

January 1997

DEFENSE INDUSTRY

Trends in DOD Spending, Industrial Productivity, and Competition



**Program Evaluation and
Methodology Division**

B-265618

January 31, 1997

The Honorable William V. Roth
Chairman, Committee on Finance
United States Senate

The Honorable Charles E. Grassley
United States Senate

The end of the Cold War marked the continuation of a decline in most DOD appropriations accounts from the peaks of the 1980s. Declines in Department of Defense (DOD) spending for procurement and research, development, test, and evaluation (RDT&E) have some effect on the broad industries that manufacture and produce weapons for DOD. The impact of declines in defense spending has been the focus of congressional and executive branch initiatives and programs designed to help communities, businesses, and workers adjust to the post-Cold War funding drawdown.

You asked us to examine several issues about defense spending and defense industry since the end of the Cold War. In this regard, you asked us to conduct a broad review of productivity and competition in the defense industrial base. In this report, we describe (1) overall trends in productivity, competition, and other financial indicators in the defense industry over time, where possible, and (2) the relationship between these trends and indicators of defense spending over time, where possible.

Background

Victory in the Cold War brought changes in the size and resources available to today's armed forces. A decline in DOD budgets has been a trend since the mid-1980's peak in defense budgets. Since the collapse of the Soviet Union, the range of public and private businesses, departments, or facilities that work in the interests of U.S. national security operate in a defense environment different from the past, where defense policy has changed accordingly.

DOD is buying and developing fewer types of military systems and purchasing smaller quantities of the systems it does buy. Weapons purchased today have gained from considerable military and technological advances made over time. In constant dollars, DOD procurement outlays in fiscal year 1995 were 52 percent smaller than 1987 levels—the highest level since 1946. This has an effect on the defense industrial base (DIB)—industries that supply, manufacture, or assemble aircraft, ships,

missiles, tanks, ammunition, weapons, and electronics and communications equipment for national defense purposes. In fiscal year 1995, DOD procurement outlays were \$55.1 billion and defense-related industry employment was approximately 2.3 million.

As companies develop and implement strategies for survival in the new spending environment, the Congress and the executive branch have considered the balance between market forces that influence the structure of the defense industrial base and the federal government's role in securing and meeting the nation's defense needs. For example, DOD's Bottom Up Review (BUR) was designed to define the nation's defense strategy, force structure, modernization and infrastructure requirements as a result of the end of the Cold War. Promoting a more efficient post-Cold War defense industrial base is a goal of initiatives to reform DOD's weapons acquisition process.

While many of DOD's recent acquisition reform efforts were embodied in the Federal Acquisition Streamlining Act (FASA) of 1994, DOD has made other efforts to adapt to the post-Cold War period of smaller procurement budgets, shrinking defense industry, and increased international competitiveness.¹ In 1994, DOD set up groups to identify, coordinate, or implement process improvements to reduce "cost drivers" believed to cause increases in the price DOD pays for goods and services.² DOD's initiatives to aggressively pursue acquisition reform include the elimination of some military standards and requirements, adopting commercial practices, and the use of Integrated Product Teams (IPTs) to continuously include government and industry stakeholders in making program and business decisions.

A large-scale post-Cold War transition assistance program, authorized under the National Defense Authorization Act for fiscal year 1994, and announced in March 1993 by the executive branch, is the Defense Reinvestment and Conversion Initiative. The initiative included funding for (1) worker training and adjustment, (2) investments in hard-hit communities, (3) dual-use technology and commercial integration, and (4) conversion opportunities in new civilian technology investment. In

¹DOD's Defense Acquisition Pilot Programs—which include the Fire Support Combined Arms Tactical Trainer, the Joint Direct Attack Munition (JDAM), the Joint Primary Aircraft Training System (JPATS), the Commercial Derivative Aircraft (also known as the Non-Developmental Airlift Aircraft), and the Commercial Derivative Engine (F-117 Engine)—are examples of programs authorized under FASA.

²See U.S. General Accounting Office, Acquisition Reform: Efforts to Reduce the Cost to Manage and Oversee DOD Contracts, GAO/NSIAD-96-106 (Washington, D.C.: April 1996).

fiscal year 1994, the Congress appropriated \$2.5 billion for DOD's defense reinvestment and conversion program.

As described above, a number of issues have been addressed through programs or legislation directed to assist the transition of the defense industrial base in the post-Cold War era. In your request, you asked for information on productivity and competition in the defense industrial base. In this report, we describe the trends in available data on productivity and competition and the related issues of trends in defense industry employment, the status of major defense contractors in the post-Cold War, and trends in defense budgets and outlays. We make use of existing statistical information and supplement these data with information collected from industry experts and defense contractors. This work makes use of findings from studies, now just beginning to emerge, that examine the industrial, economic, and national security implications associated with the post-Cold War drawdown and conducted or sponsored by DOD, as well as private research organizations or groups. We present a broad historical overview of data about the defense industry to provide a context for the significant changes that the defense industry has faced in the post-Cold War period.

Results in Brief

The size and nature of the defense industrial base is critically shaped by the amount and emphasis of U.S. defense outlays. Recent debate has centered on the effect of the post-Cold War reduction in defense spending and its effect on the viability of the industrial base. Although this downward trend in budget outlays and particularly in procurement spending is sizable, it is one of four times in post-World War II history that the industrial base has had to adjust to changes in national security requirements. In historical perspective, defense funding drawdowns are not unique.

With regard to trends in the actual expenditures in segments of the defense industrial base, after adjustments for inflation, recent spending on procurement and RDT&E prime contract awards is similar to spending just prior to the peacetime defense buildup of the early 1980s. Over the last 20 years, DOD has consistently allocated more money for procurement and research of aerospace products—aircraft, missiles, and electronics and communications equipment—than for tanks, ships, ammunition, and other weapons. Aggregate procurement and RDT&E contracts for aerospace products out-paced spending for all other equipment by over 3 to 1. Since the end of the Cold War, prime contract dollars for aircraft research and

development have increased and dollars for aircraft procurement have declined the least. The available data did not allow us to determine the distribution of spending across industrial segments based on subcontract award activity; rather, they allowed us to determine such information only for prime contracts. The available data on subcontract awards indicate that dollars allocated to businesses through DOD's mandatory subcontractor program began to decline after the Cold War and are currently below the average of the last 18 years.

Aside from outlays there are other differences in today's industrial base compared to past periods. Today's weapons cost more than in the past, so fewer can be procured as defense budgets decline. Changes in complexity and sophistication of today's weapons, and costs associated with related weapons manufacturing processes, have contributed to this trend. DOD and Department of Labor (DOL) data on productivity in defense-concentrated industries, and other studies on productivity, indicate that the value of output has increased over time while the quantity of output has decreased. In particular, comparative data for military aircraft show that the 1993 inflation-adjusted budgets for aircraft procurement were more than double those in 1973, while 65-percent fewer aircraft were produced than in 1973. Similarly, DOD expects to move from purchasing large quantities of low-cost helicopters to fewer high-cost, more capable, helicopters. DOD's ship and tank procurements also show a trend toward the purchase of fewer higher-cost units.

The business environment for defense industry has also changed over the years. Since the end of World War II the number of aircraft contractors dropped from 26 to 7 in 1994.³ Missile contractors dropped from 22 to 9 and tank contractors from 16 to 2 over the same time period. Recent defense contractor mergers and acquisitions are seen as a trend that will perpetuate constraints on the number and nature of businesses that may be willing and able to compete for business with DOD. These fewer contractors are operating in an environment where DOD tends to award more money on weapon procurement contracts using other than full and open competition. Because of the nature of what DOD buys, substantial amounts of procurement dollars are associated with single-source providers. Little is known about how the ongoing reconfiguration of the defense industrial base will affect or be affected by these trends in DOD weapon procurement processes. This condition is aggravated by the lack of data available for comprehensive analyses. There is no single,

³Includes helicopter contractors.

comprehensive source of information about competition in defense industry. Therefore, we are limited in our ability to address this issue.

Defense industry employment is another key factor affected by changes in the industrial base. The loss of jobs related to the reduction in defense budgets is widely documented, although estimates and projections vary. DOD estimates a 39-percent decrease in defense-related employment between 1989 and 1997, or 5 percent per year. Jobs have been lost in the funding drawdown, but job loss does not necessarily equate to unemployment. Losses can be absorbed as individuals acquire future work in the same or in different sectors of the economy. The Defense Conversion Commission reported to DOD that the concept of job loss can overstate the effect of the post-Cold War drawdown on employment because it does not account for the ability of the economy to absorb dislocated workers. The commission estimated that the drawdown will account for less than 2 percent of all unemployment between 1992 and 1999. The Congressional Budget Office (CBO) reports that overall growth in the U.S. economy is a greater factor in reemployment for displaced defense workers than what happens in the defense sector. We found a correlation, or statistical relationship, between an indicator of employment in defense-concentrated industrial sectors and an indicator of procurement outlays in those sectors for the period 1975-91 that is not large and is less than values considered moderate in size.⁴ However, the lack of precise data on defense industry employment, differing procedures for generating estimates, and the lack of precise figures on DOD spending linked to defense sectors make it difficult for policymakers to make definite determinations.

Market forces and expectations about future trends in DOD budgets have facilitated the restructuring of the defense industrial base. Some companies have taken action either to remain viable in the defense business or leave it, while some top defense contractors have remained profitable and financially stable in a time of reduced spending. Companies have, among other things, been (1) attempting to gain market share and to be more competitive for future defense business through mergers and acquisitions; (2) reorganizing and restructuring internally, in ways that involve job losses and layoffs, and reconfiguring job duties; (3) reducing their supplier-subcontractor base; (4) engaging in team concepts or entering joint ventures in which several firms subcontract with one another; (5) expanding defense markets to broaden the international

⁴G.V. Glass, and K.D. Hopkins, Statistical Methods in Education and Psychology (New Jersey: Prentice-Hall, 1984).

customer base and increase sales; and (6) selling the defense business segments that are not core business units or that do not represent niche markets, as well as exiting segments of the defense industry.

DOD's industrial assessments indicate that companies have been profitable since the funding drawdown and that its needs can be met in the segments it has assessed.⁵ These assessments do not suggest that the trend toward more mergers and acquisitions and fewer contractors is a liability against maintaining current industrial capabilities. They do suggest that consolidation and other efforts to reduce overcapacity in defense industry may generate cost-savings for DOD. Our review of research from DOD and the private sector and our discussions with industry consultants and defense contractors all suggest that this assumption should continue to be studied, tested, and validated.⁶

For part of its current "Defense Acquisition Reform vision" and under the FASA, DOD has recently engaged and piloted several new acquisition reform programs intended to achieve greater efficiency and value in weapons procurement and to reduce unnecessary costs. These reforms and initiatives focus on the use of commercial practices, changes in the requirements for military standards and specifications, and increased emphasis on the tradeoff between cost and performance increases, among other efforts. Although these efforts are aimed at addressing critical and relevant issues for the defense industrial base, it is too early to tell what their full effects will be.

Objectives, Scope, and Methodology

As stated previously, in this report we describe (1) overall trends in productivity, competition, and other financial indicators in the defense industry over time and (2) the relationship between these trends and indicators of defense spending over time. To focus our review of these issues, we developed the following six key questions, which we answer in this report where data allowed us to.

1. What are the trends in DOD's total, procurement, and RDT&E budgets?

⁵DOD's Office of Industrial Affairs and Installations has assessed and made available to us its conclusions on the following industrial segments: conventional ammunition (September 1994), space launch vehicles (January 1995), helicopters (July 1995), torpedoes (August 1995), tracked combat vehicles (October 1995), and heavy bombers (December 1995). The September 1994 report entitled "Building U.S. Capabilities in Flat Panel Displays" reported on a newly identified industrial segment of important interest. We did not obtain DOD's assessment of the Meal-Ready-to-Eat segment for this work.

⁶We describe known efforts to study savings associated with industry consolidation toward the end of this report.

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2. What are the trends in the dollar amount of DOD procurement and RDT&E awards to defense contractors and subcontractors over time?
 3. What are the trends in indicators of employment, productivity, and competition over time?
 4. How are employment, productivity, and competition related to indicators of defense spending?
 5. What are the trends in the financial indicators of major defense contractors over time?
 6. What is the relationship between indicators of defense spending and indicators of the financial status of major defense contractors over time?

The industries in our analysis include U.S. manufacturers of items for major DOD procurement programs. DOD and other executive agencies have identified them as “defense-dominated” industries, or industries in which the output is largely purchased for defense purposes: aircraft, guided missiles, ammunition and ordnance, tanks, ships, and electronics and communications equipment. Where the industrial output of these manufacturing industries is not purchased by DOD, it may be purchased by commercial companies, other U.S. government agencies, or international companies.

We designed a macro-level evaluation to describe overall trends and patterns and to provide a basis for the additional phases of the work that you requested.⁷ The highly aggregated nature of much of the existing data and information about defense industries also in part required that we adopt a macro-level approach. Since our focus was global, we did not examine specific disparities, differences, or nuances in the data.⁸ The aggregate nature of the data did not permit us to offer definitive explanations for the trends these data reveal.

⁷In response to your request, we have a second study in progress to compare costs and productivity in defense and commercial manufacturing sectors.

⁸For example, we calculated statistical correlations to compare trends in employment and productivity in defense-concentrated industrial sectors to trends in the DOD budgets that are linked to those sectors. The correlations characterize overall trends. A number of factors may explain any observed correlation (time lags, idiosyncrasies in specific industries, idiosyncrasies in the data we received from federal agencies, and others). Examining the range of factors that might explain observed trends or relationships was beyond the scope of the work we were asked to do.

We collected, integrated, and analyzed published and unpublished data across the period 1975-95 from the executive agencies that maintain information on defense industries—DOD, the Department of Commerce, and DOL.⁹ This resulted in multiple data sources and multiple measures. We used those that were the most comprehensive with respect to that time period and the aspects of defense industry that we focused on.

We interviewed individuals and reviewed studies at Commerce, DOD, and DOL as well as at private research and consulting organizations, Wall Street firms, and major defense contractors. (A list of the offices we contacted is in appendix I.)

The measures and data that were available provide a method to describe and illustrate trends and patterns. The information that was available has varying degrees of uncertainty and completeness. Appendix II details our methodology and study limitations and defines our terms and concepts.

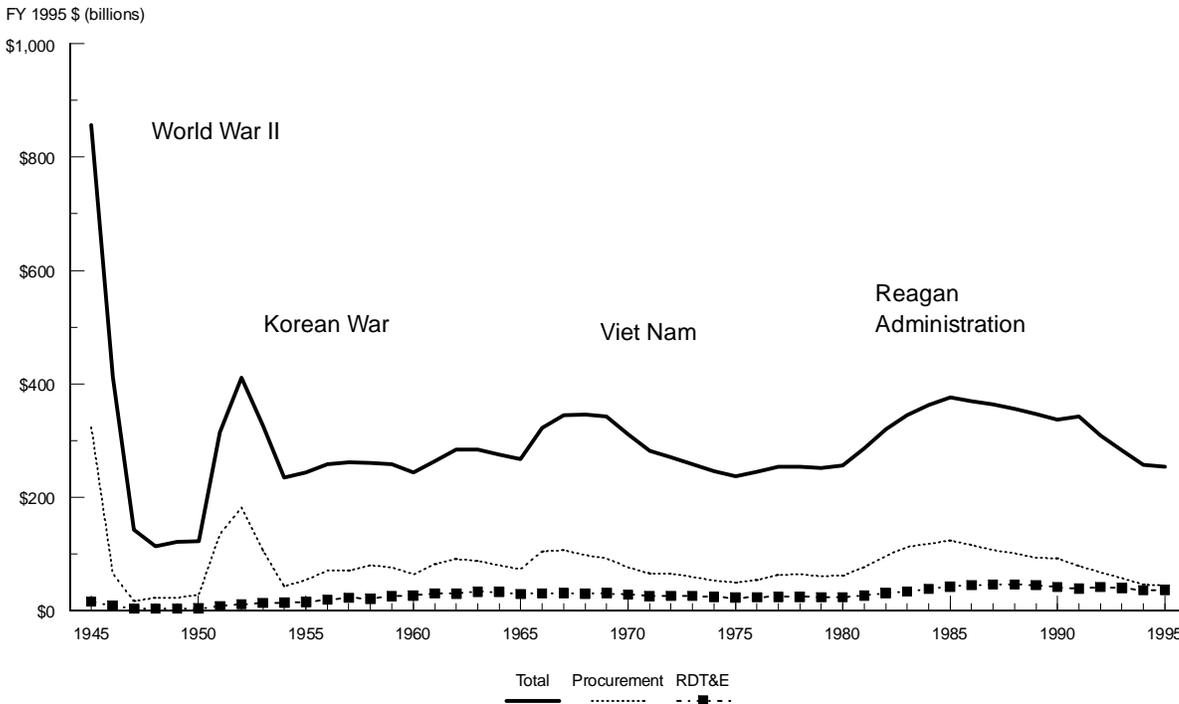
Principal Findings

Budget Trends

In order to understand the context for the post-Cold War trend in declining defense budgets, we examined trends in DOD budgets over the past 50 years. The recent downturn in defense budgets is the fourth in 50 years. The three prior funding drawdowns came at the ends of World War II, the Korean War, and the Vietnam War. This fourth one follows the peacetime defense buildup of the early 1980s. Figure 1 shows DOD's 1945-95 total, procurement, and RDT&E budgets.

⁹In answering question 1, we used DOD budget data going back to 1945.

