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The Changing Shape of the Defense Industry and Implications for Defense Acquisitions and Policy

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The Changing Shape of the Defense Industry and Implications for Defense Acquisitions and Policy[1]

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Abstract

In the mid-1990s, the US defense industry experienced a dramatic wave of consolidation. This paper seeks to establish the statistical facts of defense industry consolidation, including the ways in which it reshaped the industry in the 1990s; the ways in which it may continue to reshape the industry; and the forces that promote or discourage it. It also seeks to consider the implications of consolidation for defense acquisitions and policy. The paper places the events of the 1990s in the broad context of economic and industrial activity spanning almost five decades: 1958-2006. It draws primarily—and in new ways—from a

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contracting data set known as the DD350 and applies standard economic models and tools. The paper finds that consolidation has had its most pronounced effects at the highest levels of the industry; that the process of consolidation has abated, if not reversed itself, in recent years; and that larger domestic and international economic force have been at least as important as DoD budget decisions and policy in promoting consolidation. The DoD has a significant say in what happens in the defense industry but cannot control it.

Introduction

In the mid-1990s, the US defense industry experienced a dramatic wave of consolidation. This paper seeks to establish the statistical facts of defense industry consolidation, including the ways in which it re-shaped the industry in the 1990s; the ways in which it may continue to re-shape the industry; and the forces that promote or discourage it. It also seeks to consider the implications of consolidation for defense acquisitions and policy. The paper does not isolate the events of the 1990s; rather, it places them in the broad context of economic and industrial activity spanning a period of almost five decades, 1958-2006. It draws primarily—and in new ways—from a contracting data set known colloquially as the DD350 and makes use of standard economic models and tools. Though taking a US perspective, this paper also considers the contributing role of economic globalization.

The issue of defense industry consolidation took on particular importance in the last decade of the 20th century, a period in which the post-Cold War defense budget shrank and US Department of Defense (DoD) suppliers—especially aerospace-defense firms, but also shipbuilding and other defense-related firms—faced the prospect of declining orders, excess capacity, and rising costs. In theory, consolidation could have resulted in a smaller number of leaner and healthier firms, better able to contain or reduce cost through economies of scale and, with deeper financial pockets, better able to bear risk.[2] However, whether the DoD would have benefited from consolidation would have depended, in part, on how the process of consolidation unfolded, how the DoD wrote and executed its contracts, and how much bargaining leverage it maintained.

In 1993, at a dinner now referred to as the "Last Supper," the DoD asserted its support for industry-wide consolidation, possibly codifying the inevitable—not enough business to go around then or anytime soon—but also suggesting that, in its view, the effects of consolidation would be positive.[3] The DoD backed its assertion by taking a more pro-active role in anti-trust policy, (i.e., consulting and advising the lead anti-trust agencies: the US Department of Justice and the Federal Trade Commission), and by reimbursing firms for some consolidation-related

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[2] Consolidation can occur in at least three dimensions: "physical," involving the combination or elimination of physical assets; "managerial," involving the combination or elimination of managerial assets; and "corporate," involving the combination or elimination of corporate entities. Corporate consolidation, which is the main focus of this paper, may or may not be accompanied by physical or managerial consolidation, though some amount of both, especially managerial, is likely. When physical or managerial consolidation occurs, an industry may shed unneeded infrastructure and overhead and reap economies of scales; corporate consolidation may yield financially stronger firms but less competition.

[3] At least implicitly, DoD's position suggested that some amount of physical and managerial consolidation would accompany corporate consolidation and that the gains from economies of scale and risk-bearing capabilities would dominate any ill-effects of a reduction in competition. For a recent look back at the dinner event, see Augustine (2006).

costs. The DoD is still involved in the anti-trust policy process, but it discontinued the reimbursements in 1998.[4]

Questions remain as to what happened after 1993 and also what happened before. How consolidated has the defense industry become and is it becoming more or less consolidated over time? Questions also remain as to the causes and ultimate effects of consolidation and whether the DoD should—or can—do anything about it.[5]

A chart, sometimes referred to as the "eye chart" provides one perspective on the course of events (see Figure 1). The chart has become a popular fixture in defense community briefings, sometimes serving as a summary statement for all that has happened in the industry in recent decades.[6] It shows corporate consolidation among aerospace-defense firms from the point of dozens in the 1980s to the point of only a handful, literally, 25 years later. But the chart tells only part of the story. For example, it disregards new entrants; the changing composition of defense spending, including the increased importance of spending on war-related and other services; and the role of globalization. Moreover, it alludes to a potential consequence of consolidation (i.e., less competition) but does not speak to such consequences directly.

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[4] The reimbursements, sometimes referred to as "payoffs for layoffs," and most other visible signs of DoD support for consolidation ended in 1998, when the anti-trust agencies with DoD backing, denied the Lockheed-Martin-Northrop-Grumman merger.

[5] For early assessments of the effects of consolidation on excess capacity, cost savings, and other economic parameters, see GAO (1997), GAO (1998), and Gholz & Sapolsky (1999-2000); Hensel (2007) relates consolidation patterns to cost.

[6] Though completely unscientific as a measure of popularity, the author notes that she has seen this chart or charts like it in nearly every defense industry conference she has attended.
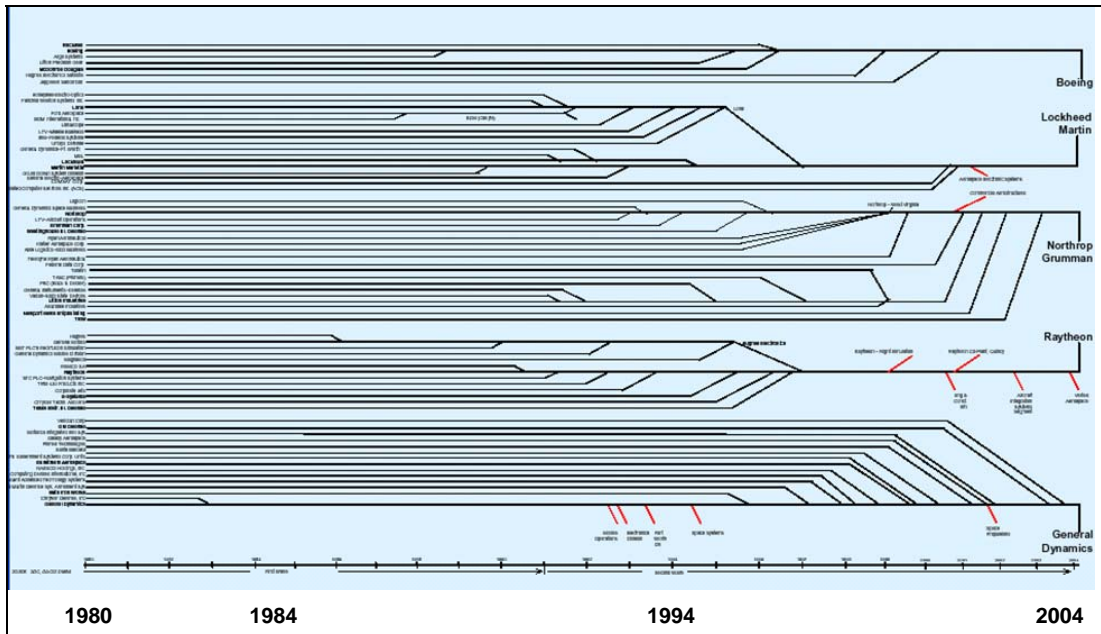
Figure 1. Five Big Players Emerge from Consolidation
(Chao, 2005, p. 13, citing others)

