08	F-16 Operational FLT Trainer
09	GBU-15
10	JTIDS
11	Laser Guided Bomb
12	PMALS
13	SACDIN

SUBSYSTEMS

01	Accelerometer
02	ACE Rack
03	ACES II Seat
04	Actuator
05	ACU
06	AIM-9 Launcher
07	AIM-9 Launcher Adapter
08	AIM-9 Missile RIU
09	Air Vehicle
10	Attitude Heading Gyro Set
11	Avionics Control Unit
12	Battery
13	Bomb Rack, MAU-12C/A
14	Brake
15	CDM/IU
16	Centerline Pylon
17	Computational System
18	Conventional Weapons RIU
19	CPU-123/B Computer
20	Data Transfer Unit
21	DCU-199/B Control
22	DSU-18/B Detector

23	ECM C/L Adapter
24	F-100 PW 100 Engine
25	Flight Sensor Assembly
26	Fuel Pylon
27	Guidance Assembly
28	Guidance Processor Electronics
29	Gyro Stabilized Platform
30	HPA
31	HP/APS
32	Identification
33	Inertial Navigation System
34	Instructor/Operator Station
35	Integrated Servo Actuator
36	Inverter/Coverter
37	Landing Gear
38	LPA/PS
39	Main Wheel
40	Mechano-Receptor Queuing System
41	Motor
42	MXU-650/B and MXU-651/BAFG
43	Nuclear RIU
44	OBTM & M
45	Pallet
46	Pylon Wing Adapter
47	Radar Altimeter
48	Radar E/O

49	Receiver/Transmitter/Modulator
50	Roll and D/V Gyros
51	Roll Reference Assembly
52	RSC
53	Shelter
54	SIE Rack
55	Simulator
56	Speed Brake Actuator
57	Student Station
58	TF34 GE100 Engine
59	30 MM GAU-8A Gun
60	TPU
61	Translator/Processor
62	Transponder
63	TTY Comsec Rack
64	20 MM M61A1 Gun
65	UME Rack
66	Vidicon
67	Visual System
68	Weapon Pylon

REASONS FOR GIVING LONG LEAD TIMES

01 Air Force demand increase (for example, a particular program expanding

02 Aluminum shortage

03 Capacity problems (incl. machine time, lack of expansion)

04 Changes made later (in design)

05 Cobalt shortage

06 Commercial sector factors (especially cars, toys)

07 Competiton from other subs

08 Component delivery late or unavailable (or has long lead time

09 Component delivery late (within same company)

10 Concentration of industry in S. California and lack of machine time there

11 Custom or special devices

12 Demand at testing labs

13 Demand in general

14 Design problems, including slow release of plans

15 Distrust of long-term government business (uncertain of volume)

16 Economy in general

17 Energy supply and costs

18 Failure to give priority ratings, or to monitor them

19 Government year to year funding

20 Higher quality/reliability parts

21 Labor problems (strikes...)

22 Deferred investment incentives, etc.

23 Lack or shortage of qualified suppliers, e.g., single supplier

24 Low demand (on the part of the military)

25 Low yield rate

26 Management/Administrative problems

27 Manpower shortage

28 Manufacturing processes limited to specific number of times per year

29 Materials shortage/availability, including long lead times for raw materials

30 Metals shortage

31 Nichrome shortage

32 Obtaining tools and dies

33 Patent rights

34 Performance requirements pushing state-of-the-art

35 Plant closings (or company going out of business)

36 Procurement lead time

37 Piece part lead time

38 Reduced inventories

39 Regulations/requirements (EPA, OSHA, mil specs...)

40 Secondary machining

41 Short lead time orders

42 Silicon shortage

43 Small firms hesitant to do business with government, (or can't)

44 Small volume orders

45 Sole sourcing

46 Time for package/transportation/inspection

47 Technological Change/advances

48 Titanium shortage

49 Tooling no longer available

50 Turnover

51 Transportation problems

52 Unique manufacturing problems (including some part of the processing being delayed)

53 Variations in administrative time

54 Variations in dock time

55 High capital costs

56 Variety of parts

RECOMMENDATIONS

01 Aggressive procurement management (including management in general)

02 Better capital investment incentives

03 Blanket/annual agreement PO's

04 Buy stock, make advance buys, expect shortage

05 Combine orders

06 Coordinate procurement of common piece parts with subs

07 Develop new capacity in speciality technologies

08 Early buy-outs

09 Early planning, identification of potential problems earlier

10 Ease degree of specificity

11 Ease environmental restrictions

12 Encourage mills to make desired quantities

13 Enforce priority ratings (or use them)

14 Evaluate contractors' purchasing systems, inventory, etc.

15 Evaluate subcontractor lead times and past performance

16 Five year commitment

17 Frequent communication, such as status reviews, with primes and subs

18 Funding for second source qualification

19 Higher allowable profit margins

20 Improve mill capacity

21 Increase titanium sponge supplies

22 Increased demand

23 Large orders

24 Long lead procurement funding (including raw materials, facility funding)

25 Manpower analysis and training

26 Manual ordering of some critical parts

27 More active role in schedule negotiation

28 Multiple source procurements

29 Multi-year program funding

30 Order a number of spare parts with original order

31 Premium pay

32 Reserve manufacturing time

33 Use DX rating on POs

34 Use off-the-shelf, commercial items, instead of system items

35 Government provide high reliability items

36 Substitute type

37 Make components in house

TYPES

Bearings --

01 Ball

02 Large

03 Lined

04 Non-commercial

05 Non-std

Integrated Circuits --

06 Chips

07 CMOS

08 Digital

09 DTL

10 Hybrid IC

11 Linear

12 Low Power Schottky

13 Memories

14 Micro Processor ICs

15 MOS Devices

16 PROMs

17 RAMs

18 Schottky

19 TTL

Castings --

20 Aluminum

21 Complex

22 Complex Thin Wall

23 Fairing

24 Magnesium

25 Semi-Complex

26 Simple

27 Stainless Steel

Connectors --

28 Breakaway

29 Circular

30 Coaxial

31 Mating

32 Positive Engage

33 Quick Disconnect

34 Rack Panel

35 Scoop Proof

36 Terminal Blocks

Forgings --

37 Aluminum

38 Bearing Retainer

39 Body Bolt

40 Compressor disk (stage 2)

41 End Plate

42 Fan Disk (2 piece)

43 500-499 sq. in.

44 500-1499 sq. in.

45 Forward fan shaft

46 Forward spool (2 piece)

47 Front casing

48 Housing halfs

49 Large (complex)

50 Main Manifold

51 Piston and Outer Cylinder

52 Rotor

53 Small

54 Steel

55 Under 159 sq. in.

APPENDIX F
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