Figure 1: DOD's Total, Procurement, and RDT&E Budgets, 1945-95^a



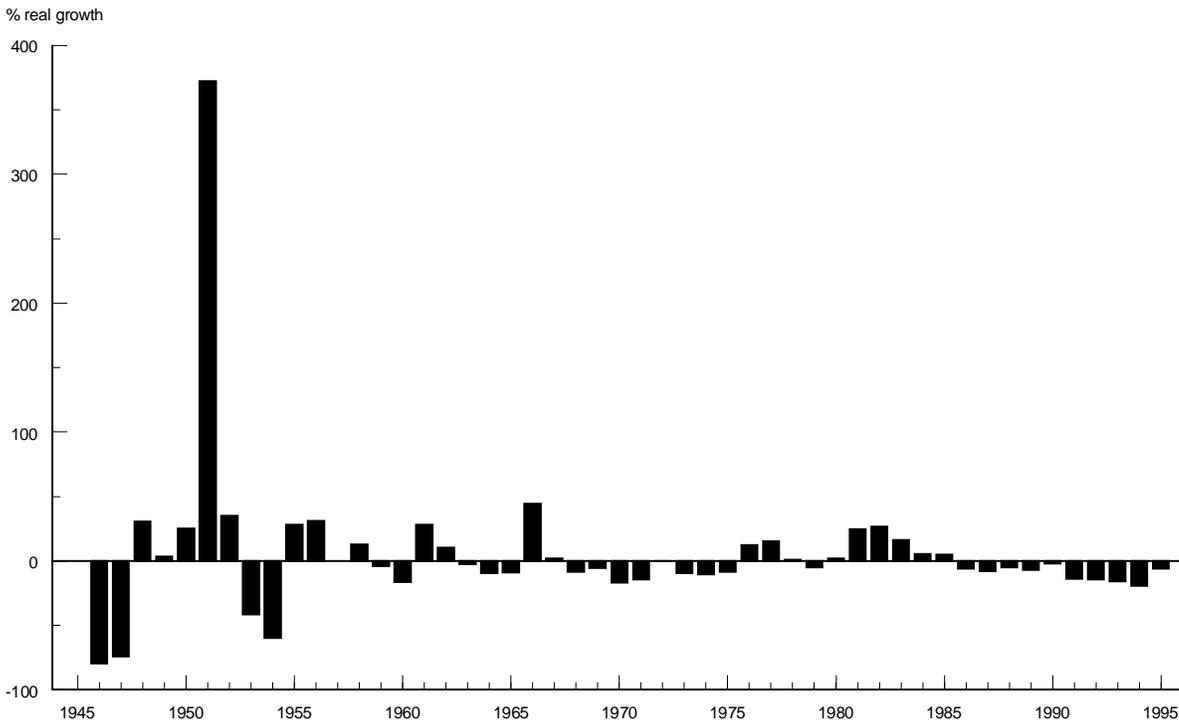
^aDollars are for total obligational authority. Total budget also includes military pay, operations and maintenance, military construction, family housing, and revolving and management funds.

Average post-Cold War (1990-95) procurement outlays are 10 percent higher than average Cold War outlays (1947-89). DOD's yearly average procurement outlays were \$69.3 billion during the Cold War; since the collapse of the Soviet Union, they have been \$76.3 billion. Since 1990, average yearly RDT&E outlays have been \$38.5 billion, compared to the average \$24.3 billion from 1947 to 1989.

Because defense industry is most concerned with DOD's procurement budget, as it includes the purchase of weapon systems, we focus on broad trends in procurement budgets specifically. The greatest 1-year percentage decline in the procurement budget's growth was the 80-percent decline in 1945, following World War II. The greatest increase was the 372-percent increase in 1951, preceding the Korean War. These periods represent the

most extreme past cases of growth increase and decrease. In post-World War II history, the period 1985-95 represents the longest consistent decline in the procurement budget. However, this period of decline includes fiscal year 1987, a year marked by the highest procurement outlays since the Korean War.¹⁰ Figure 2 shows the yearly percentage growth or decrease in DOD's procurement budget throughout the past 50 years.

Figure 2: Yearly Percentage Growth and Decrease in DOD's Defense Procurement Budget, 1945-95^a



^aDollars are total obligational authority.

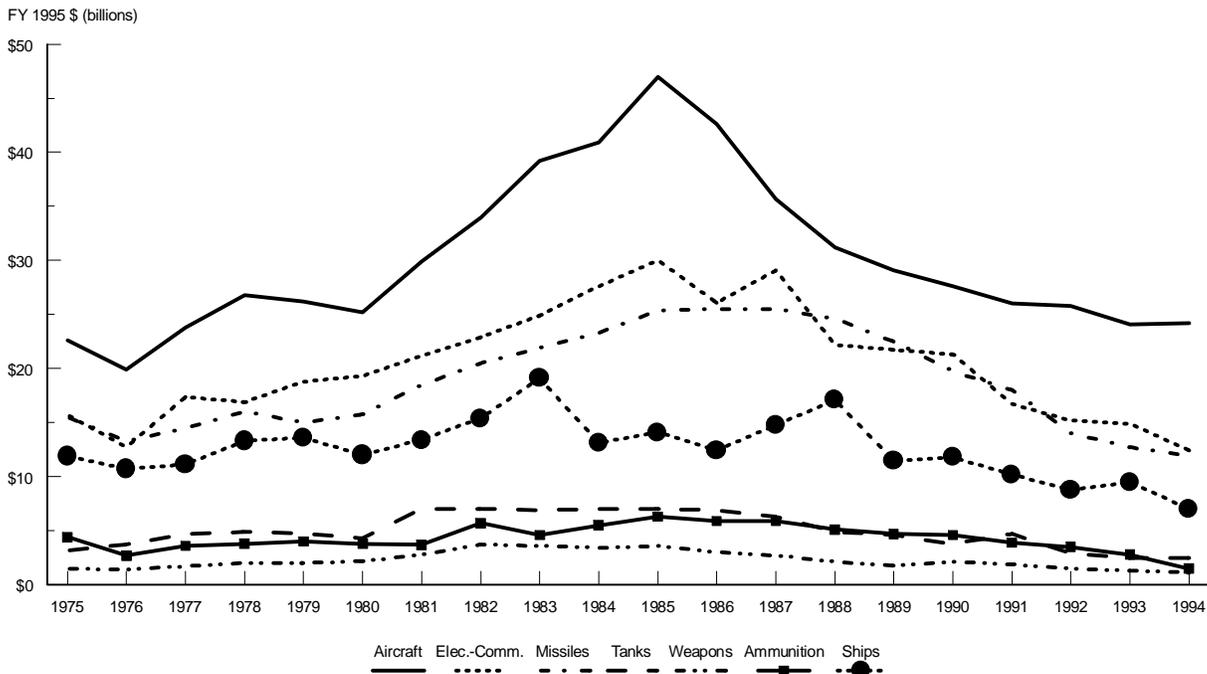
Trends in Contract Awards

Examining trends in procurement and RDT&E contract awards indicates DOD's spending within industry segments. These data show where DOD's procurement and RDT&E dollars have gone in the past. They also provide an indication of the industry segments that have experienced the most

¹⁰After 1995, further decline in procurement is not projected for the out years. DOD's future-years defense plan (FYDP) projects procurement increases to at least 1999.

funding decline in DOD post-Cold War contract dollars. In the past 20 years, DOD has spent more in procuring aircraft, guided missiles, and electronics and communications equipment than in procuring other major hard goods for national defense.¹¹ (See figure 3.) In particular, expenditures for aircraft exceeded all others during the period.

Figure 3: DOD's Procurement Contract Awards by Major Program, 1975-94



DOD's 1975-94 prime contract awards for aircraft, missiles, and electronics and communications equipment show a trend in which spending exceeded that on other weapon systems. Figure 3 shows that aggregate procurement spending on aerospace products has been 65 percent greater since 1975

¹¹Major hard goods are aircraft, missiles and space systems, ships, tanks and automotive, weapons, ammunition, and electronics and communications equipment (these are detailed in appendix II, table II.1, by DOD claimant program).

than the cumulative spending on ships, tanks, weapons, and ammunition.¹² Contract awards for missiles, electronics and communications equipment, and especially aircraft peaked in the 1980s. While their levels have since fallen, DOD's constant dollar spending for aircraft, missiles, and electronics and communications equipment, and for most other major hard goods, is the same or nearly the same as just prior to the peacetime defense buildup of the early 1980s.

The change in post-Cold War procurement contract spending has not been constant or equal across procurement programs. While the average post-Cold War reductions in spending for aircraft in 1990-94 were the smallest, at 3.6 percent, reductions in spending for ammunition were the largest, at 18.7 percent. The post-Cold War average percentage change in the dollar amounts of DOD's prime contract awards for procurement were

- aircraft: -3.6
- ships: -8.7
- weapons: -9.0
- tanks: -10.0
- electronics and communications equipment: -10.2
- missiles: -11.7
- ammunition: -18.7.¹³

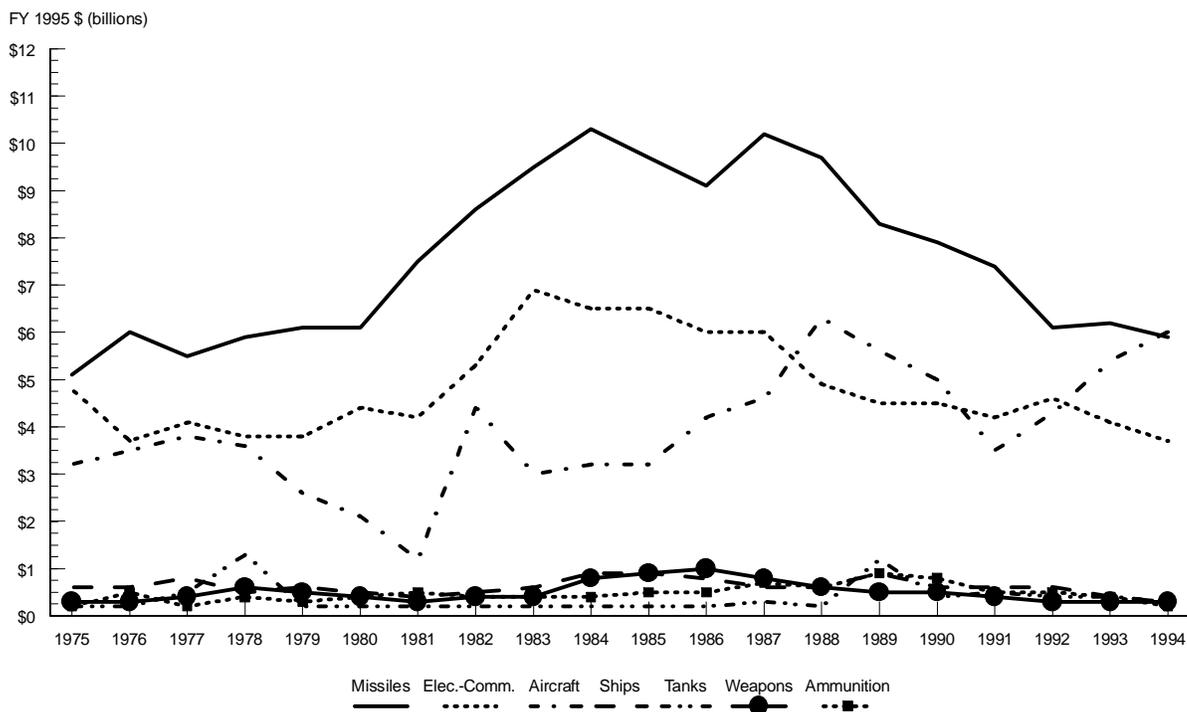
Like DOD's procurement spending, its expenditures in the aerospace industry have dominated its RDT&E contracts. In every year of the past 20, RDT&E investments for aircraft, missiles, and electronics and communications equipment differed, but their trend was always to surpass RDT&E investments in weapons, ships, and ammunition (figure 4). The post-Cold War average percentage change in the dollar amounts of DOD's RDT&E contract awards from 1990 to 1994 were

¹²The aircraft (fixed and nonfixed wing) and guided missiles and much of the electronics and communications equipment that DOD purchases are considered products of the broader aerospace industry. We note that the DOD definition of "electronics and communications equipment" includes equipment that may be installed in ships, tanks, and other "nonaerospace" products.

¹³This list includes funding through DOD prime contract awards and is a subset of all procurement spending mentioned previously. Average post-Cold War spending fell in all programs, but not all programs were reduced in every year. In some years, contract awards for aircraft, tanks, weapons, and ships were stable or increased.

- aircraft: +1.6
- electronics and communications equipment: -3.7
- missiles: -6.3
- weapons: -9.0
- ships: -18.3
- tanks: -18.3
- ammunition: -23.7.¹⁴

Figure 4: DOD's RDT&E Contract Awards by Major Program, 1975-94



Post-Cold War RDT&E reductions in aerospace have been the smallest relative to other major weapon systems; spending for aircraft has even increased approximately 1.6 percent. Post-Cold War RDT&E reductions for ammunition have been the largest, at 23.7 percent.

¹⁴This list includes funding on DOD RDT&E prime contracts for major weapon systems and is a subset of all RDT&E spending mentioned previously. Funding in all programs increased in one or more years or remained the same from one year to the next.

The only source of information available to describe trends in subcontract awards to defense contractors, over time, is DOD's records of participants in its subcontracting program (see appendix II). The participants can be small or small disadvantaged businesses or large businesses. For example, companies like Lockheed Martin and Boeing have received subcontractor awards under this program. DOD's published sources did not permit us to determine awards by weapon system or industrial segment but we were able to observe that the trends in the dollar amounts awarded to subcontractors are similar to those for prime contractors. Subcontractor awards peaked in the 1980s and began a gradual decline in 1989. The average change in post-Cold War funding available through DOD's subcontractor program is -6.7 percent.

A recent RAND report sponsored by the Office of the Secretary of Defense (OSD) indicates that in the aerospace industry, small suppliers to "large military aircraft programs" receive about 10 percent of defense dollars that go to contractors. Therefore, in some cases, reductions in defense spending should be expected to affect small suppliers differently relative to large defense firms. Views that small defense subcontractors are disproportionately affected by defense spending reductions merit further evaluation given constraints in the macro-level information about defense subcontractors we were able to obtain.

Trends in Employment, Productivity, and Competition

Employment

Our ability to examine relationships between defense spending and employment, and to generate conclusions, is complicated by the fact that employment data are often derived from models or estimation procedures that have degrees of uncertainty. Post-Cold War cutbacks in defense spending have been associated with declining employment in military force levels, federal defense-related civilian employment, and defense-related employment in private industry. On the one hand, DOD estimates show a 39-percent decrease in defense-related employment between 1989 and 1997—approximately 5 percent per year. DOL reports that private employment generated by defense spending fell by 600,000 jobs between 1987 and 1992 and projects at least an additional 1.2 million job losses by 1997. Between 1989 and 1994, McDonnell-Douglas

Corporation reduced its total corporate staff by approximately 70,000 people.

On the other hand, the Defense Conversion Commission reported to DOD that the concept of job loss can overstate the effect of the post-Cold War drawdown on employment because it does not account for the ability of the economy to absorb dislocated workers. The commission estimated that the drawdown will account for less than 2 percent of all unemployment between 1992 and 1999. In a report to the U.S. Senate Budget Committee, CBO found that cuts in defense spending, or in any type of federal spending, will temporarily reduce employment. However, it notes that defense cuts that are matched by increases in public-sector investment, or nondefense spending, can offset the short-term effects of spending reductions. CBO reports that overall growth in the U.S. economy is a greater factor in reemployment for displaced defense workers than what happens in the defense sector. CBO reports, as well as other reports we reviewed, also indicate that the effect of reduced defense spending on employment varies by regions of the country, whereas those that are less dependent on defense spending are generally affected to a lesser extent.

We analyzed available indicators of defense sector employment and an indicator of DOD procurement outlays linked to those sectors over the period of our study to determine the strength of the relationship between the two (see appendix II for methods discussion). We found a statistical relationship between the available indicators of employment levels and procurement outlays for the period 1975-91 that was not large in size and is less than values considered moderate in size ($r = .27$ to $.36$, depending upon the indicator used). (See appendix III.) Because the available indicators of defense sector employment and DOD spending are estimates, they are subject to possible error that may come from the estimating procedures and “operational” errors, or errors in the primary data collection reporting or coding procedures of the offices that collected the data. Moreover, the limitations of correlational analysis also introduce uncertainty that does not permit definitive conclusions regarding the exact nature of the relationship between defense sector employment and defense spending.

Productivity

DOD, Commerce, and DOL maintain or collect some information related to productivity in defense industries, some of which overlaps and some of which is unique. All the information on defense industry productivity that we obtained from these agencies was based on economic models or methodologies that have some degree of uncertainty. From this

information and data from others such as the Aerospace Industries Association (AIA), we observed the following trends.

The value of production output in most defense-concentrated industries has risen while defense budgets, as well as subsequent contract spending for major hard goods, have fallen (see appendix III, figure III.2).¹⁵ When AIA data on unit production are plotted with trends in DOD's aircraft procurement budget, there is a trend between 1969 and 1986 in which more aircraft procurement money is associated with the production of fewer aircraft. From about 1986 to 1993, the trend shows a relatively constant number of aircraft being produced while aircraft procurement budgets have declined.¹⁶

In other segments of the aerospace industry, in its 1995 assessment of the helicopter industry DOD projects that the unit cost for military helicopters will increase while the number of units produced will remain relatively flat through 2004. DOD expects to procure fewer, "more capable," higher-cost helicopters rather than larger quantities of lower-cost helicopters. Other DOD data on trends in ship and tank procurement indicate that DOD is purchasing fewer units at higher costs. One explanation for this trend is that the complexity and sophistication of weapons, and related weapons manufacturing processes, have increased over time. We were unable to locate research that could address this issue systematically and comprehensively for the range of weapon systems within the scope of our work.

Competition

Long-Term Trends in DOD Contracting. Within the scope of this report, and where data were available, we studied longitudinal trends in competition. There is little consensus on how to measure competition. Consequently, we chose to base our analysis on the concept of competition embodied in the Competition in Contracting Act of 1984 and the Federal Acquisition Regulation.

¹⁵"Value of production" is a standard DOL measure of productivity. Whenever possible, DOL uses actual physical quantities as the unit of measurement; when this information is not available, as in this case, it uses a constant-dollar value of shipments, sales, or revenues. (See also appendix II.)

¹⁶During this period, AIA data show that in 1989 and 1993 the numbers of military aircraft that U.S. defense manufacturers have produced for export surpassed the numbers produced for domestic use. Consultants at Booz-Allen and Hamilton indicate that if it were not for international business, many U.S. production lines would be closed, and, in fact, DOD views international business as one means of ensuring DOD's future helicopter requirements.

DOD collects a variety of information on contracting actions. The dollar value of the contracts and the solicitation procedures used are recorded in DOD's DD350 database. It provided us with trend data on where the defense dollar was being spent and in what solicitation category it was being spent, such as "full and open competition" and "other than full and open competition." Hence, using the DD350 data, we measured one aspect of competition: the total dollars awarded in each solicitation category.