This paper lays a foundation for a more thorough investigation of consolidation, by establishing a broad but tractable definition of "defense industry" and by exploiting a rich but, for these purposes, largely untapped data set.

Defense industry analysts have long debated the meaning of "defense industry," offering wide-ranging, but plausible definitions that generate very different lists of defense or defense-related firms.[7] Chu and Waxman (1998) review several possible definitions and conclude that "the approach we choose must reflect a reasoned choice about the attributes which concern us most" (pp. 35-39). On that basis, this paper takes a DoD-centric approach and defines the industry as those firms that supply goods and services to the DoD or, more generally, those firms that could supply goods and services to the DoD either now or in the future.

This paper draws data from several governmental sources, most notably, a DoD contracting database, commonly known as the DD350, so named for a form completed for each DoD contract action over a certain dollar threshold; an annual DoD publication reporting the awards to the top 100 contractors; various DoD budget documents, including the annual National Defense Budget Estimates; the US Department of Labor, Bureau of Labor Statistics, for estimates of labor productivity; and the US Department of Commerce, Bureau of Economic Analysis (BEA) and the US Department of Commerce, Bureau of the Census (Census Bureau)

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[7] For example, Dunn (1995, pp. 402-403) suggests classifying defense firms on the basis of their products: lethal large or small weapons systems; non-lethal but strategic products (vehicles and fuel); and other products consumed by the military (food and clothing). He also suggests constructing a matrix of dependencies, one that compares the dependency of the firm on defense-related contracts and the importance of the firm to the military. The greater the mutual dependence, the more readily a firm can be considered a defense firm. One such matrix plots the share of each firm's revenue coming from defense contracts against the share of defense contracts going to each firm (Chu & Waxman, 1998, p. 37).

for other economic parameters. It also uses data from two non-governmental sources: FactSet Mergerstat, LLC (hereafter, Mergerstat), a firm that specializes in tracking the value and number of mergers and acquisitions, and the Aerospace Industries Association (AIA). The DD350 has known limitations both in terms of coverage and reliability, but it is the best available means of identifying "firms that supply goods and services to DoD," calculating their market shares, and evaluating the extent to which they compete for DoD contracts (see Dixon, Baldwin, Ausink & Campbell, 2005, for a discussion of some of the shortcomings of the DD350).

Trends in Consolidation

Figure 2 shows the number of mergers and acquisitions (M&As) among aerospace-defense firms from 1992 to 2007 and in the overall economy from 1962 to 2007.[8,9] For purposes of scaling, the total value of the economy-wide M&As was an estimated $1,124 billion in 2007, in year-2000 dollars, and about $175 billion in 1968—the first year for which value data are available, also in year-2000 dollars.

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[8] Mergerstat defines the aerospace-defense firms as "Aerospace, Aircraft & Defense," consisting of SICs 3721-3728; 3761-3769; and 3795. The data include M&As that involve a US firm as either a buyer or seller. Mergerstat provided the aerospace-defense data for 1992-2006 to the author on February 13, 2007; the economy-wide data and 2007 aerospace-defense data are available online at, https://www.mergerstat.com/newsite/freereport_log.asp .

[9] Mergerstat reports on the number of M&As in each year and their total value, based on the equity prices offered; it assigns M&As to the years in which they are announced. The data on the quantity and value of economy-wide M&As reach back to 1962 and 1968, respectively; the data on the quantity and value of aerospace-defense M&As reach back to 1992.

Mergerstat does not report any values that could reveal proprietary information and, in the smaller aerospace-defense sample, the gaps matter (just over half the 523 aerospace-defense deals reported for the 1992-2006 period had no information on value). The quantity and value series track closely for the overall economy but diverge for the aerospace-defense firms. For this reason, Figure 2 reports only the number of aerospace-defense and economy-wide M&As. For the aerospace-defense firms, the correlation between the value and quantity series was only 0.144 in the 1992-2007 period; for the overall economy, the correlation between the two series was 0.844 in the 1992-2007 period and 0.872 in the 1968-2007 period. The correlations were calculated using year-2000 dollars to eliminate the effects of inflation.
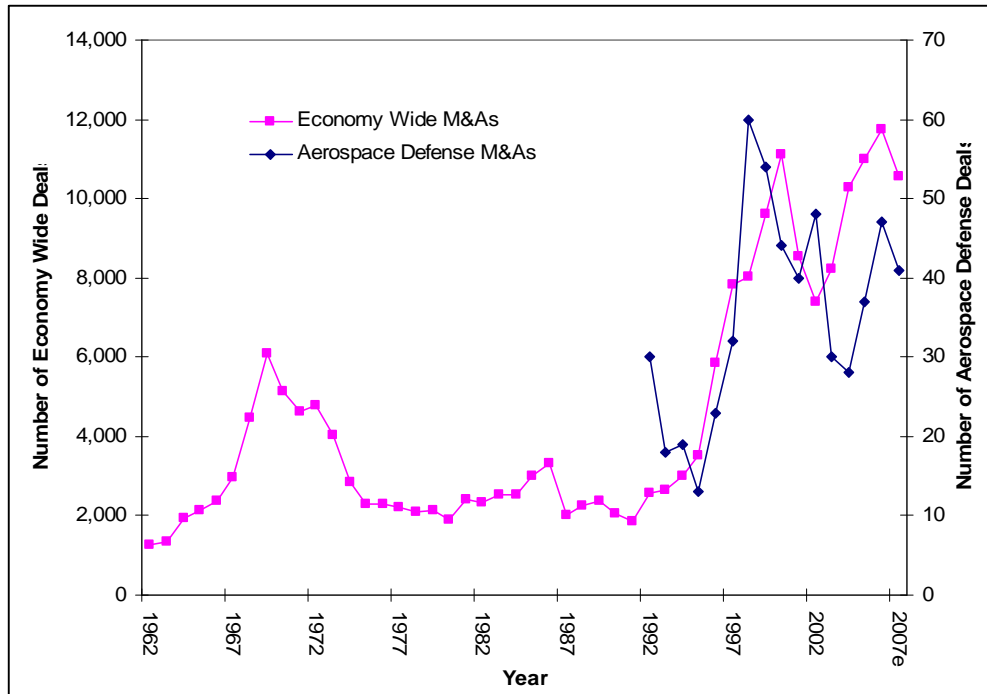
Figure 2. M&As Economy Wide and in Aerospace Defense
(Based on data from FactSet Mergerstat, LLC (a) and (b))