The shortcoming of this database is that it does not fully capture the number of offers received in response to solicitations in each solicitation category, which could be another indicator of competition.

The DD350 serves as a basis for internal reports and reports to other agencies and the Congress and contains the only available data on the dollar amounts of contract actions for full and open and other than full and open competition. The "other than full and open competition" category captures instances where DOD uses various authorities to limit competition such as soliciting only one source when awarding follow-on contracts or when a "unique source" exists (see table III.1 for a complete list of authorities).

Among all the legal authorities for using other than full and open competition, dollars awarded under the broad category "only one source" accounted for 80 percent of the total contract dollars between 1986 and 1994. Included in this broad category are "follow-on contracts" (17 percent of the total), awards to a "unique source" (37 percent of the total), and awards categorized as "only one source-other" (25 percent of the total).

DOD's data on competition in contracting reveal that in the categories of major hard goods we looked at, over the past 18 years, the money associated with major systems procurement has been greater for contracts awarded using other than competitive methods than for those awarded using competitive ones. We found this trend as an 18-year average (see figure 5 and figure 6) and in each individual year for most programs in the period. (See also appendix III.3, figure III.16.)

DOD's definition of its competitive and other than competitive contracting procedures on the DD350, used as guides in our work, are shown in appendix III, table III.1. Figure 5 shows the DD350 competition data we were able to obtain for the period 1977-85, or "pre-CICA" (Competition in Contracting Act) data. Figure 6 shows "post-CICA" data, for 1986-94. We note that pre- and post-CICA data are based on different categories of

required information that DOD collected concerning the use of competitive or other than competitive procedures used to award procurement contracts. Differences between pre- and post-CICA data stem from the 1984 enactment of CICA. In our work for this request, we did not audit the pre- and post-CICA data derived from the DD350. Therefore, the full extent of differences between pre- and post-CICA data and the accuracy of DOD's reported data for both time periods would require more evaluation.¹⁷

In general figures 5 and 6 show similar findings, although the data presented are different measures of competition used in pre- and post-CICA periods. The portion of average contract dollars awarded using noncompetitive methods ranged from 66 percent for ships to 80 percent for aircraft (figure 5). For the post-CICA period, the range for other than full and open competition was 58 percent for ships and 81 percent for ammunition (figure 6).

¹⁷See appendix III for additional discussion and definition of the data elements extracted from the DD350 database for the pre- and post-CICA time periods.

Figure 5: Average Dollars DOD Awarded Using Competitive and Noncompetitive Procurement Methods, 1977-85

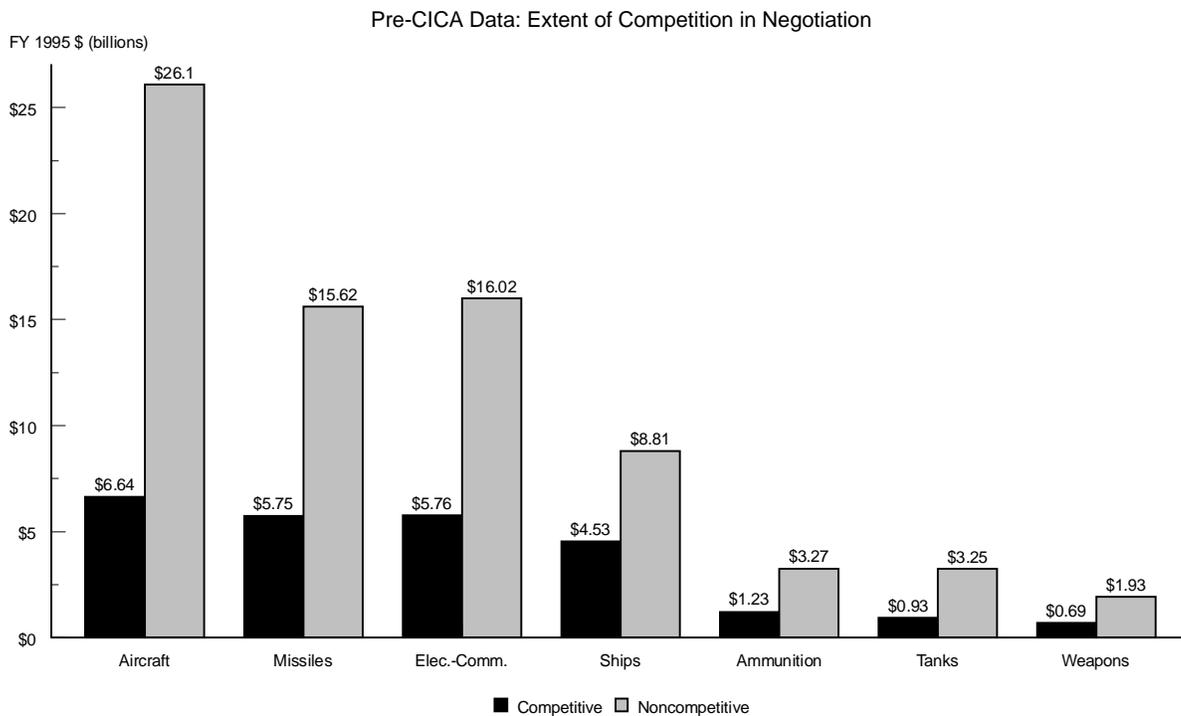
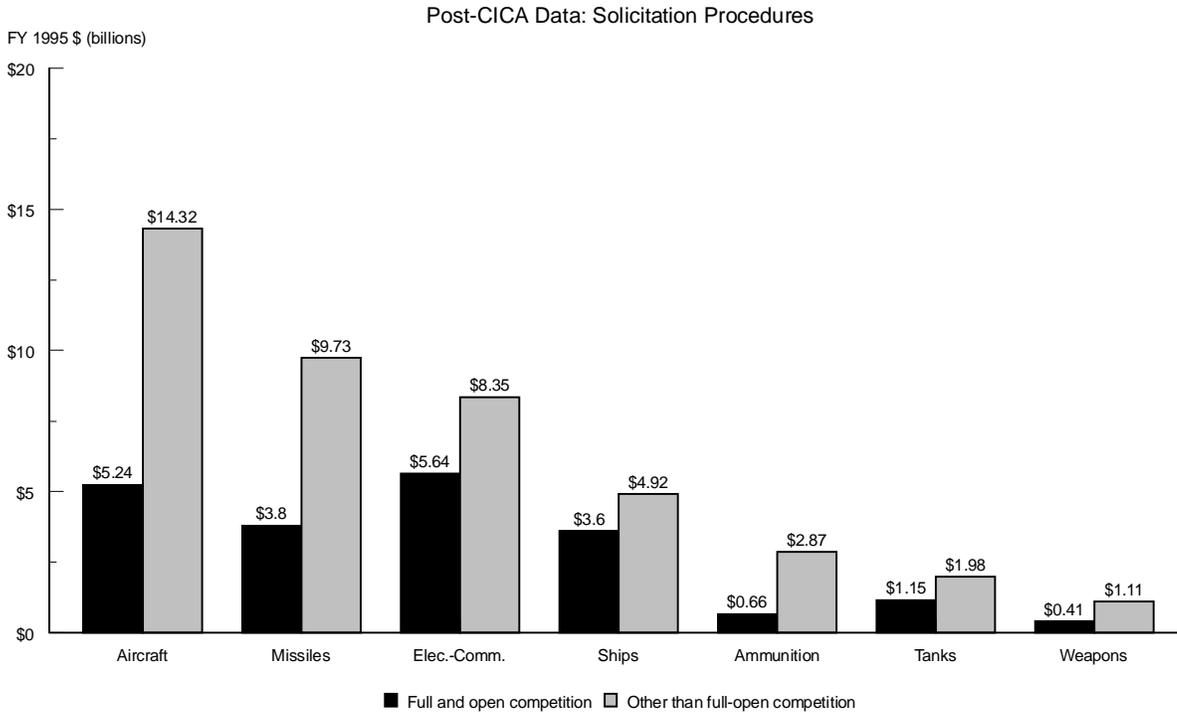


Figure 6: Average Dollars DOD Awarded Using Full and Open Competition and Other Than Full and Open Competition, 1986-94



Post-Cold War Restructuring and Reform. The major defense contractors we spoke with indicated that in the post-Cold War drawdown, defense companies have been acting to improve production efficiency, reduce costs and overhead, streamline operations, and reorient themselves toward a more cost-conscious customer. One outcome of changes in the way defense firms have been doing business since the Cold War, with relevance for competition, is a reduction in the number of independent defense firms by company mergers and acquisitions or by companies leaving the defense business. Notable examples include the March 1995 merger of Lockheed and Martin Marietta, Lockheed Martin’s acquisition of Loral’s defense electronics and systems integration business, the intended Boeing-McDonnell-Douglas merger, Raytheon’s purchase of Texas Instruments defense unit, and Northrop-Grumman’s acquisition of

Westinghouse defense electronics.¹⁸ In other areas of defense industry, the January 1994 agreement between FMC Corporation's Defense Systems Group and Harsco's BMY-Combat Systems Division to form United Defense Limited Partnership (UDLP) changed three major competitors in the light and medium armored vehicle market to two: UDLP and General Dynamics Land Systems.

A goal of business restructuring in the post-Cold War environment is to enhance or at least maintain a competitive position in the marketplace. We did not evaluate the effect of the recent trend in mergers and acquisitions on competition. However, in its 1996 annual report, while supportive of consolidations, DOD has concluded that "Consolidation carries the risk that DOD will no longer benefit from the competition that encourages defense suppliers to reduce costs, improve quality, and stimulate innovation." Moreover, in its assessment of the conventional ammunition segment, DOD concluded that a reduction in the number of suppliers has reduced competition.

The number of contractors will continue to decrease, according to DOD's published findings, officials we interviewed at Booz-Allen and Hamilton and TASC, and projections from officials at McDonnell-Douglas. They expect more mergers in some segments of the defense industry, such as helicopters and missiles, and expect some companies to keep the possibility of acquisition within their long-term strategies. Moreover, at least one noted defense industry expert has reported that barriers to entering the defense business—created by the need for large amounts of capital for preparing contract proposals and by the need to gain access to scientific and engineering talent and to specialized, expensive, production equipment—will continue to lessen the likelihood that new defense companies will enter the market in the near future.

This post-Cold War process of defense industry consolidation and restructuring may reduce some segments of the defense industry to one major provider. For example, one possible avenue DOD sees to achieve its stated goal of reducing costs for medium and heavy space launches is to consolidate the medium and heavy launcher booster families and "evolve"

¹⁸This does not include the additional reductions in the number of defense contractors resulting from acquisitions that Loral made before its agreement with Lockheed Martin. For example, in May 1995 Loral acquired the Defense Systems Operations of Unisys Corporation.

a new family of launch vehicles. DOD's procurement plan for this Evolved Expendable Launch Vehicle (EELV) is to have a single provider by 1998.¹⁹

While not taking a position on consolidation and mergers, the Defense Science Board's 1994 report to DOD on the antitrust aspects of defense industry consolidation states that reducing the number of firms capable of developing a suitable design for a new weapon system may lead to higher prices, poorer products, smaller advances in technology, and a reduction in the number, variety, or quality of the proposals that companies submit to DOD. The report further states that congressional findings, industry opinion, and a large body of literature lead to the conclusion that DOD's regulatory and auditing procedures cannot substitute for competition as a way of ensuring the best mix of price and quality.

Within its current Defense Acquisition Reform vision, DOD has recently implemented several new acquisition reform programs intended to increase efficiency and value in weapons procurement and to reduce unnecessary costs. DOD's cost as an independent variable (CAIV) reform represents a move toward making cost the significant driver in system design, compared to the Cold War era in which the emphasis was on systems that could outperform or overwhelm Soviet threats. The fiscal year 1996 Defense Authorization Act simplifies the processes for commercial item acquisition by exempting procurements for commercial items from cost or pricing data requirements. DOD created the Defense Standards Improvement Council to carry out policies mandated in June 1994 by the Secretary of Defense to develop performance-based solicitation requirements and expand the use of nongovernment standards or specifications.

An assessment of the effect of recent acquisition reforms on DOD's weapons procurement process and the broader defense industrial base would supplement the information presented here. To date, however, an independent assessment of the effect of DOD acquisition reform initiatives or programs on the issues discussed in this report has not been

¹⁹DOD awarded Alliant Tech Systems, Boeing, Lockheed Martin, and McDonnell-Douglas \$30 million each to develop a concept for the EELV, within some specific boundaries it has defined. In December 1996, DOD selected Lockheed Martin and McDonnell-Douglas to proceed to preengineering manufacturing, scheduled to last 15 to 17 months, at the end of which DOD will select a single provider. DOD stated that a single provider may be defined as a consortium, joint venture, or a teaming arrangement.

conducted.²⁰ We believe this is an important area for future evaluation, given the potential for reform initiatives to reduce or contain costs and facilitate efficiency improvements.

Defense Companies After the Cold War

Some defense contractors among the top 100 receiving the largest dollar amount of DOD prime contract awards in 1994 have grown in the post-Cold War budget environment, while others have not shown growth. (We detail the financial indicators in appendix IV.) DOD finds that most of the defense firms it has assessed have been profitable in the drawdown.²¹ Assessments of a random sample of small California aerospace businesses that supply goods or services to large military aircraft programs show that between 1992 and 1995, 94 percent were still in business while 3 percent had either merged or been acquired.

Officials at the major defense contractors we visited, the defense industry experts we interviewed, and the annual reports from major defense contractors we reviewed indicate that, in order to survive and remain viable in the funding drawdown, the top companies have, among other things, been (1) attempting to gain market share and to be more competitive for future defense business through mergers and acquisitions; (2) reorganizing and restructuring internally, in ways that involve job losses and layoffs, and reconfiguring job duties; (3) reducing their supplier-subcontractor base; (4) engaging in team concepts or entering joint ventures in which several firms subcontract with one another; (5) expanding defense markets to broaden the international customer base and increase sales; or (6) selling the defense business segments that are not core business units or that do not represent niche markets, as well as exiting segments of the defense industry.²²

²⁰Examples of recent GAO acquisition reform work is reported in U.S. General Accounting Office, Acquisition Reform: Comparison of Army's Commercial Helicopter Buy and Private Sector Buys, GAO/NSIAD-95-54 (Washington, D.C.: March 1995); Acquisition Reform: Military-Commercial Pilot Program Offers Benefits but Faces Challenges, GAO/NSIAD-96-53 (Washington, D.C.: June 1996); Acquisition Reform: Regulatory Implementation of the Federal Acquisition Streamlining Act of 1994, GAO/NSIAD-96-139 (Washington, D.C.: June 1996).

²¹In DOD's assessment of companies in the conventional ammunition segment, it found that they were not profitable. However, in its report, DOD stated that the nature of the analysis used would overstate companies that were not profitable.

²²For item 4, examples of existing team arrangements and joint ventures include the production and development of the F-22 fighter aircraft (Lockheed Martin and Boeing); the V-22 Osprey tilt-rotor transport rotorcraft (Bell and Boeing); and the Crusader, a tracked self-propelled artillery system (UDLP as prime contractor with General Dynamics, Lockheed Martin, Perkins Engines, and Teledyne Industries). For item 6, see also U.S. General Accounting Office, Defense Contractors: Pay, Benefits, and Restructuring During Defense Downsizing, GAO/NSIAD-96-19BR (Washington, D.C.: October 1995).

For various reasons, defense manufacturers have not given emphasis to converting their products or capabilities to commercial ones.²³ Officials at Lockheed Martin have noted that if defense businesses understand commercial markets, they may be able to produce competitive commercial products, but officials at Booz-Allen and Hamilton have emphasized that producing competitively for the commercial sector is different from producing for the defense sector. The production process and infrastructure that have been set up to serve DOD's customers are markedly different from those of commercial companies manufacturing competitive products for the average consumer. Further, some industry experts suggest that there are no commercial markets for converted military products. However, an official at a large defense firm noted that Rockwell International corporation achieved success in establishing a commercial market for Global Positioning System (GPS) receivers. In responding to this issue, however, some top defense firms have survived by investing in mergers and acquisitions and by reorganizing and downsizing their companies.

The defense industry experts and major defense contractors we spoke with agreed that companies that choose to stay in a post-Cold War defense industry must remain viable and competitive. They indicated that while industry consolidation can help them do this, the heart of consolidation is the reduction of overcapacity. Overcapacity increases costs through excess, underutilized overhead. When fewer dollars are available, companies must reduce costs in order to remain competitive. DOD also views the elimination of excess capacity as a means of achieving some cost-savings.

Booz-Allen and Hamilton has pointed out that while mergers and acquisitions have the potential to produce cost savings, particularly administrative savings, cost-savings benefits associated with consolidation are limited if excess production capacity is not reduced. They note that reduction of excess product design capability, as well as general production capacity, should be addressed in consolidation decisions. Booz-Allen and Hamilton also notes that cost-savings are minimized to the degree that merging companies or segments have dissimilar business. Similarly, internal company reorganization, teaming, and joint ventures may not result in any real savings if excess production capacity is not eliminated. Increasing foreign military sales might help spread out overhead costs normally charged to DOD but only as long as production

²³See U.S. General Accounting Office, Defense Conversion: Capital Conditions Have Improved for Small- and Medium-Sized Firms, GAO/NSIAD-94-224 (Washington, D.C.: July 1994).

lines remain open for weapons to be purchased by international customers.

Although DOD's industrial assessments have all claimed that consolidating the defense industry will produce cost-savings, our past work, our review of research from DOD and the private sector, and our discussions with industry consultants and defense contractors all suggest that this assumption should continue to be studied, tested, and validated.

There are efforts to study costs and savings associated with specific defense business combinations. Section 818 of Public Law 103-337 requires DOD to provide the Congress with the projected amounts of costs and savings for defense contractor mergers or acquisitions when DOD is asked to reimburse the contractor for the costs associated with company restructuring. At the time we completed our work, under this provision, DOD had so far certified restructuring payment for three business combinations: United Defense Limited Partnership between FMC Corporation, Defense Systems Group, and Harsco Corporation, BMY Combat Systems Division; Martin Marietta Corporation purchase of multiple business entities of GE Aerospace; and Northrop Corporation purchase of Grumman Corporation. Further, under section 818, GAO has a requirement to report to the Congress on restructuring costs. At the time we completed our work, we had issued two reports under this provision.²⁴ Aside from reimbursements for restructuring costs, section 818 does not provide for analysis and validation of the type of broad cost-savings claims that appear in some of DOD's published industrial assessment reports. Moreover, in both reports, we found that defense contractor's estimates of savings associated with business consolidation activity, submitted for official DOD review and certification, were greater than the estimates DOD could later verify. Finally, we have also reported that although contractors have been reducing overhead rates by consolidating facilities and by other means, they have been projecting future increases in overhead rates.²⁵

Vertical integration in defense industry was pointed out, by one external reviewer and DOD officials who reviewed a draft of this report, as an emerging issue of interest or concern for the defense industry linked to recent defense industry consolidation activity. Vertical integration can

²⁴See *Defense Contractor Restructuring: First Application of Cost and Savings Regulations*, GAO/NSIAD-96-80 (Washington, D.C.: April 1996), and *Defense Contractor Restructuring Costs: Projected and Actual Savings From Martin-Marietta Acquisition of GE Aerospace*, GAO/NSIAD-96-191 (Washington, D.C.: September 1996).

²⁵See *Overhead Costs: Defense Industry Initiatives to Control Overhead Rates*, GAO/NSIAD-95-115 (Washington, D.C.: May 1995).

occur in multiple ways. Vertical integration that occurs when major prime contractors acquire control of key components that make up the systems they sell has recently received attention. Industrial concentration that occurs through the acquisition of lower-tier firms by prime contractors can create the opportunity for contractors to freeze out of the market competitors that do not have access to these particular components. An external reviewer noted that vertical integration can allow prime contractors to shut out as sellers traditional second- and third-tier component suppliers who normally sell to the prime contractors.

A DSB task force on vertical integration convened in September 1996, at the request of the Under Secretary of Defense for Acquisition and Technology. The task force is expected to issue a report in 1997.²⁶ We note that the effect on lower-tier smaller suppliers is considered by one industry leader as a relevant issue in assessing vertical integration. In our work, we were limited in our ability to obtain comprehensive data about smaller subcontractors in the post-Cold War defense industry. However, we believe that the effect of defense industry consolidation is fully understood by reviewing the state of the smaller defense subcontractors in addition to the larger prime contractors. Given that small suppliers may typically concentrate on making one or a handful of products, compared to a broader mix among the primes, industry activity that limits the market for small suppliers may exert a disproportionate impact on them.

Agency Comments

We provided copies of a draft of this report to the Department of Defense. To obtain DOD's comments, we met with officials from the Offices of Deputy Under Secretary of Defense for Industrial Affairs and Installations; Under Secretary of Defense, Comptroller; Secretary of the Air Force, Acquisition Research and Engineering; and Assistant Secretary of the Navy, Research Development and Acquisition. Further, we conducted follow-up work on DOD's comments with officials from the Office of Program Evaluation and Analysis; Directorate of Defense Procurement; and Office of the Assistant Secretary of the Army, Research, Development, and Acquisition.

Officials conveyed to us that DOD planning, execution, and review of these matters is routinely at much lower levels of detail. From these levels, DOD

²⁶The Department of Justice and the Federal Trade Commission have a role in reviewing proposed mergers and acquisitions for antitrust activity. In the proposed merger of Lockheed and Martin Marietta, for example, the FTC saw potential anticompetitive effects from the vertical integration in the production of navigation devices and military aircraft and, as a result, the companies agreed to restrictions on the merger with the intent of maintaining competition.

determines that a particular issue may be indicative of a broader problem. DOD officials stated that there were differences between the level and type of analysis we used to depict the data trends and the level and type of information they readily have at hand to manage and evaluate the agency's programs, which hampered their ability to provide a complete and timely review.

The scope of the work we report here is consistent with the terms of the congressional request. Our ability to present the data trends was greatly challenged by the fact that neither DOD nor other executive agencies maintain in a single office or location the information required to address the issues raised by the congressional request. It was necessary for us to obtain data and information from multiple executive agencies and to adopt methodologies based on existing or commonly used practices of executive agency offices and other knowledgeable groups so that we could furnish and present the data. DOD officials did not disagree with the data sources we used. However, where they identified additional data sources relevant to the issues discussed in the report, or had questions that we could resolve concerning the information presented, appropriate changes were incorporated in the text.

DOD officials indicated that their office of Program Analysis and Evaluation compiled reports that would have been useful in determining the disbursement of procurement dollars across industry, although we did not use them. We determined that the data referred to were produced under the Defense Economic Impact Modeling System. During our earlier data collection work, we determined that data from this source were insufficient in scope relative to other survey-based data collected by DOD's Washington Headquarter's Services on DOD procurement outlays.

DOD noted that the pre- and post-CICA DD350 data we report are based on different measures that DOD collected about the use of competitive procedures in DOD procurement contracting. DOD's pre-CICA data we present (1977-85) are data DOD collected, consistent with the reporting requirements and data elements relevant to track competitive contracting procedures within the period (see appendix III, table III.1). Similarly, DOD's available post-CICA data (1986-94) are those consistent with and relevant to track DOD's results pertaining to the current laws and regulations governing competitive procurement procedures (see table III.1). We believe it is relevant and informative to present the data elements that are consistent with and representative of the laws and reporting requirements

to track competition that were in place in the pre-CICA time period and in the post-CICA time period.

Major contributors to this report are listed in appendix V. If you have any questions concerning this report or need additional information, please call me at (202) 512-3092.

A handwritten signature in black ink, appearing to read 'Kwai-Cheung Chan', written in a cursive style.

Kwai-Cheung Chan
Director of Program Evaluation in Physical
Systems Areas

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Abbreviations

AIA	Aerospace Industries Association
BLS	Bureau of Labor Statistics
BUR	Bottom Up Review
CAIV	Cost as an independent variable
CBO	Congressional Budget Office
CICA	Competition in Contracting Act
DIB	Defense industrial base
DOD	Department of Defense
DOL	Department of Labor
DSB	Defense Science Board
EELV	Evolved Expendable Launch Vehicle
FASA	Federal Acquisition Streamlining Act
FTC	Federal Trade Commission
FYDP	Future-years defense plan
GPS	Global Positioning System
IPT	Integrated product team
JDAM	Joint direct attack munition
JPATS	Joint Primary Aircraft Training System
OSD	Office of the Secretary of Defense
PA&E	Office of Program Analysis and Evaluation
RDT&E	Research, development, test, and evaluation
TASC	The Analytic Sciences Corporation
TOA	Total obligational authority
UDLP	United Defense Limited Partnership
WHS	Washington Headquarters Service

The Government, Industry, and Research Contacts We Made

Government Offices

Bureau of Labor Statistics
Employment Projections
Producer Price Indexes
Productivity and Technology

Congressional Budget Office

Congressional Research Service

Department of Commerce
Bureau of the Census
Business and Industrial Analysis
Industrial Resource Administration

Department of Defense
Defense Contract Audit Agency
Defense Contract Management Command
Defense Logistics Agency
Directorate for Information Operation and Reports
Economic Security/Industrial Affairs
Office of the Comptroller
Program Analysis and Evaluation

Defense Contractors

Lockheed-Martin
McDonnell-Douglas
Teledyne Industries

Industry Associations

Aerospace Industries Association
American League for Exports and Security Assistance
Electronics Industry Association
National Association of Manufacturers
National Coalition for Advanced Manufacturing
National Security Industrial Association

Research Groups and Consultants

Booz-Allen & Hamilton
Brookings Institution
Business Executives for National Security
Center for Strategic and Budgetary Assessments¹

¹Formerly known as the Defense Budget Project.

Appendix I
The Government, Industry, and Research
Contacts We Made

Center for Strategic and International Studies
Lehman Brothers
Office of Technology Assessment
Rand Corporation
The Analytic Sciences Corporation

Objectives, Scope, and Methodology

The six key questions and the data we used to answer them are outlined in this appendix. Because our approach was at a macro-level, we used as a general rule the data sources that were the most comprehensive with respect to 1975-95 and the defense industries we examined (aircraft, guided missiles, tanks, shipbuilding, ammunition and ordnance, and electronics and communications equipment).

The Data Analysis

1. What are the trends in DOD's total, procurement, and RDT&E budgets?

We obtained our information on DOD's budgets from DOD's Office of the Comptroller and from DOD's Future Years Defense Plan (FYDP). We present the budget figures in terms of either total obligational authority or outlays, depending upon availability. We used outlays when they could be made available to us in a timely manner. They generally represent cash payments. "Total obligational authority" is a financial term that DOD uses to express the value of the direct defense program for a fiscal year. We transformed all FYDP budget figures from current dollars to constant-year dollars to correct for inflation, using 1995 as the base year. We used DOD deflators in adjusting current-year dollars to constant dollars. Where DOD's Office of the Comptroller sources reported constant dollar (fiscal year 1995) budget figures, we used them.

Budget figures from 1945 to 1995 reflect both peacetime and wartime spending. DOD's Office of the Comptroller could provide the incremental costs (that is, outlays) associated only with the Vietnam War and the Desert Shield and Desert Storm conflicts. The aggregate incremental costs for Vietnam were \$110.6 billion from 1965 to 1976 and include the transition period. The aggregate incremental costs for Desert Shield and Desert Storm were \$1.9 billion from 1990, projected to 1998. That they appear to have been considerably less than those for Vietnam may be partly because the Persian Gulf war was much shorter but also because DOD received for it offset payments from foreign nations that totaled at least \$48.4 billion.

2. What are the trends in the dollar amount of DOD procurement and RDT&E awards to defense manufacturers and subcontractors over time?

We used data from publicly available reports provided by DOD's Directorate for Information, Operations, and Reports, Washington Headquarters Service (WHS), on the dollar amounts of obligations for prime

Appendix II
Objectives, Scope, and Methodology

contract awards and RDT&E awards for each category of major hard goods that DOD purchased. (See table I.1.)

Table II.1: Major Hard Goods Defined by DOD Claimant Program

Program	What it includes
Aircraft	Complete aircraft, including helicopters; Airframe assemblies and spares; Aircraft engines and parts, propellers and hubs, instruments and parts, jet engines and parts used without major modification on guided missiles; Electrical equipment; Accessories including gun turrets, bomb racks and releases, rocket launchers, fuel tanks, droppable aircraft tanks, tires and tubes, control wires, servo and other control mechanisms; Special jigs, dies, and fixtures for fabricating only a specific model; Maintenance tools peculiar to the aircraft and to the engine; Ground handling equipment; Assist takeoff other than droppable units; Mobile training units; Flight simulators
Missiles and space systems	All missile and space system parts and related equipment procured from prime contractors; GFE electronic equipment; Special jigs, dies, and fixtures; Booster cases; Ground handling and launching equipment; Target drones
Ships	Construction of vessels of all types, including assault boats and tracked amphibious vehicles such as LVTs; Ship parts; Ship armor not procured as weapons; Shipborne deperming and degaussing equipment; Aircraft catapults and arresting gear; Floating cranes, floating drydocks, bridge erection boats, and production equipment procured as part of and mounted on floating equipment; Special jigs, dies, and fixtures; Total cost of services, civilian labor, and ship parts used in conversion, repair, overhaul, and modernization
Tanks/automotive: combat vehicles	Tanks and self-propelled gun motor carriages; Other combat vehicles; Combat vehicle parts; Special jigs, dies, and fixtures; Modification, private or government

(continued)

Appendix II
Objectives, Scope, and Methodology

Program	What it includes
Tanks/automotive: noncombat vehicles	Trucks, ambulances, passenger cars, buses, motorcycles, and other motorized vehicles, including wheeled amphibious vehicles; Power-driven decontaminating trucks; Trailers and semi-trailers; Truck tractors; Repair, maintenance, and other special-purpose noncombat vehicles; Bicycles; Prime-contractor-furnished repair, rebuild, production, and service equipment; Special jigs, dies, and fixtures; Other accessories and parts; Modification, private or public
Weapons	Small arms, automatic weapons, mortars, artillery, guns, rocket and grenade launchers, and pyrotechnic projectors, including those mounted on vehicles, ships, and aircraft; Flame throwers; Smoke generators, land; Torpedo tubes; Harpoon protection nets and depth-charge protectors; Wholly optical, electrical, or mechanical fire control equipment, including binoculars, bomb sights, other optical equipment, stop watches, and fire control mounts; Nonelectronic portions of electronic fire control equipment; Special jigs, dies, and fixtures; Deperming and degaussing equipment
Ammunition	Rockets, bombs, mines, grenades, torpedoes, depth charges, and other ammunition and demolition material and pyrotechnics; ATO units (droppable only) and fuel; Rocket and guided-missile fuel; Machine-gun links; Ammunition parts; Chemicals used in bombs, flame throwers, smoke generators, and ammunition; Special jigs, dies, and fixtures

(continued)

Appendix II
Objectives, Scope, and Methodology

Program	What it includes
Electronics and communications equipment	Electromagnetic radiating and nonradiating equipment except that which radiates in the visible spectrum, including radio equipment used for telegraph, telephone, teletype, facsimile, television, and IFF signals; Radar equipment, Radiac, and Infrared; Electronic and electro-mechanical computers; Radiation aids to aircraft control and navigation, including control of guided missiles, fire bombing, armament, and related electro-mechanical types; Radiation countermeasures; Meteorological and sonar equipment; Equipment for magnetic amplifiers, detecting noise and interference, and transmitting and receiving intelligence and ancillary equipment such as antennas and headphones; VT fuzes and guided bombs such as Tarzon and Razon; Special jigs, dies, and fixtures; Electronic fire control equipment

Source: Adapted from Department of Defense, "Commodities and Services Reported on DD Form 350," Procurement Coding Manual (Washington, D.C.: October 1994).

WHS collects information on DOD prime contracts and RDT&E (contract obligations) awards from Department of Defense Form 350 (DD350), "Individual Contract Action Report." The DD350 form is used to collect data on contract statistics within DOD. The data gathered by means of the DD350 are used for reporting the size and distribution of DOD contracting actions; types of contracts used; numbers and amount of contracts placed with categories of contractors such as small, small disadvantaged, and women-owned small business concerns; the extent competed and other essential facts about contract actions. Prior to 1982, the DD350 was completed only on contracts greater than \$10,000. Since 1982, it has been completed for contract actions greater than \$25,000. The data reported on the DD350 may be subject to operational errors in reporting, collecting, or coding the data for entry into database or other electronic formats. We did not assess possible operational errors or other errors in the reporting procedures followed by WHS.

WHS publishes information on awards to subcontractors from the information it receives from participants in DOD's mandated subcontracting program. This information is collected on Standard Form (SF) 295. The 1978 Amendments to the Small Business Investment Act of 1958 (15 U.S.C. 637(d) (1994)) require business firms that have received a contract in excess of \$500,000, or a contract in excess of \$1 million for

construction, to establish a small business and small-disadvantaged business subcontracting program. The nature of DOD's reporting procedures makes it possible to determine aggregate amounts of awards to subcontractors but not what the awards are made for. These data are not classified by procurement program or weapon system in published sources that aggregate the data. Because DOD subcontractor awards are given to large and small businesses, this information cannot be used to make generalizations about a given "tier" of the defense industry. In addition, as stated above, we did not assess operational errors or other possible errors in the data collection and reporting procedures followed by WHS.

3. What are the trends in indicators of employment, productivity, and competition over time?

In developing methods to address these issues, we interviewed and consulted with knowledgeable experts in the defense industry from the private and federal sectors as well as defense contractors on trends in employment, productivity, and competition. Given the scope of our work, the most comprehensive employment data were available from the Annual Survey of Manufacturers series published by the Bureau of the Census. The macro-level quantitative data we used were indicators of productivity and data that are relevant to the evaluation of competition. For productivity, they included the value of production output in defense-concentrated industries from DOL's Bureau of Labor Statistics (BLS). From DOD offices and AIA records, we obtained limited information on units produced for some defense sectors. For competition, it included dollars spent on procurement contracts awarded using competitive and other than competitive procedures identified on the DD350 form and retrieved from DOD's DD350 database. We describe these measures in detail.

The employment and productivity data were defined according to separate defense-concentrated industry groups—a cluster of one or more manufacturing industries identified by a four-digit Standard Industrial Classification code.¹ DOD, Commerce, and DOL, as well as private research firms that study trends in defense industry, refer to them as "defense-dependent" or "dominant" industries because a large proportion of their output is purchased for defense purposes. For example, in 1985, shipbuilding, ammunition (except small arms ammunition), ordnance (not elsewhere classified), and aircraft and missile engines industries produced

¹Excluding data from AIA and DOD's Office of Program Analysis and Evaluation (PA&E).

75 percent or more of their output for defense. Nondefense related output produced by these industries may be purchased by commercial companies, other U.S. government offices, or international companies. When we conducted our work for this report, aircraft, guided missiles, ammunition and ordnance, tanks, electronics and communications equipment, and shipbuilding and repairing were the principal defense-concentrated industry groups identified by defense industry researchers in federal agencies and private research organizations.

The value of production output in defense-concentrated industries is measured by productivity indexes that we obtained from the Bureau of Labor Statistics (BLS) Office of Productivity and Technology. The index BLS provided—the constant-dollar value of production output per hour—is derived by dividing an index of the value of production (shipments, revenue, or sales) in each of the manufacturing industries by an index of aggregate employee hours. This is a standard measure of productivity used in BLS' program of productivity measurement and technology studies. The limited data on procurement or production rates we used came from reports prepared by AIA and DOD's Office of Economic Security and PA&E.

Extant data from DOD's DD350 database gave us information about the competitive nature of procurement contracts awarded for major weapon systems or components. We retrieved and analyzed data from the blocks of information on the DD350 that specifically indicated the extent of competitive procedures used to award contracts in pre- and post-CICA time periods (see table III.1). These data provide an indication of the processes DOD uses (that is, competitive or noncompetitive) in awarding weapon procurement contracts to defense contractors. We did not determine the degree to which these processes are reliable indicators of competition or noncompetition within the defense industry.

4. How are employment productivity and competition related to indicators of defense spending?

The available quantitative data permitted us to provide a limited response to this question. We developed methods that made use of existing information and we supplemented the quantitative data with information we collected from the experts we spoke to and our review of existing literature.