Note that the increases in M&A activity among aerospace-defense firms in the 1990s and 2000s were not unlike those in the overall economy. The later discussion of possible reasons for consolidation addresses this point in statistical detail.

The M&A data in Figure 2 account for the corporate activity that, as a practical matter, would give rise to consolidation, but they say little about the ways in which it unfolds and reshapes an industry (i.e., the defense industry). A simple tally, or even a dollar count, cannot provide this insight; however, the DD350 data and figures from DoD's annual top 100 reports can fill in some of the detail.

The actual DD350 form collects information on DoD contracting actions, which is posted in large text files, by fiscal year, on a central website; the data are currently available from 1966 to 2006.[10] The reporting threshold was $10,000 for actions occurring prior to 1982; $25,000 for actions occurring from 1983-2004; and $2,500 for actions occurring from 2005 to the present. The recent threshold reduction has had a noteworthy effect on the coverage of the data set. In 2004, the data set included filings for just under 700,000 actions; in 2005, it included well over 1.3 million.

Historically, the DD350 has collected information on the timing of the action (month, day, and year), the contractor's name and location, the dollar value of the action, the type of contract, and as many as 70-80 other variables relating to the award process, product, and nature of the business entity, (e.g., small or minority owned). Starting in 1984, the DoD also began assigning

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[10] Information is available at the following website:
http://siadapp.dmdc.osd.mil/procurement/Procurement.html.

an "Ultimate Parent Code" to each contractor, making it possible to track how much business the DoD was doing with each overarching corporate entity in any given fiscal year.[11] On that basis, it is possible to calculate each entity's annual share of the DoD market, defined here as the dollar value of all DD350 actions ("awards"), and to produce lists of top DoD contractors over time.[12] The DoD has been publishing annual lists of top 100 contractors and their market shares since the 1950s, initially only in hard copy and later only electronically, but the secondary-source data do not contain the full range of information available in the DD350 text files nor can they be manipulated readily.[13] To the extent possible, this analysis draws from the primary data found in the DD350 text files.

Drawing from traditional concepts of both industry and aggregate concentration, this section constructs 4-firm, 8-firm, 20-firm, 50-firm, and 100-firm concentration ratios for the defense industry (i.e., the firms that supply goods and services to the DoD market by fiscal year, for 1958-2006). The concept of "industry concentration" applies insomuch as the analysis focuses on a particular industry; the concept of "aggregate concentration" applies insomuch as it groups firms that, albeit serving a common consumer (DoD), do not necessarily produce like goods or services.[14] The concentration ratio is the market share of each group of firms, in this case the top 4, top 8, top 20, top 50, and top 100, calculated as the group's share of the net dollar value of all DoD contract awards.[15] The concentration ratio serves as a proxy for consolidation: if, for example, the concentration ratio is rising for a particular group of firms, then, for purposes of this analysis, that group is becoming more consolidated.[16,17]

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[11] Note: The code can—and does—change from year to year so that the data for each year must be handled separately before it can be combined with others in a single time series.

[12] The DD350 reports on actions with prime contractors, thus it does not capture an entity's indirect market share, via its subcontracts with other contractors. A company that is a prime on a large number of contracts may also be a subcontractor on many others and vice versa.

[13] See DoD, SIAD (2008a), "100 Companies Receiving the Largest Dollar Volume of Prime Contract Awards," for fiscal years 1996-2006, at http://siadapp.dmdc.osd.mil/procurement/historical_reports/statistics/procstat.html and available in hard copy through the Defense Technical Information Center for 1958-1997.

[14] For a non-exhaustive glimpse into the uses and drawbacks of these types of measures, see Bain (1951), Curry & George (1983), Kwoka (1981), O'Neill (1996), and White (2002).

[15] Why choose 4-, 8-, 20-, 50-, and 100-firm concentration ratios? The choice of the "K-Firm" ratio is inherently arbitrary (Curry and George, 1983, p. 207). The 4-firm and 8-firm ratios are widely accepted in industry studies, so much so, that "AmosWEB"—a.k.a. "The Encyclonomic WEBpedia"—describes them as the "analytical standards in the study of the structure of the industry." For a more academically compelling justification of the 4-, 8-, 20-, and 50-firm concentration ratios, the US Department of Commerce, Bureau of the Census provides them in the "Economic Census" and other reports that address industry concentration. The calculation of the 100-firm concentration ratio provides a direct bridge to DoD's top-100 reports and is a common measure in aggregate studies (Curry & George, 1983, p. 207). Lastly, Kwoka (1981) provides strong justification for considering more than one concentration ratio.

[16] Concentration ratios have also been used as proxies for competition (O'Neill, 1996); however, this paper considers concentration and the relationship between concentration and competition separately.

The results show a striking increase in the 4- and 8-firm concentration ratios over the 1990s (see Figure 3). In 1990, the top 4 firms accounted for about 18.5% of the DoD contract awards, just above the 17.7% average for the 1960s, '70s, and '80s. By 1996, they accounted for 23.6% of the market, breaking the previous "record" of 23.2% in 1958, and by 1999 they accounted for about 28.1%. The ratio was relatively stable through 2003, decreasing in 2004 and 2005, and it rose slightly in 2006, but not to the most recent peak, which was 28.8% in 2002. The calculations for 2005 and 2006 may overstate the decline from 2002 because of the change in the DD350 reporting threshold; however, even after accounting for the change, the concentration ratio likely remained below the 28.8% peak.

Speculatively, the post-2003 decline in concentration ratios may reflect the effects of the Iraqi War. The DoD may be drawing from different firms at different market levels for different types of products (e.g., it may be requiring more sustainment services and ordering fewer new weapon systems). The rise of Halliburton to the top 8 in 2005—it ranked 6th—provides circumstantial evidence.
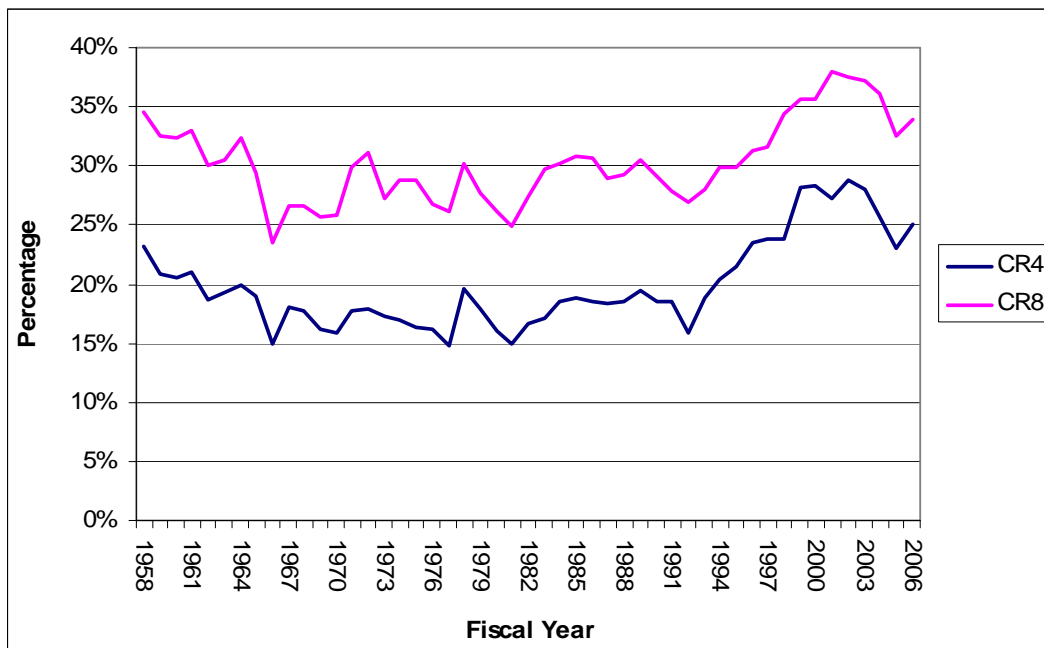
Figure 3. 4- and 8-Firm Defense Industry Concentration Ratios
(Based on data from DoD DD350 (DoD, SIAD, 2008a; 2008b, from 1958-2006))

The 20-, 50-, and 100-firm defense industry concentration ratios did not rise along with the 4- and 8-firm ratios; the 50- and 100-firm ratios declined over much of the 1990s, just as they did through much of the preceding decades and did not begin to rise until the end of the 1990s (see Figure 4). The 50- and 100-firm ratios have also dropped off since 2003, with a slight resurgence in 2006.

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[17] The ratios also make partial use of Dunn's matrix (see footnote 7; Dunn, 1995, pp. 402-403), by establishing a rough measure of DoD's dependence on suppliers at different market levels.
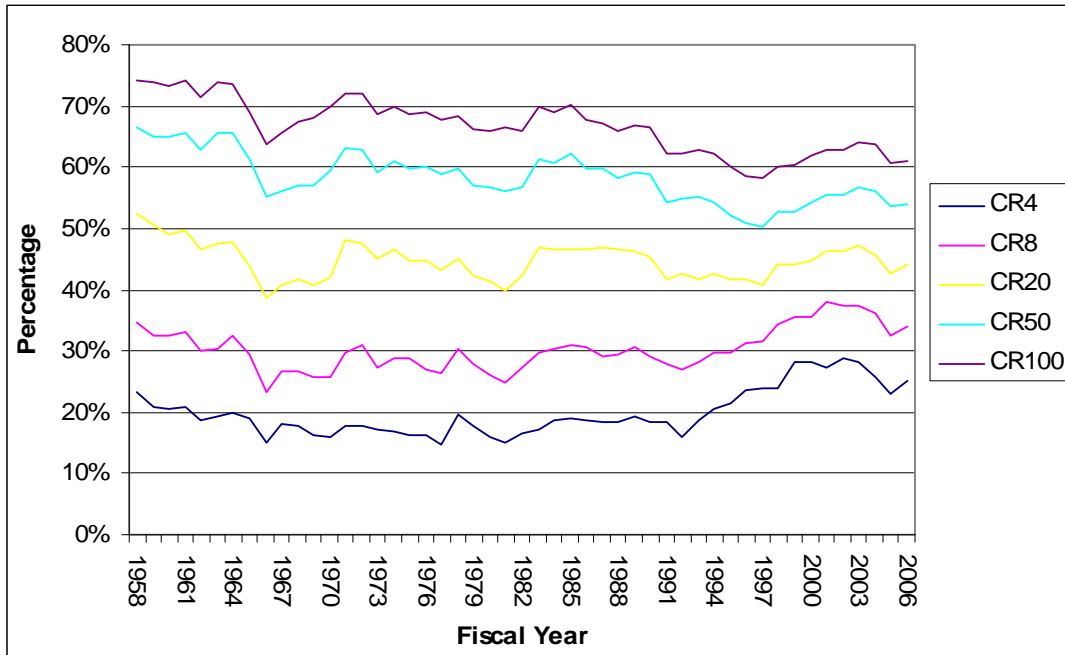
Figure 4. 4-, 8-, 20-, 50-, and 100-Firm Concentration Ratios
(Based on data from DoD DD350 (DoD, SIAD, 2008a; 2008b, from 1958-2006))

A more formal correlation analysis clarifies the relationships among concentration ratios at different market levels. The relationships between the 4- and 8-firm concentration ratios and the 50- and 100-firm concentrations are the strongest. The 4-firm and 8-firm concentration ratios are positively and significantly correlated at 0.926; the 50-firm and 100-firm concentration ratios also are positively and significantly correlated at 0.977. To the extent that the 4- and 8-firm concentration ratios are correlated with the 50- and 100-firm concentration ratios, however weakly, they are negatively correlated. The results pivot around the 20-firm concentration ratio. The highest levels of the industry do not appear to be "behaving" like the next highest levels.