Our quantitative method for examining the relationship between indicators of defense spending and productivity over time involved

generating correlation coefficients between available measures of defense budgets and the BLS productivity indexes.² For example, we correlated the productivity indexes for the tank industry with DOD's budgets for tank procurement for the years available. We used the same approach in examining the relationship between indicators of defense spending and defense-related employment: correlating the available measures of total employment in the defense-concentrated industrial sectors from Census with the total dollar amount of contracts awarded for procuring major hard goods (see table I.1 for the categories of major hard goods) over the period of our study (data were available only for the period 1975-91). We also conducted the analysis using DOD budgets (FYDP, TOA) as an indicator of DOD spending linked to defense-concentrated industrial sectors.

An important issue in selecting appropriate measures of employment in defense-concentrated industrial sectors and an indicator of spending (that is, outlays) linked to those sectors was selecting measures that were independent from one another. For example, in the course of our work we discovered that data on defense-related industry employment reported in DOD's series of reports on national defense budget estimates (also known as the "green book") is not independent from data on procurement outlays also reported in these series. The lack of independence between the two data sets calls into question the validity, or accuracy, of any correlational analysis done using this data and, of course, any resultant correlation coefficient observed.

Given available data, we were unable to develop a comparable quantitative method for addressing the relationship between competition and levels of defense spending over time. Our interviews on these relationships with defense contractors and defense industry experts supplemented the quantitative information on defense industry competition that we were able to obtain.

5. What are the trends in the financial indicators of major defense contractors over time?

Considerable variability characterizes the methods used to determine appropriate financial indicators or financial viability. For example, defense industry analysts at the Center for Strategic and Budgetary Assessments indicate that there are at least 12 ways to conduct financial assessments of

²Correlational analysis provides one indication of how two or more variables are related. A correlation coefficient provides an indication of the strength and direction of a linear relationship. The procedures used to generate a correlation coefficient make it impossible to determine whether changes in one variable cause changes in another variable. More analysis is required to reach such conclusions.

the defense industrial base. We interviewed Wall Street business analysts, reviewed the procedures DOD recommends for conducting financial assessments, and spoke with defense contractors and industry experts. They agreed that financial viability is best assessed with multiple indicators. We used sales and cash flow because they are conventional indicators and because information on them could easily be retrieved from Standard and Poor's COMPUSTAT database.³ Other measures or variables from company income statements that can be used to analyze financial viability include gross income, operating income, and net income.

Our sample of defense companies included those among the top 100 that received the largest dollar amount of DOD prime contract awards in 1994. So that most of the defense industries would be represented, we included companies that have business units in one or more of the defense industry segments.

6. What is the relationship between indicators of defense spending and indicators of the financial status of major defense contractors over time?

Our focus was predominantly on trends in the financial status of companies in the last several years of the recent defense spending reduction. We supplemented the information on corporate sales and cash flow from Standard and Poor's database with reviews of DOD's assessments of the financial state of major defense companies since the end of the Cold War. We also incorporated into our review the perspectives of Wall Street experts and defense contractors.

The Data Limitations

When we collected our information, data for all years and industries in our study were not available; our depiction of trends in some years and industries may therefore be incomplete. Existing data sources do not collect or specifically identify comprehensive data on DOD's subcontractors or large defense contractors. Therefore, unless we have indicated otherwise, we could not define the data by the size of a business or its position in the defense industry "hierarchy." Unless noted otherwise, potential error introduced by estimation or modeling procedures or in the data collection or reporting procedures used by the offices that provided original data used in our work may be reflected in findings generated with those data.

³DOD told us that it prefers operating income (after depreciation) as a performance measure relative to cash flow.

Data on Employment, Productivity, and Competition

Employment

In this section, we present the results of the correlational analysis conducted on the available measures of employment in defense-concentrated industrial sectors obtained from Census and defense spending linked to those sectors obtained from DOD's records of contract awards for major hard goods procurement.

Correlational analysis provides one indication of how two or more variables are related. The possible range of a correlation is -1 to $+1$. A correlation of zero means that two numbers (variables) are not correlated. A negative correlation means that large values of one number are associated with small values of another number. A number correlated with itself returns a correlation of 1. A correlation coefficient provides an indication of the strength and direction of a linear relationship. In this case, the observed correlation coefficient allows us to determine the strength of the relationship between indicators of defense industry employment and defense spending over a specific time period. The procedures used to generate a correlation coefficient, by themselves, make it impossible to determine whether changes in one variable cause changes in another variable. More analysis is required to reach such conclusions.

Declining defense-related employment since the post-Cold War spending reduction began has been described.¹ We statistically compared total employment in the defense-concentrated industrial sectors where data were available (aircraft, ammunition and ordnance, shipbuilding, electronics and communications equipment, and tank manufacturing) to an indicator of defense spending linked to those sectors (total amount of contract awards for major hard goods procurement) for the years data were available (1975-91). The observed correlation, $r = .27$, indicates that the strength of the relationship is not large and is less than values considered moderate in size.²

In addition to the limits of correlational analysis stated above, other factors limit the ability to generate definite determinations or generalizations about the relationship between defense spending and defense industry employment. At minimum, they include the absence of fully comprehensive data on DOD spending specifically attributed to the

¹See U.S. General Accounting Office, Defense Sector: Trends in Employment and Spending, GAO/NSIAD-95-105BR (Washington, D.C.: April 1995).

²We also conducted analysis using defense budgets (FYDP, TOA) as a second indicator. The resultant correlation was slightly higher ($r = .36$).

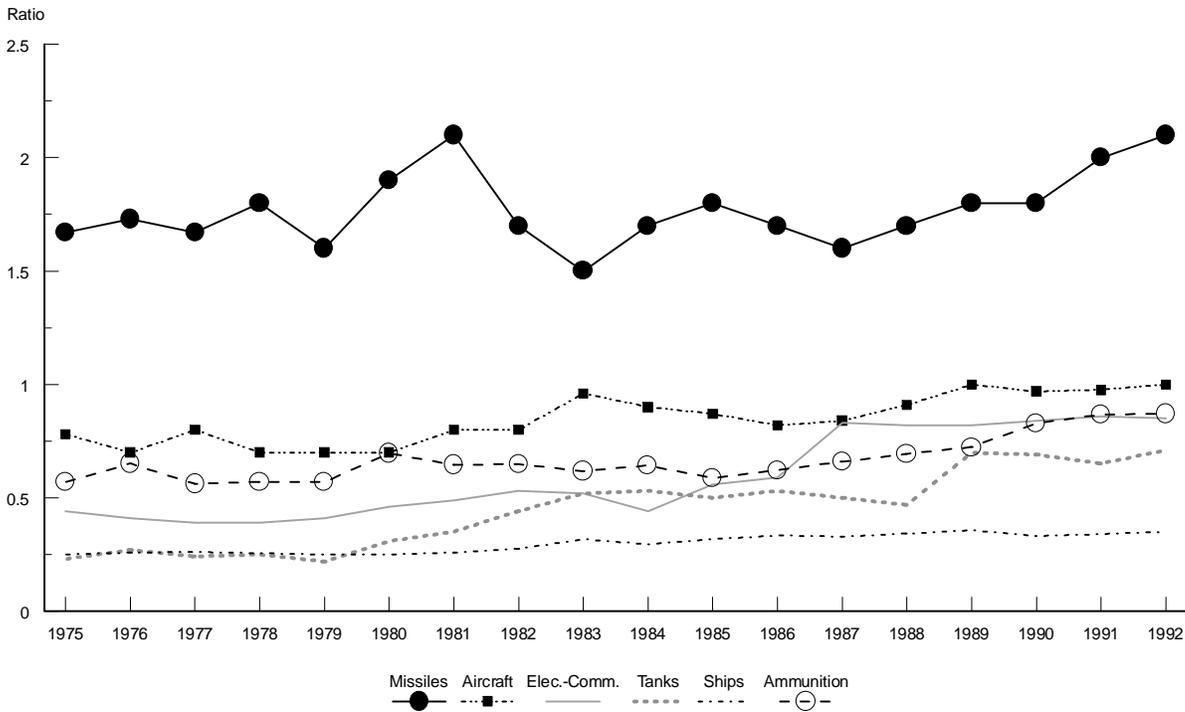
“defense industrial base” and the use of estimation or modeling procedures to generate defense industry employment data.

Census documents provided additional data about employment trends in defense-concentrated industrial sectors from their annual surveys of manufacturers, which include numbers of all employees as well as production workers in defense-concentrated industries.³ From these data, we calculated the ratio of nonproduction employees to production workers. Figure III.1 shows the trends in these ratios for 1975-92.

³Commerce defines “all employees” as “all full-time and part-time employees on the payrolls of operating manufacturing establishments.” Production workers are “workers (up through the line-supervisor level) engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing, warehousing, shipping (but not delivering), maintenance, repair, janitorial and guard services, product development, auxiliary production for plant’s own use (power plant, etc.), recordkeeping, and other services closely associated with these production operations” at the establishments covered by its survey. The available Census reports did not separately report figures for nonproduction workers. To arrive at a figure for nonproduction workers, we subtracted the number of production workers from the number of all employees.

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Figure III.1: Ratio of Nonproduction to Production Workers in Defense-Concentrated Industries, 1975-92^a



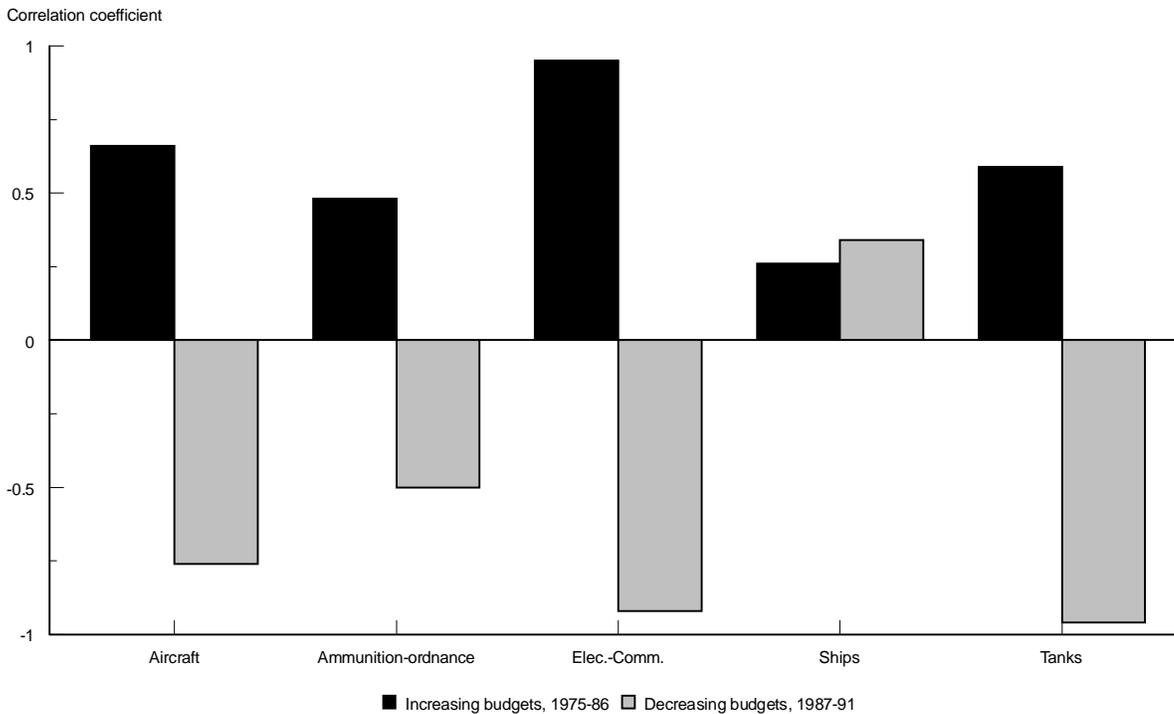
^aRatios greater than 1 indicate more nonproduction workers relative to production workers. As ratios approach 1, the number of nonproduction and production workers is more equal.

Production workers have consistently been fewer than nonproduction workers in the guided missile industry: in all years, the ratios of nonproduction to production employees are consistently greater than 1. Moreover, ratios of production to nonproduction workers in the guided missile industry are considerably higher than in all other industries. In more recent years, the ratios have increased in the missile, aircraft, tank, and ammunition manufacturing industries, indicating that the split between production and nonproduction workers is widening. In 1993, TASC reported that the defense sector employed a high proportion of engineers and technicians and relatively few production workers. Officials whom we interviewed at Lockheed-Martin also indicated that there are no major defense companies in the manufacturing business anymore.

Productivity

To provide an indication of the relationship between trends in BLS' productivity indexes (value of production) and trends in DOD's budgets, we compared them statistically through a correlational analysis. Figure III.2 shows the correlation between BLS indexes of productivity and trends in DOD's procurement budgets for five industries. During 1975-86, budgets increased along with the value of production (the correlation coefficients are all positive). For more recent years for which data were available (1987-91), the value of production continued to increase but defense budgets did not (the correlation coefficients are all negative).⁴

Figure III.2: The Relationship Between DOD Budgets and Productivity in Defense-Concentrated Industries, 1975-91^a



^aThe productivity index is based on all employees.

⁴The data for shipbuilding are an exception.

The shipbuilding and repairing industry data differ from those of the other industry groups. The strength of the relationship between budgets and productivity is weaker, and the direction of the relationship in recent years is positive. There could be any number of reasons for this, ranging from disparities in the data to unique aspects of shipbuilding. However, the nature of the data we were provided and the statistical technique we applied do not permit us to specify explanations. We simply note that there is some apparent difference.

Competition

There are multiple ways of defining, conceptualizing, and measuring competition. The data that were available on competition permit a limited discussion and presentation of information about this issue. We were able to develop methods that allow us to address the extent of the use of competitive and noncompetitive procedures used in major systems procurement from data reported on the DD350. From the available information, we determined the total dollar amounts associated with these processes for procurement of the major hard goods listed in table I.1 for the time period and scope covered in our work.

Among other data elements, the DD350 provides data on the processes (competitive or noncompetitive) that DOD has used in awarding procurement contracts for weapons. Because DOD is the primary, and in some cases only, buyer of weapons produced by U.S. defense contractors, the processes and patterns it uses in purchasing goods and services are relevant to understanding the potential effect on business practices of defense firms and the broader defense industrial base. However, because competition is a multifaceted concept, and we did not determine the extent to which the DD350 measures of competition are reliable or valid, this information should be considered an indicator of DOD's use of competitive or other than competitive processes.

As reported on the DD350, DOD's pre- and post-CICA definitions, used as guides in our work, are shown in table III.1.⁵ Pre- and post-CICA definitions and categories differ because of the 1985 enactment of CICA.⁶

⁵The data elements described in table III.1 were the primary retrieval criteria used to extract data from the DD350 database. Secondary criteria included the DOD claimant program numbers for the categories of major hard goods listed in table I.1 (that is, aircraft; missile and space systems; ships; tanks/automotive; weapons; ammunition; and electronics and communication equipment).

⁶In 1985, the Competition in Contracting Act (CICA) was passed, producing changes in the way goods and services are procured in DOD and other federal agencies. Fiscal year 1986 is the first full year for which the DD350 database contains information on the new categories of information required by CICA provisions.

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**Table III.1: Pre- and Post-CICA
Measures from the DD350 Used**

Period	Procedure		Definition
Pre-CICA (data available, 1977-85)	Extent of competition in negotiation	Competitive ^a	Design technical competition; Price competition
		Noncompetitive ^b	Catalog or market price; Follow-on to design and technical competition; Follow-on to price competition; Other
Post-CICA (data available, 1986-94)	Solicitation procedures	Full-and-open competition ^c	Competitive proposal; Sealed bid; Combination
		Other-than-full-and- open competition ^d	Authorized by statute; Authorized resale; Essential research and development capability; Follow-on contract; International agreement; Mobilization; National security; Patent and data rights; Public interest; Standardization; Unique source; Only one source, other; Unsolicited research proposal; Urgency; Utilities

^aData for this category were extracted from data element 18, "Extent of Competition in Negotiation," subitems 1 and 2 for competitive, on a pre-1983 version of the DD350. This data element is the same as data element C5, "Extent of Competition in Negotiation," on the October 1983 version of the DD350.

^bData for this category were extracted from data element 18, "Extent of Competition in Negotiation," subitems 3 through 6 for noncompetitive, on a pre-1983 version of the DD350. This data element is same as data element C5, "Extent of Competition in Negotiation," on the October 1983 version of the DD350.

^cData for this category were extracted from data element C9, "Solicitation Procedures," subitems A-C for full and open competition, on the May 1985 version of the DD350.

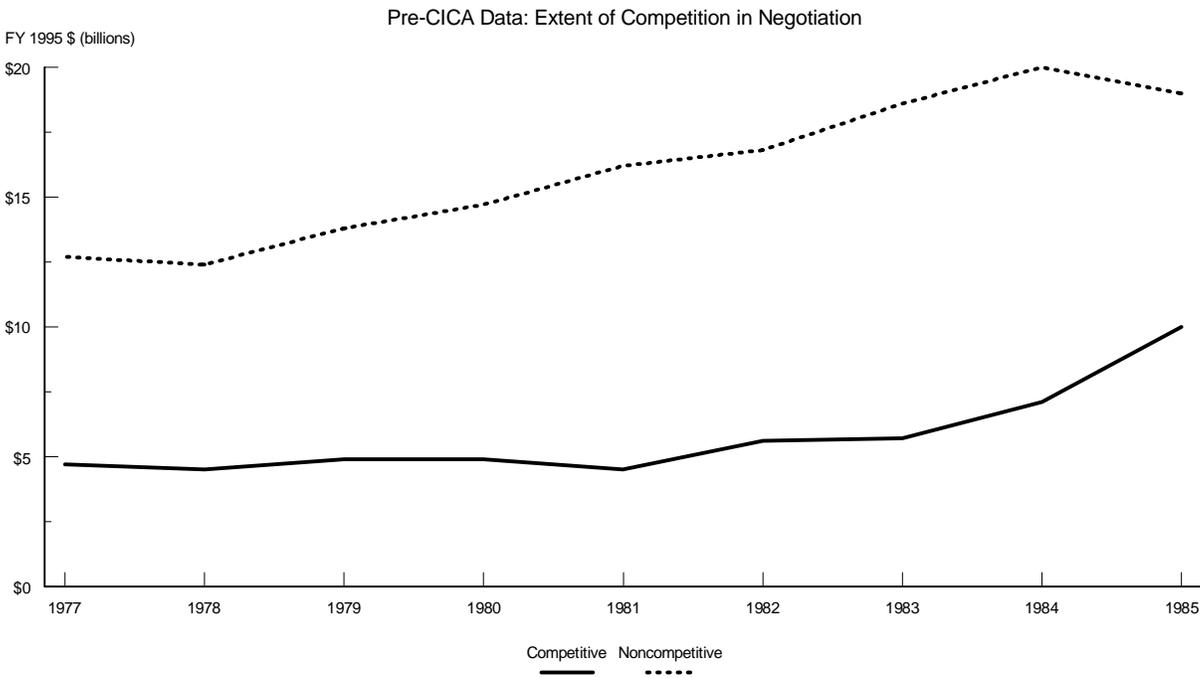
^dData for this category were extracted from data element C9, "Solicitation Procedures," subitem N, other than full and open competition, on the May 1985 version of the DD350.

The DOD data show that, on average, in 1977-94, more money was associated with major systems procurements that were awarded using DOD's other than competitive procedures compared to competitive ones (see figures 5 and 6). In our analysis, we found not only greater average

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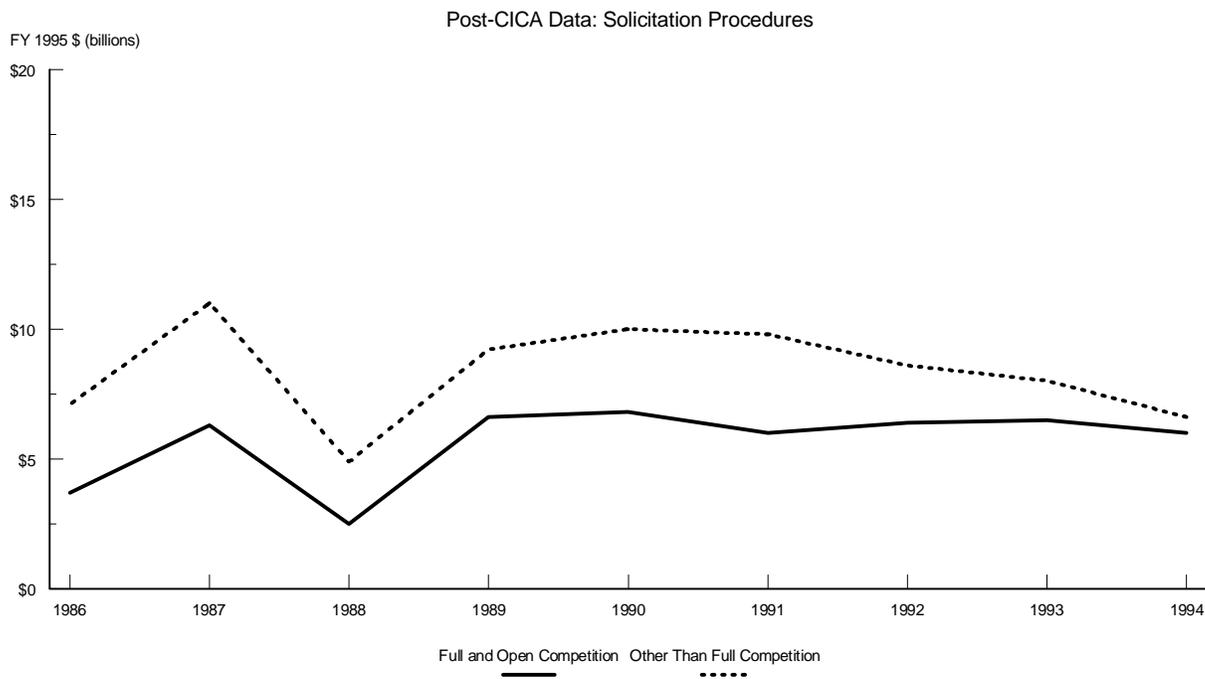
dollar amounts associated with other than competitive procurement procedures but also more money spent on other than competitive contracts for electronics and communications equipment, ammunition, weapons, and aircraft in every year of the past 18. With exceptions in a few years, we found the same trend for procurement contracts for missiles, tanks, and ships. These trends are detailed in figures III.3 through III.16 for each procurement program and separately for pre- and post-CICA time periods.

Figure III.3: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Electronics and Communications Equipment, 1977-85



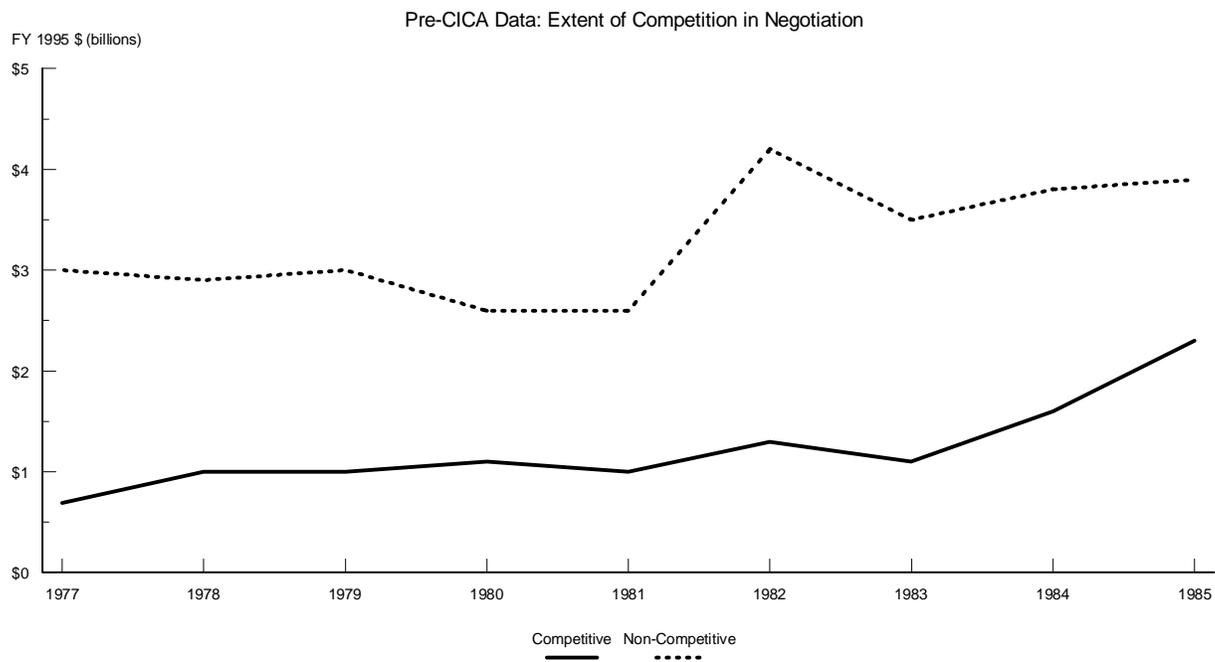
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Figure III.4: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Electronics and Communications Equipment, 1986-94



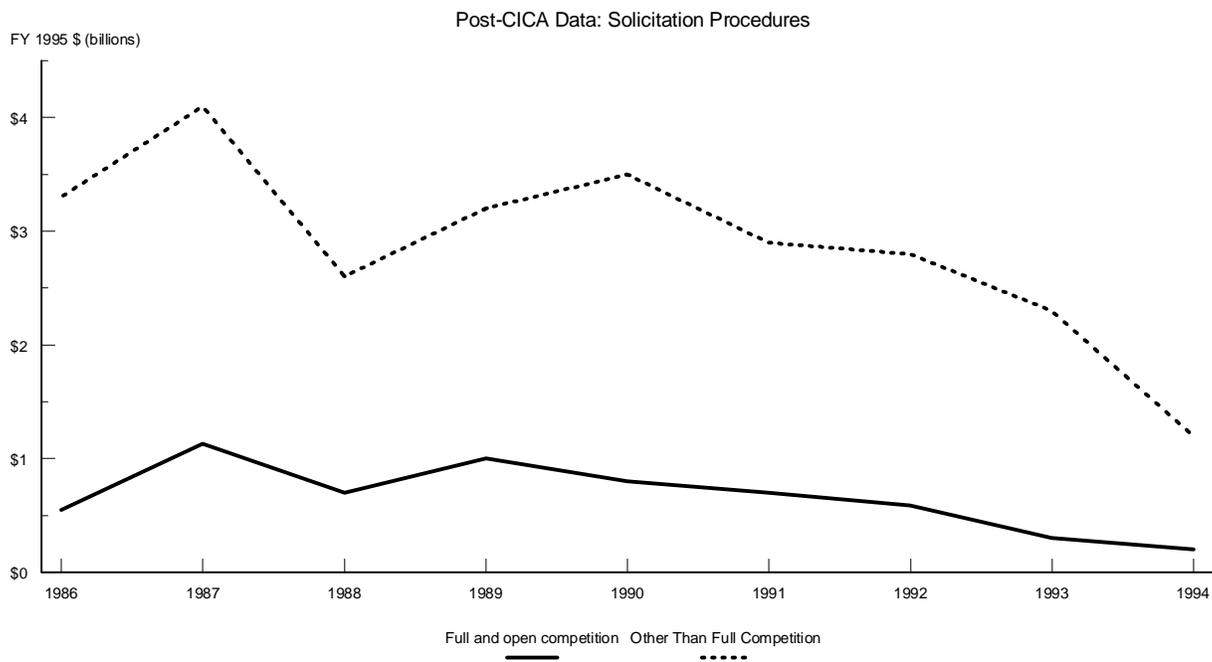
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Figure III.5: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Ammunition, 1977-85



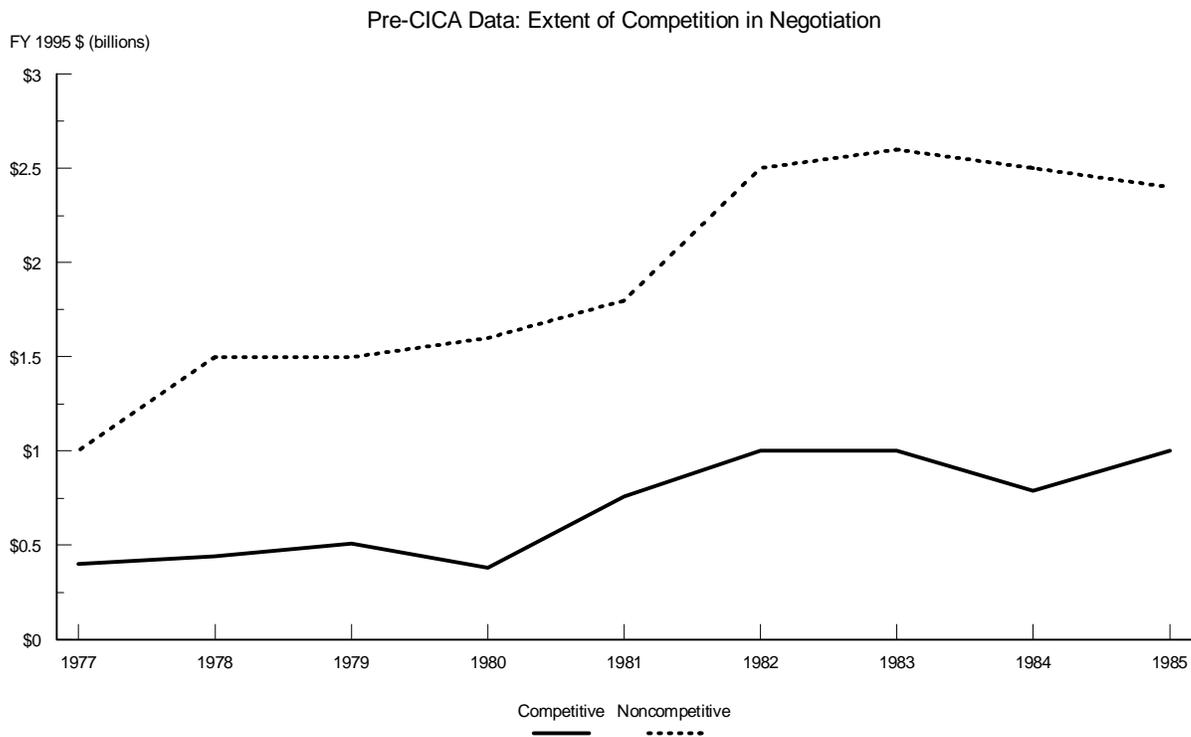
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Figure III.6: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Ammunition, 1986-94



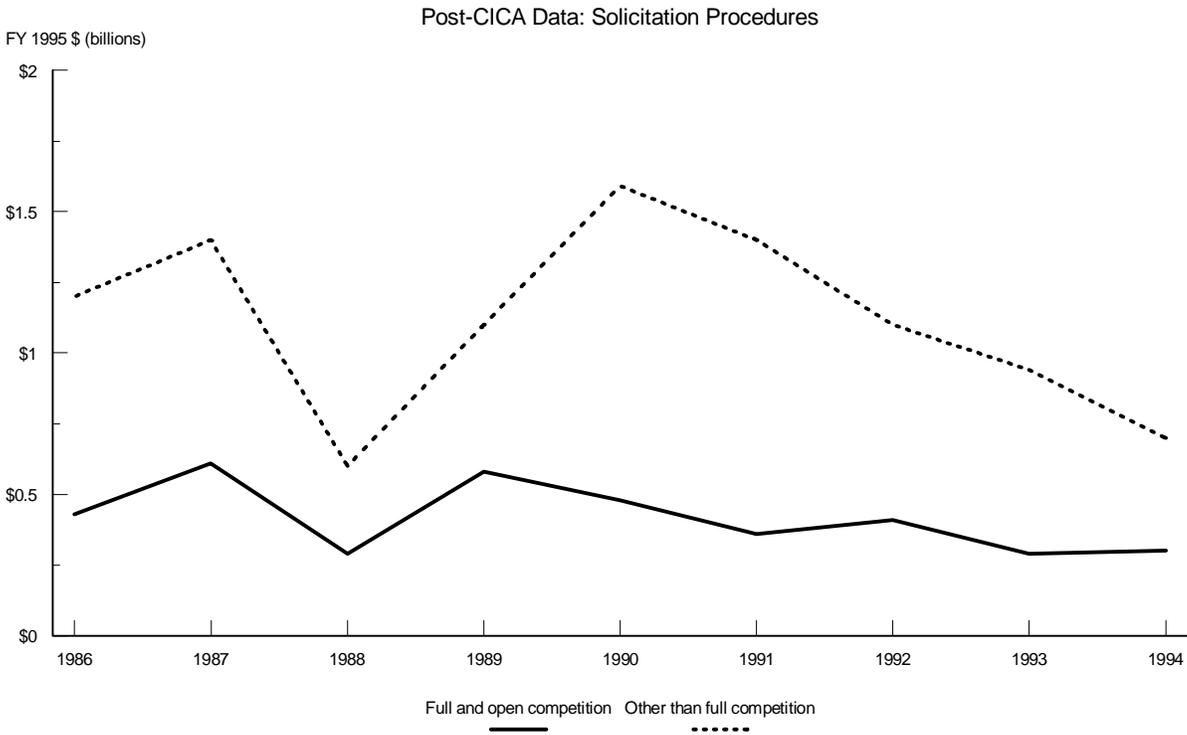
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Figure III.7: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Weapons, 1977-85



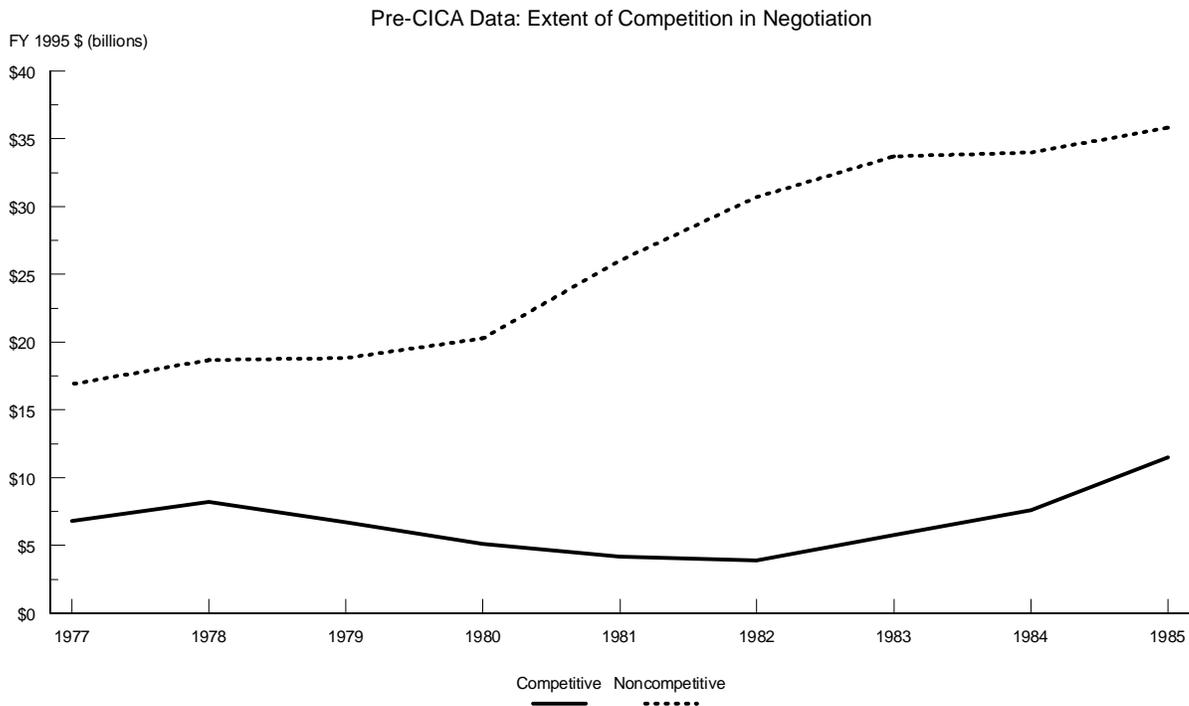
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Figure III.8: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Weapons, 1986-94