Two alternative data presentations shed additional light on the time-path of industry consolidation and on differences across and within market levels.

The first presentation replaces the concentration ratios of the top 4, top 8, top 20, etc., which are aggregate categories, with marginal market-level breakouts, i.e., the top 1-4, top 5-8, top 9-20, top 21-50, and top 51-100 (see Figure 5).[18] The marginal breakouts highlight substantial differences across and within the market levels. While the "paths" of the top 4 and top 8 firms look nearly identical in Figures 3 and 4, the paths for the breakouts of the top 1-4 and top 5-8 firms in Figure 5 are quite dissimilar. Whereas the top-most firms became increasingly concentrated—a handful of major players became even more major—at lower but-still-quite-high levels, the industry became more diffuse or remained largely as it was in the 1980s and prior decades. For the top 5-50 firms, a downward slide in concentration began in

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[18] According to Curry & George (1983, p. 207), R.A. Miller introduced the concept of the marginal concentration ratio in a paper, "Marginal Concentration Ratios and Industrial Profit Rates: Some Empirical Results," published in the *Southern Economic Journal* in October of 1967.

the mid-to-late-1980s, when the DoD budget began its decline (the budget peaked in real terms in 1985). The 51st to 100th firms have experienced less change, particularly in recent decades.[19]
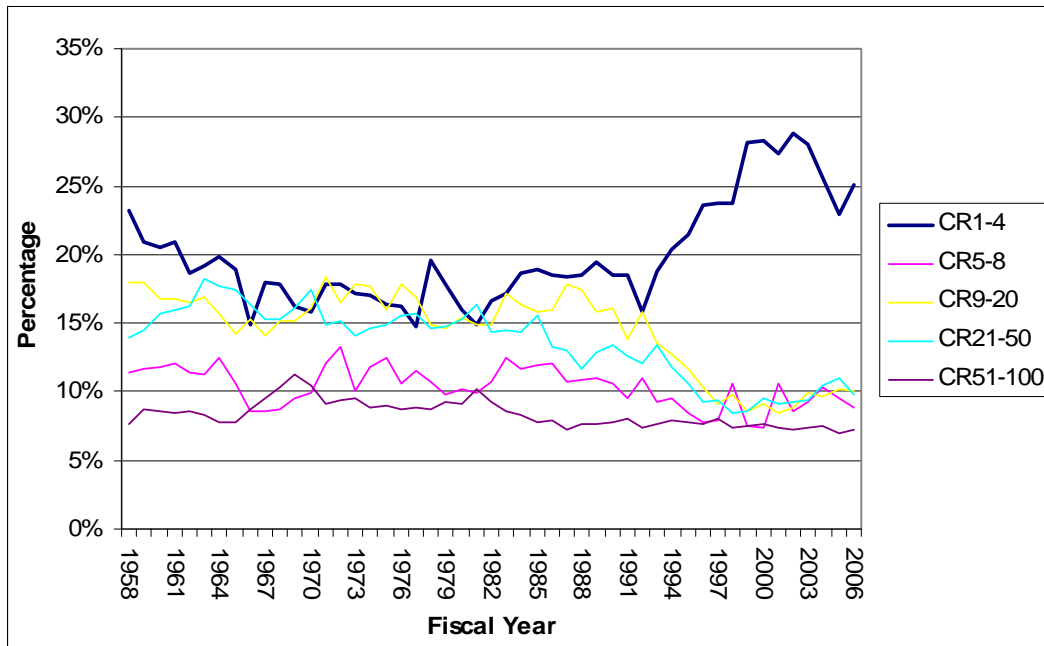

Figure 5. 1-4-, 5-8-, 9-20-, 21-50-, and 51-100-Firm Concentration Ratios
(Based on data from DoD DD350 (DoD, SIAD, 2008a; 2008b, from 1958-2006))

The second presentation compares the market shares of each of the top 50 firms at 5-year intervals (1989, 1994, 1999, and 2004) to their counterparts in 1984 (see Figure 6).[20] The x-axis in Figure 6 shows the rank of the firm from 1 to 50 (based on its share of the DoD market, measured in the dollar value of DoD contract awards), and the y-axis shows the difference between its market share and the share of the equally-ranked firm in 1984. For example, in 1989 the first-ranked firm's market share was almost 1 percentage point higher than that of the first-ranked firm in 1984 (in this case, the same firm, but not necessarily so); in 1994 the first-ranked firm's market share was 2.1 percentage points higher than that of the first-ranked firm in 1984; in 1999 the first-ranked firm's market share was 4.3 percentage points higher than that of the first-ranked firm in 1984; and in 2004 the first-ranked firm's market share was 3.2 percentage points higher than that of the first-ranked firm in 1984.

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[19] Though tempting to equate rank with size to draw conclusions for large, medium, and small firms, rank and size are not equivalent. Firms of similar rank may be quite different in size and firms of less-than-top-most rank may also be quite large. The top-100 firms are the top of literally tens of thousands of firms that serve the DoD market, to rank 50th or 51st is not trivial. In 2006, the 50th firm, Dell, did about $636 million in business with DoD; the 51st firm, American Body Armor, did another $635 million.

[20] The authors initially conducted this analysis using data from 1984, the first year for which the DD350 text files provide ultimate parent company identifiers and are in the process of incorporating data from earlier years. However, a comparison of the top-50 firms' ranks and market shares in the mid-to-late 1980s and around each of the interval years suggests that 1984 provides a reasonable anchor and that the 5-year intervals are representative of overall trends in the industry. The 4-firm concentration ratio for 1984 is also close to the historical average for the decades preceding the 1990s.
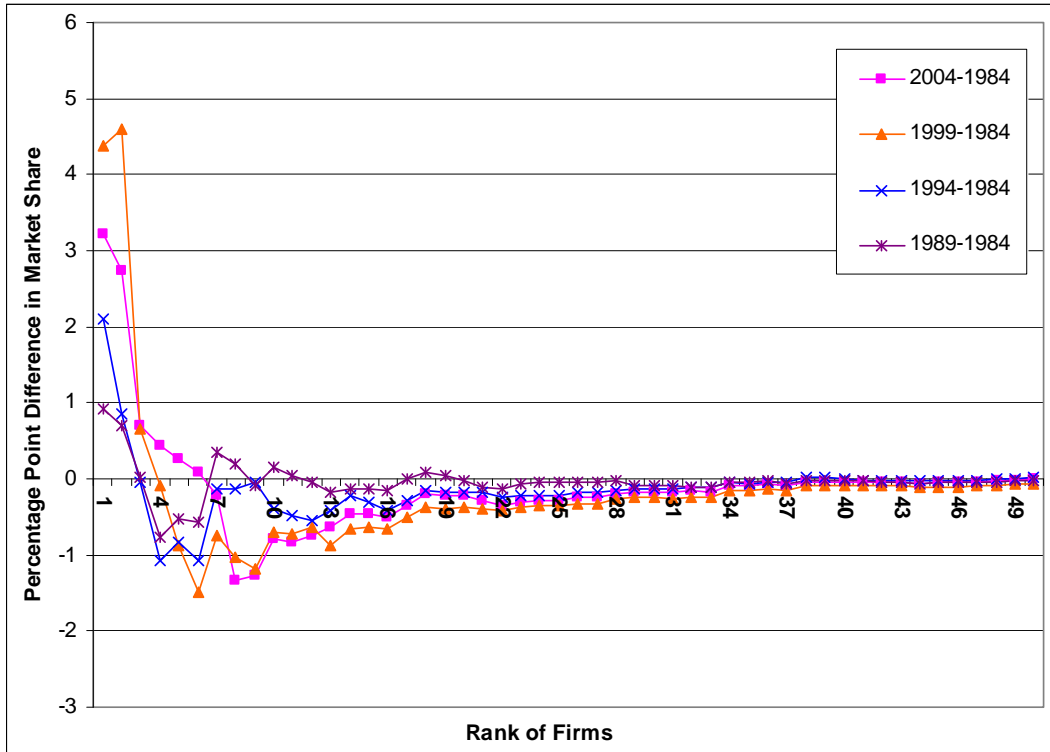
Figure 6. Changes in Market Share by Firm Rank
(Based on data from DoD DD350 (DoD, SIAD, 2008b, from 1984-2004))

The differences in market shares grew over the 1990s but then subsided in the 2000s. The differences in shares are most pronounced among the top-20 firms, especially the top 10, and all but vanish by the 50th firm. Lastly, the differences for the top-5 to top-50 firms are often negative, not positive, which implies that, for all but the very top-most firms, the market became more diffuse, not less. The change in distribution might be consistent with consolidation among the DoD's very top-most firms and a "hollowing out" of upper-to-mid-ranking firms, perhaps by absorption, but also with equal or heightened competition among all but the very top-most firms. For firms ranked outside the top 50, the market shares in 1989-2004 look like "business as usual."

Possible Explanations

Why did the defense industry's top-most firms consolidate in the 1990s, and why has consolidation shown sign of abating more recently? It is tempting to view the numbers and say "it's all about the defense budget" or "it's all about DoOD policy," but the seemingly obvious could be wrong and potentially misleading. Why the red flag?[21] First, US defense budgets,

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[21] Other analysts have also questioned popular wisdom. Hensel (2007) suggests that that economy-wide exuberance in the 1990s might have been responsible for the wave of M&As in the defense industry and assesses the correlations between aerospace-defense M&As, economy-wide M&As, and DoD outlays in the 1992-2004 period. Flamm (1998, pp. 45-46) notes that the aircraft, aircraft engines, and munitions industries became more consolidated in the 1980s, during a period in which spending "soared." Note:

including procurement budgets, have seen substantial downturns in the past without inspiring dramatic consolidation (see Figure 7), and second, the defense industry does not operate in a vacuum. Yes, demand for defense products contracted when the Cold War ended declined, possibly so-much-so that it could no longer sustain the then-larger number of major contractors, and, yes, DOD reportedly announced its support for consolidation during the Last Supper of 1993, but the rest of the US economy was also experiencing a dramatic wave of corporate activity, particularly M&As (Emmons & Perry, 1997). Other factors may also have been drivers.
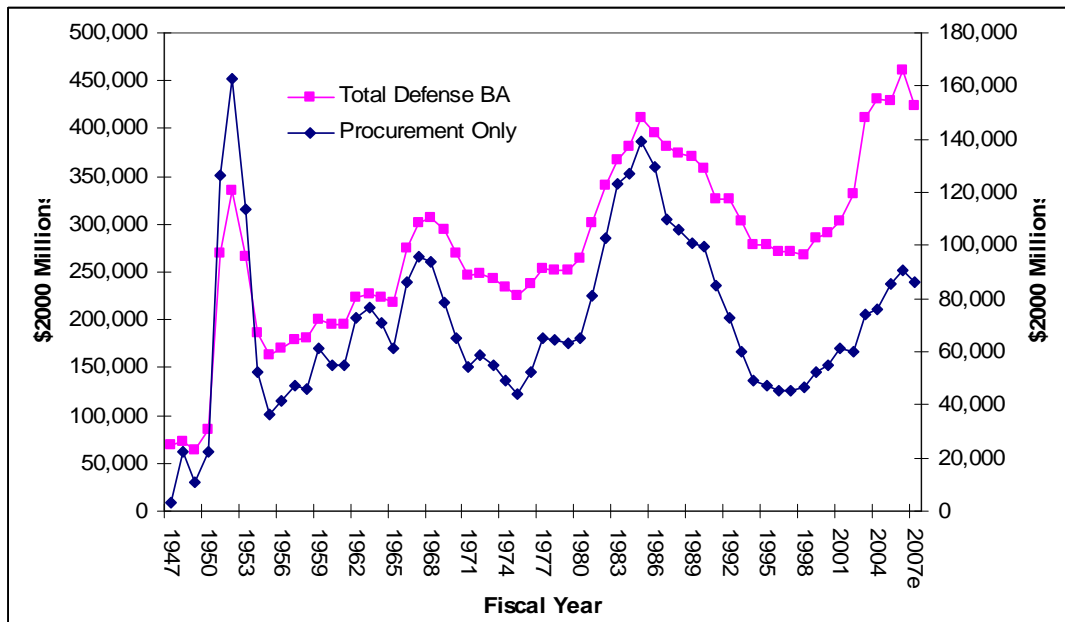

Figure 7. DoD Budget Authority in 2000 Dollars
(Based on data from the DoD National Defense Budget Estimates for the FY 2007 and 2008 Budgets and Department of Commerce, Bureau of Economic Analysis)

A simple empirical model considers the possibility of multiple contributing factors by regressing the 4-firm concentration ratio for 1958-2006 on combinations of both economy-wide and DoD-specific variables, including real gross domestic product (GDP), the number of M&As in all industries, real DoD budget authority (BA), and a dummy variable for DoD policy, to capture the effects of the Last Supper and subsequent DoD policy actions, including cost reimbursements.