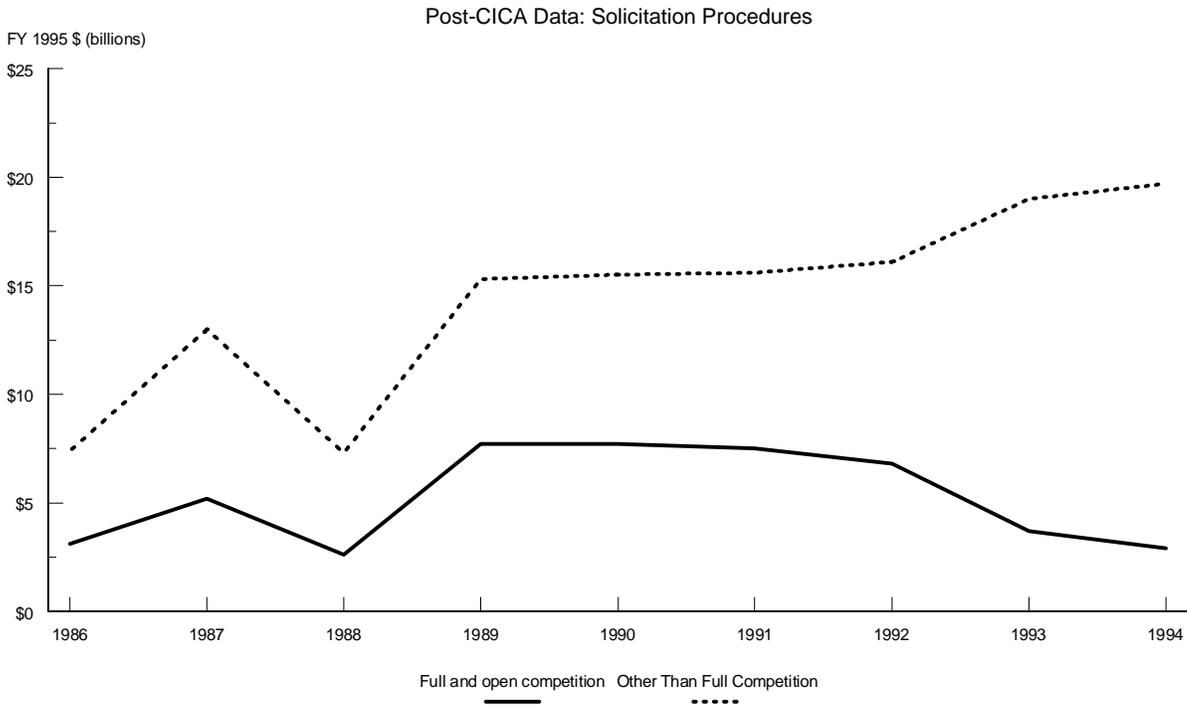
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Figure III.9: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Aircraft, 1977-85



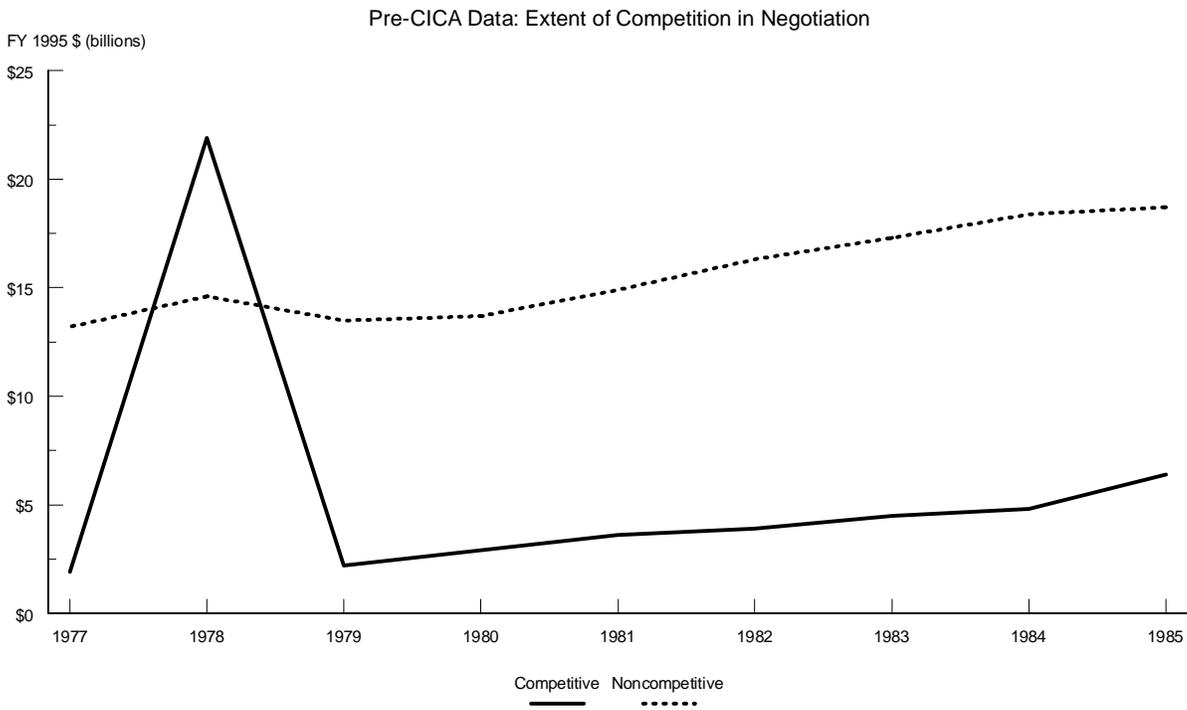
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Figure III.10: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Aircraft, 1986-94



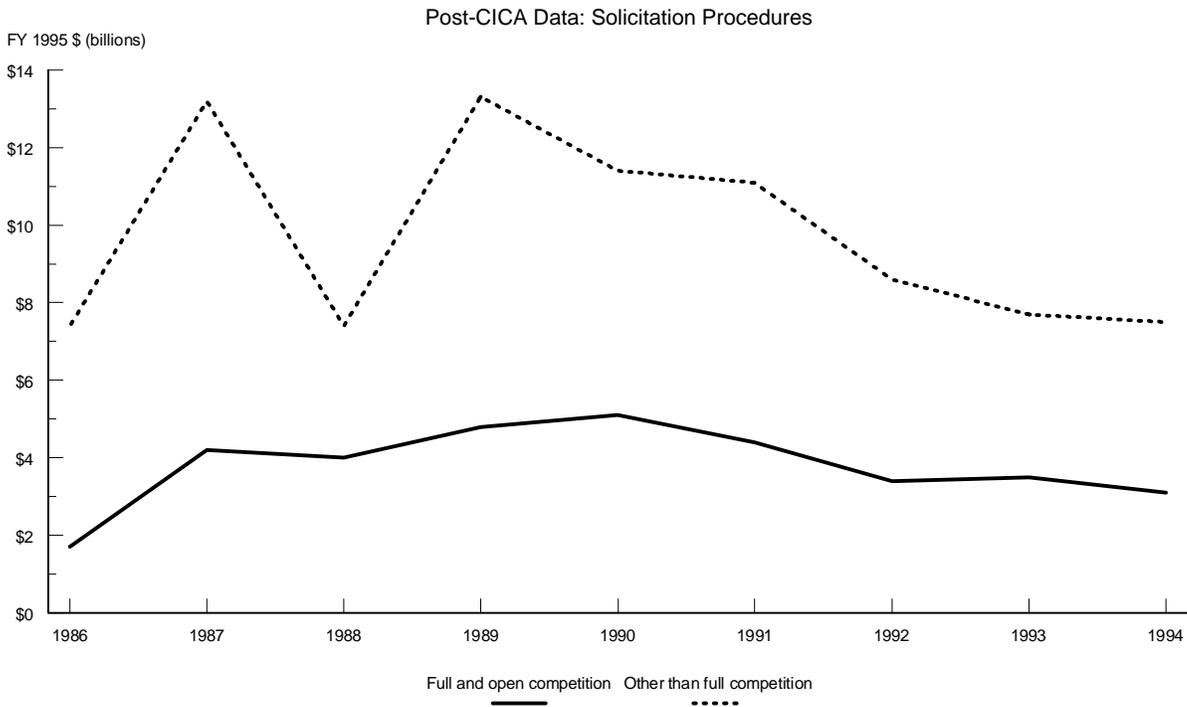
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Figure III.11: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Missiles, 1977-85



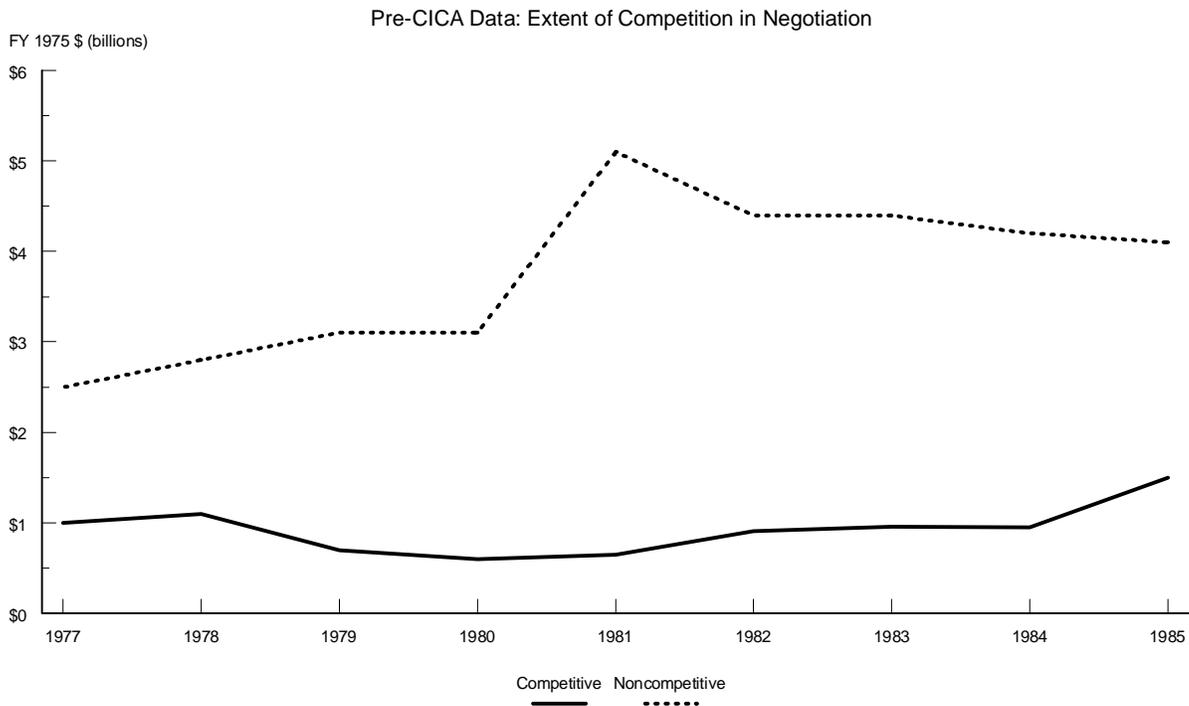
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Figure III.12: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Missiles, 1986-94



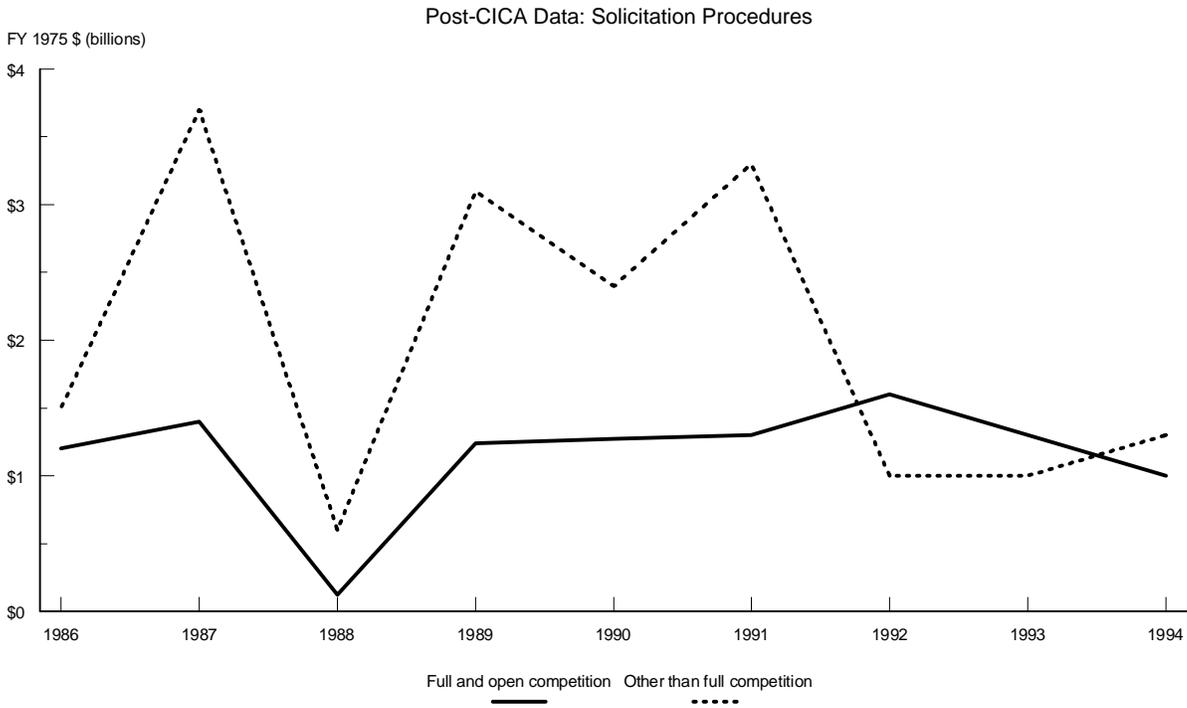
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Figure III.13: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Tanks, 1977-85



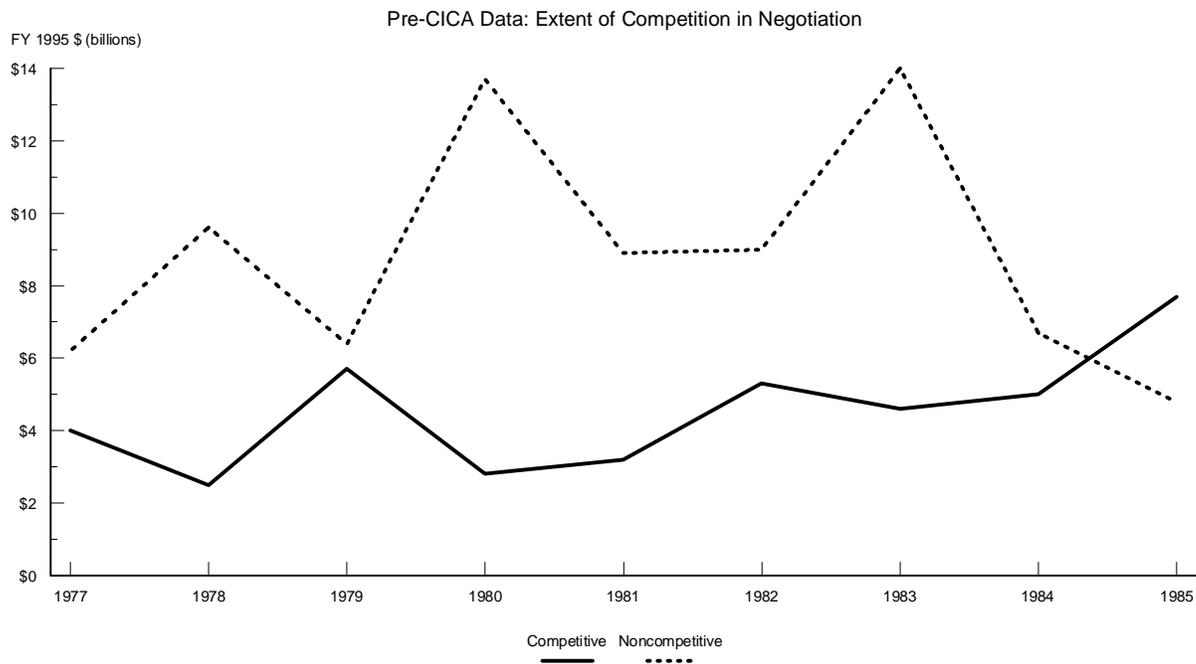
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Figure III.14: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Tanks, 1986-94



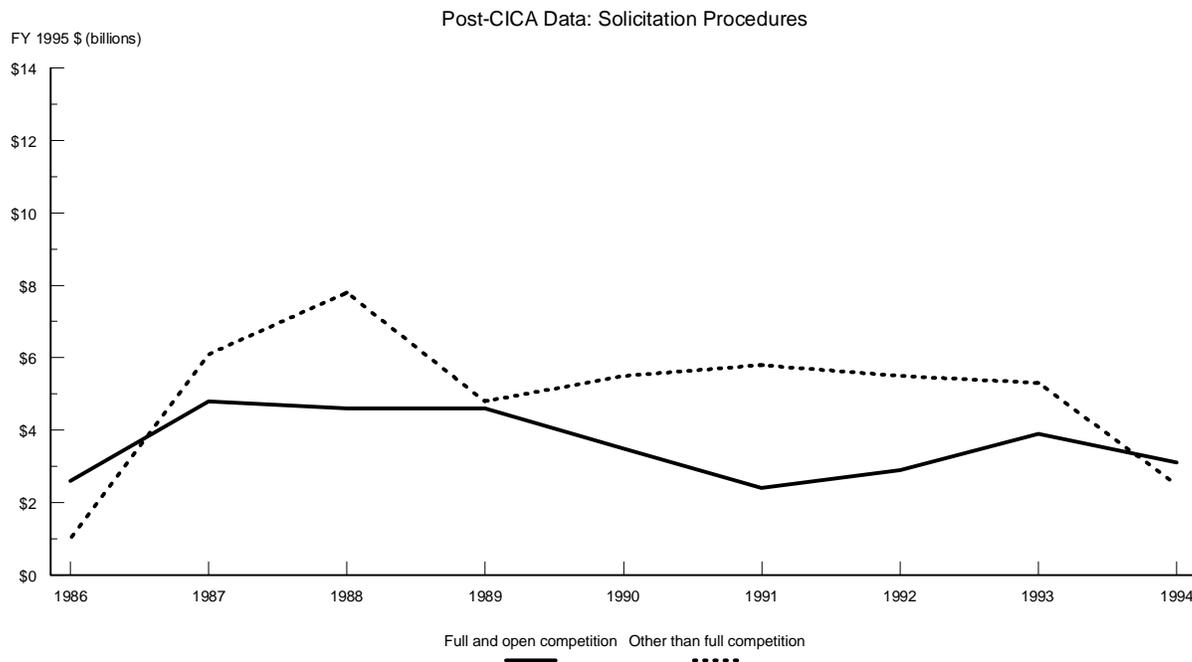
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Figure III.15: Dollars Awarded Using Competitive and Noncompetitive Procurement Methods for Ships, 1977-85