Several statistical challenges arose in the analysis, including missing data, i.e., the absence of economy-wide M&A data for 1958-1961; evidence of autocorrelation and collinearity; and the presence of a non-specific upward trend over most of the period of analysis. Initial data runs indicated positive first-order serial correlation at a significance level of 0.01, suggesting the importance of including a lagged industry concentration variable among the independent variables. Initial data runs also indicated likely collinearity among the independent variables, especially among GDP, economy-wide M&As, lagged industry concentration, and a

This analysis does not report an increase in overall defense-industry concentration during that period; rather, it suggests stable or declining market shares.

proposed trend term.[22] Ultimately, a model that included economy-wide M&As and excluded GDP offered the strongest statistical results but necessitated a 1962 start date (n = 45).[23]

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5$$

Where:

Y = 4-firm concentration ratio (in decimal terms, e.g., 0.18, 0.25, etc.) (CR4F)

X_1 = Lagged 4-firm concentration ratio (one period lag) (CR4F-L)

X_2 = Lagged real DoD BA (in \$2000 billions) (BA-L)

X_3 = DoD policy (0, 1 dummy) (POL)

X_4 = Number of economy-wide M&As (MA)

X_5 = Trend term (Linear, 1…N) (TR)

Table 1 shows the results of six model runs. The first considers only one independent variable, X_1, the lagged 4-firm concentration ration (CR4F-L). The second run adds the trend term, X_5. The third run adds X_2, lagged real DoD BA (BA-L). The lag allows firms to adjust to new information about the budget and for changes in BA to begin to transform themselves into changes in actual spending and contracting actions.[24] The fourth run adds X_3, the policy variable (POL), defined as "1" for 1993-1997 (arguably, the period in which DoD most actively promoted consolidation) and "0" for all other years.[25] The fifth run adds X_4, the number of economy-wide M&As (MA). The 6th and final run removes the policy variable. A priori, one might expect the signs on the X_1 (CR4F-L), X_2 (BA-L), X_3 (POL), X_4 (MA), and X_5 (TR) coefficients to be positive, negative, positive, positive, and positive, respectively.

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[22] We model the concentration ratio with a deterministic time trend, implying the process is trend-stationary. Dickey-Fuller and Phillips-Perron tests of stationarity support this modeling choice. Specifically, a process is trend-stationary if the de-trended series is stationary (see Hamilton, 1994, p. 435). We also tested for a cointegrating relationship between the concentration ratio and the BA series or the MA series. The Johansen procedure failed to find evidence of cointegration for either pair of variables.

[23] Starting with either 1958 or 1962 and substituting other economy-wide variables, such as GDP, the Dow Industrial Average or corporate profits, yields similar but statistically weaker results, which tend to conflate the roles of the economic variables and the underlying positive trend.

[24] Eliminating the lag on BA does not have a dramatic effect on the results nor does substituting other lagged or un-lagged measures of defense spending, including total outlays and various measures of procurement, research and development, and operations and maintenance.

[25] Some have described the discontinuation of reimbursements and the denial of the Lockheed-Martin-Northrop-Grumman merger in 1998 as a change in DoD policy (e.g., Flamm, 2005), but it may be more accurate to describe it as a continuation of the same policy in the face of a change in circumstance. The DoD had said that it would support consolidation to the point that it made sense, and, in 1998, it may have stopped making sense. Nevertheless, be it a labeled a change of "policy" or "circumstance," something appears to have changed in the DoD's behavior in 1998.

Table 1. Regression Results for Concentration Ratio Model

	Intercept	CR4F-L	BA-L	POL	MA	TR
(1)	B_0	B_1	N/A	N/A	N/A	N/A
Coefficient (t-stat)	0.18 (1.297)	0.913 (13.110)				
Test results	R^2(adj.) = 0.795; F = 171.878; DW = 2.082					
(2)	B_0	B_1	N/A	N/A	N/A	B_5
Coefficient (t-stat)	0.034 (2.337)	0.753 (8.452)				0.001 (2.626)
Test results	R^2(adj.) = 0.820; F = 101.169; DW = 2.060					
(3)	B_0	B_1	B_2	N/A	N/A	B_5
Coefficient (t-stat)	0.059 (2.693)	0.710 (7.685)	-7.976E-5 (-1.515)			.001 (3.024)
Test results	R^2(adj.) = 0.825; F = 70.291; DW = 2.133					
(4)	B_0	B_1	B_2	B_3	N/A	B_5
Coefficient (t-stat)	0.051 (2.099)	0.736 (7.336)	-6.315E-5 (-1.086)	.007 (0.694)		.001 (2.165)
Test results	R^2(adj.) = 0.823; F = 52.172; DW = 2.153					
(5)	B_0	B_1	B_2	B_3	B_4	B_5
Coefficient (t-stat)	0.069 (2.709)	0.609 (5.144)	-6.653E-5 (-1.180)	0.008 (0.885)	2.628E-6 (1.883)	0.001 (1.817)
Test results	R^2(adj.) = 0.834; F = 45.103; DW = 2.109					
(6)	B_0	B_1	B_2	N/A	B_4	B_5
Coefficient (t-stat)	0.077 (3.283)	0.582 (5.101)	-8.682E-5 (-1.690)		2.516E-6 (1.815)	0.001 (2.737)
Test results	R^2(adj.) = 0.835; F = 56.490; DW = 2.081					

(Based on data from DoD DD350 (DoD, SIAD, 2008a; 2008b, from 1958-2006), DoD National Defense Budget Estimates for the FY 2007 and 2008 Budgets, the Department of Commerce, Bureau of Economic Analysis; and FactSet Mergerstat, LLC (b), using SPSS v16)

The results of the 1st regression indicate that lagged industry concentration accounts for a large share of the variance in industry concentration.[26] Nevertheless, the underlying statistical process may be more than just an autoregressive "Black Box." Focusing on the results of the 6th and final regression:

- The coefficient on the DoD BA variable is statistically significant, at the 0.10 confidence level, and signed as expected (if BA decreases by a billion dollars in one year, the 4-firm concentration ratio increases by about 0.00009 in the next year, indicating a small but non-negligible increase, for a budget that moves in increments of multiple billions of dollars.)