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Figure III.16: Dollars Awarded Using Full and Open Competition and Other Than Full and Open Competition for Ships, 1986-94



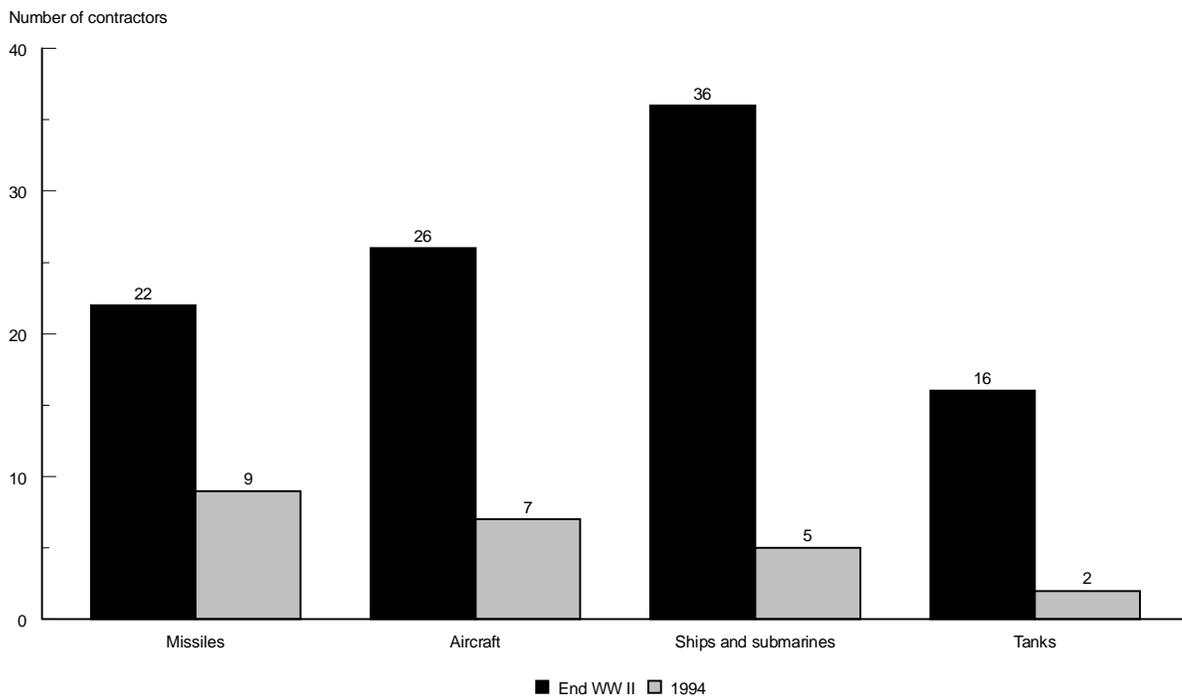
In recent years, the amount of money associated with DOD competitive and other than competitive contracts has declined for most procurement programs. At the same time, the gap between money awarded on competitive and other than competitive contracts is getting smaller. The only exception to this is contract dollars DOD spent on aircraft procurement, as shown in figure III.10. The split between dollars spent for competitive and other than competitive aircraft procurement has actually increased in recent years, such that increasingly greater amounts of money are associated with aircraft procurement contracts that DOD awards with procedures it defines as other than competitive.

In addition to data trends on the processes DOD uses to award procurement contracts, another indicator related to understanding competition in defense industry is the number of businesses available to enter into competition. In the post-Cold War, there has been a decline in the number of independent defense contracting businesses, either through business combinations or exiting the defense business. From a broader

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historical view, figure III.17 shows that there are clearly fewer contractors today than 50 years ago, at the end of World War II.

Figure III.17: Number of Defense Contractors From the End of World War II to 1994^a



^aThe data for missile contractors are from about 1960 to the present. All information obtained from Lockheed Martin.

U.S. Defense Companies After the Cold War

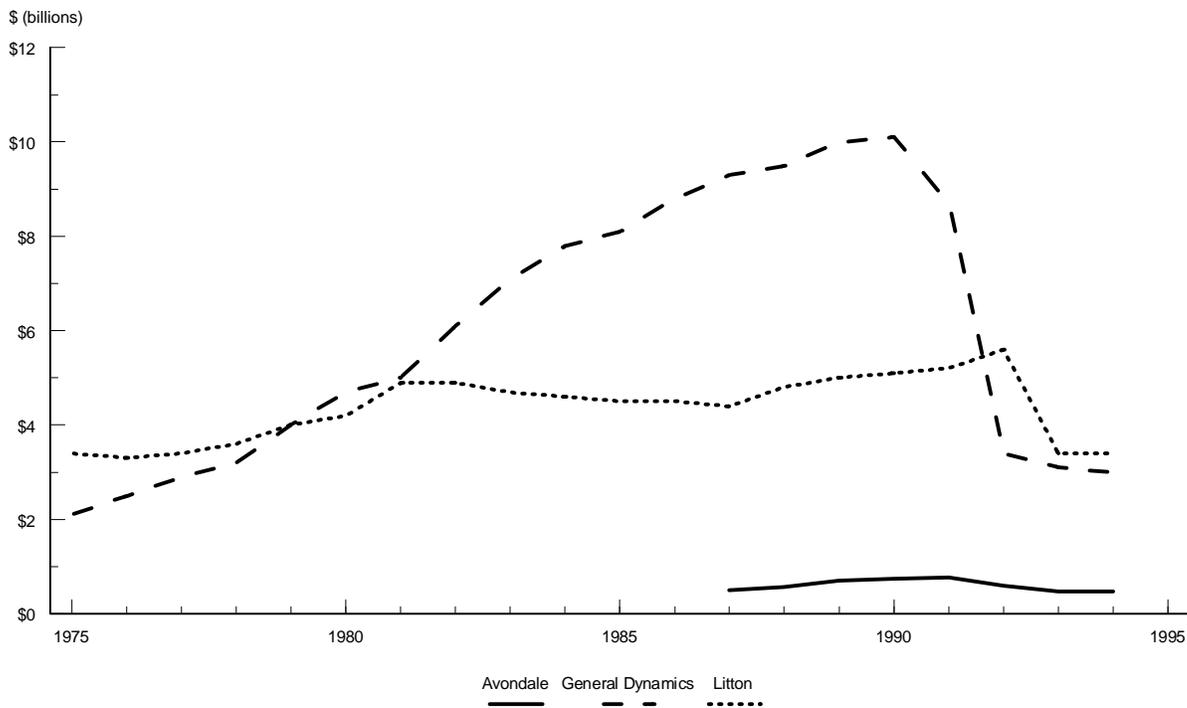
There is some consensus that the top defense firms have come through the post-Cold War funding reduction well and that they remain profitable. The Wall Street analysts whom we spoke with indicated that the forecasts for defense companies are not as bad as the companies perceive. Analysts at Lehman Brothers indicated that companies are more pessimistic than necessary about future growth, given DOD's plans to increase defense spending in the outyears. It is important to note, however, that many companies have suffered difficult reorganization and employee loss as they have made the transition to decreased defense spending.

Still, companies have not all been equally affected, and some variability in the financial indicators of the top companies suggests that the period of reduction has been less painful for some companies than for others. We selected financial indicators to examine—sales and cash flow—after our discussions with Wall Street defense business analysts, defense contractors, and experts from the private sector and after reviewing DOD's work in this area. Other measures or variables from company income statements that can be used to analyze financial viability include gross income, operating income, and net income.

The companies that we report data for are companies among the top 100 that received the largest dollar volume of DOD prime contract awards in 1994. Figures IV.1 and IV.2 show multiyear trends for five top defense contractors whose corporate sales and cash flow fell, while figures IV.3 and IV.4 show multiyear trends for four top defense contractors whose corporate sales and cash flow rose or remained stable.

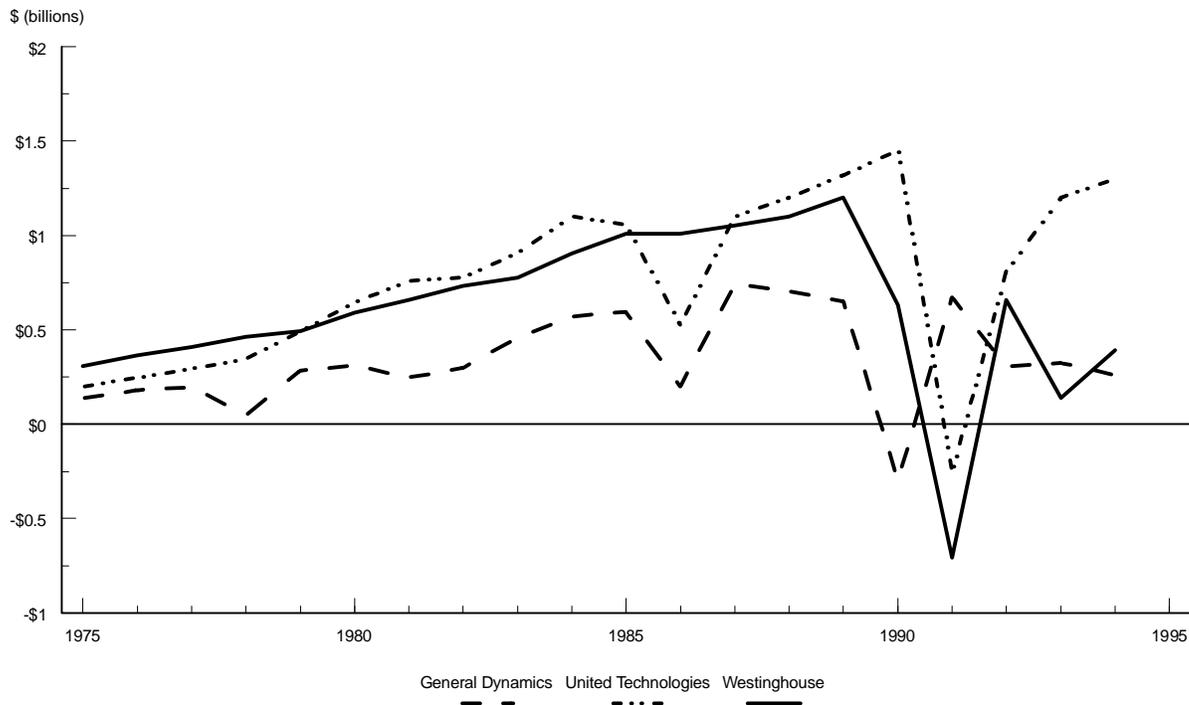
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U.S. Defense Companies After the Cold War

Figure IV.1: Financial Indicators of Three Top Defense Contractors: Falling Corporate Sales, 1975-95



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U.S. Defense Companies After the Cold War

Figure IV.2: Financial Indicators of Three Top Defense Contractors: Falling Cash Flow, 1975-95



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U.S. Defense Companies After the Cold War

Figure IV.3: Financial Indicators of Four Top Defense Contractors: Rising Corporate Sales, 1975-95

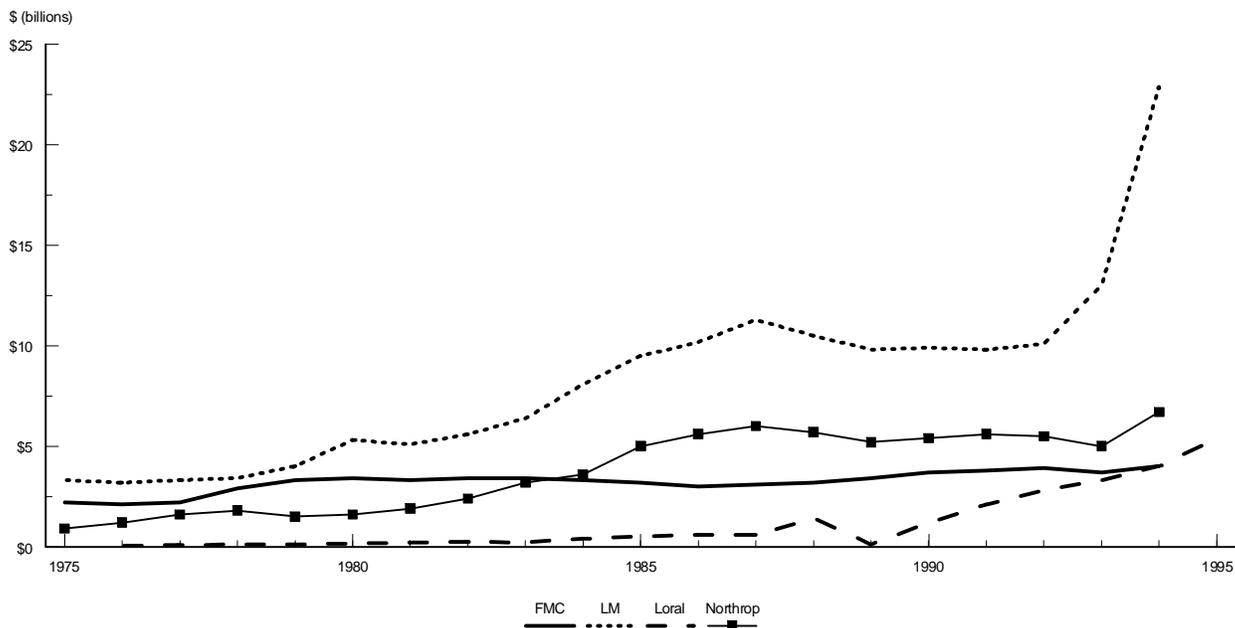
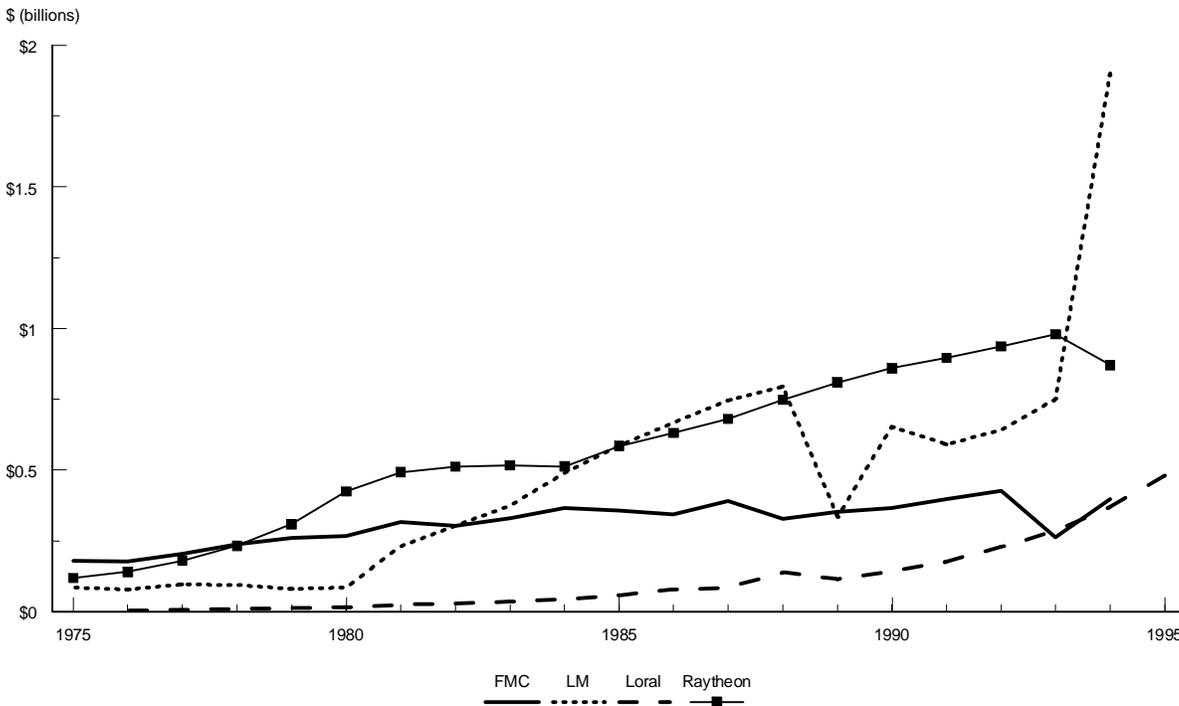


Figure IV.4: Financial Indicators of Four Top Defense Contractors: Rising Cash Flow, 1975-95



The sales and cash flow figures shown are the amounts reported for that year. Sales and cash flow may appear to be better for some companies than for others for many reasons. A detailed assessment of this issue was beyond the scope of our work. However, we can suggest explanations such as how diversified a company is, the range and number of defense segments that some companies have (for example, General Dynamics is involved in shipbuilding and tank manufacturing), transactions associated with business combination or divestiture activity (for example, Lockheed Martin; Northrop-Grumman; General Dynamics; other acquisitions by Raytheon, Loral, FMC), and other profitable business segments companies have with other federal agencies or offices, commercial clients, and foreign companies. Some of the largest changes shown in the figures reflect merger and acquisition activity, such as the growth in sales and cash flow for Lockheed Martin and the declining sales and cash flow for General Dynamics.

Major Contributors to This Report

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Acknowledgments

Other noteworthy contributions to the work were made by Winslow Wheeler, who contributed to the project's early direction, and Robert Copeland, who contributed to the study design.

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