- The coefficient on the economy-wide M&A variable is also statistically significant and signed as expected (all else constant, the increase in economy-wide M&As in 2006, would have been associated with an increase in the 4-firm concentration ratio of about 0.002, also a small but non-negligible increase).

- Lagged industry concentration and economy-wide M&As are significantly correlated, but fortunately this is one of the "happy situations" that Gujarati discusses in his text (2006, p. 377). The variables' collinearity neither eliminates statistical significance nor results in "incorrect" signage.

In the 4th and 5th regressions the coefficient on the DoD policy variable is not statistically significant and, in an unreported regression that focuses solely on policy, by excluding the DoD BA variable, it is not significant either.[27] The budget data may say all that needs to be said about DoD's role in shaping the industry—hard dollars may be more important than proclamations, even when proclamations come with changes in policy processes and the possibility of cost reimbursements.

Given the predictive strength of the lagged defense-industry concentration variable, it is striking that both BA and economy-wide M&As find moderate predictive significance. The jump from "predictor" to "driver" is a long and dangerous one; however, the results suggest a role for the defense budget and the general economy in shaping events. The declining DoD budget may have been an important driver of defense industry consolidation in the 1990s but perhaps not the only driver. Ironically, it may have been a peculiar combination of economy-wide exuberance and defense-wide doldrums that led to the industry's reformation.[28,29]

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[26] The standardized coefficient (Beta) for CR4F-L is 0.894 in the first regression; 0.738 in the second regression; 0.696 in the third; 0.721 in the fourth; 0.597 in the fifth; and 0.571 in the sixth.

[27] The unreported regression includes lagged industry concentration, policy, and the trend term.

[28] For insight to the underlying causes of the economy-wide wave, including the roles of deregulation and governance, see Andrade, Mitchell & Stafford (2001) and Holmstrom & Kaplan (2001). Note that past authors have not necessarily found a strong correlation between M&As and industry or aggregate concentration ratios; for example, see Curry & George (1983) and White (2002).

[29] A closer look at the industrial composition of DOD's top firms suggests another possible driver requiring further consideration: an aging or "maturing" industry, like aircraft manufacturing, may have less ability—or need—to sustain a large number of leading firms than a newly developing industry. Whether the industry's relative maturity would have contributed positively, negatively, or not at all to the corporate activity of the 1990s remains an open empirical question.

Over the past few years, the 4-firm concentration ratio has tracked more closely with the DoD budget, which has been growing,[30] and less closely with economy-wide M&As, which have been largely increasing. It is also tracking less closely with aerospace-defense M&As, which may speak to the rising importance of sustainment services and other war-related purchases in the spending mix.

These results are not just academically interesting, they are also relevant to policy making. The DoD may be the sole purchaser of some or even many defense-related products, thus, highly influential in its purchase habits, but its purchase habits do not solely determine the fate of the industry. The DoD's control over the firms that arm, feed, and clothe it is by no means absolute. Defense firms, even including the firms that are most dependent on the DoD, are also captive to larger market forces: they seek financing in global markets and must satisfy their investors. Need be, they can opt out entirely—in the extreme, by terminating their operations and liquidating their assets—if the opportunity cost of doing business with the DoD becomes too great. With that in mind, the following section briefly considers the possible implications of consolidation.

Implications for Defense Acquisitions

Building on a long-standing tradition, this section relies heavily on standard economic models and tools to consider the implications of defense industry consolidation for DoD acquisitions (for some early examples, see Adams & Adams, 1972; Bohi, 1973; Peck & Scherer, 1962; Stigler & Friedland, 1971; and Weidenbaum, 1968).[31,32]

Concerns about consolidation stem in large part from those about deviations from competition (see Ackerman, Giovachino, Tighe & Trunkey, 1995): are firms in the defense industry consolidating that are behaving less competitively and, if they are, will their behavior have a pronounced effect on the price, quantity, quality, or timeliness of deliveries in the near term or on productivity and innovation in the longer term?

Consolidation and Competition

A simple market model and a preliminary assessment of data on the extent of competition in contract awards shed light on static concerns about price and quantity.

The Simple Market Model

The "simple market model" is a model of bilateral monopoly. In the bilateral monopoly a single buyer, a monopsonist, meets a single seller, a monopolist (Pindyck & Rubinfeld, 2001,

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[30] In the context of a negative relationship, to "track" really means to move in opposition.

[31] Peck & Scherer (1962) have an entire chapter addressing "The Nonmarket Character of the Weapons Acquisition Process"; nevertheless, they conduct an economic analysis of the acquisition process, relying almost exclusively on standard economic—and market—principles.

[32] Occasionally, skeptics argue that the defense industry is unique; that it has no real market for its products; and by extension, that standard economic models and tools have little practical use. This skepticism may reflect a misunderstanding both of the nature of the "standard economic models and tools" and of how "uniqueness" enters into economic analysis. See Johnson (1958) for a related study of the possible uniqueness of agricultural markets. The issue is not whether an industry is unique but whether standard models and tools can identify and incorporate its uniqueness.

pp. 358-359 and pp. 525-527). Prices and quantities are indeterminate but bound by the standard monopsonist and monopolist outcomes. The model is highly stylized. In most instances, the sole-buyer-sole-seller assumption is an exaggeration; however, the model provides a basis for considering the effects of convergence toward unity on either side of the market.[33] To the extent that defense industry consolidation reduces competition among producers of particular defense-related products, particularly those with a single primary purchaser (i.e., the DoD), the model provides insight.

Figure 8 depicts the marriage of the monopsony and monopoly. In a case that concerns a pre-existing monopsony or quasi-monopsony, such as the DoD, and the possible convergence of the supply side of the market to monopoly, the relevant comparison is not that of the bilateral monopoly and a perfectly competitive market but of the bilateral monopoly and a stand-alone monopsony. Nevertheless, in comparing the two imperfect markets, perfect competition provides a useful reference point.

When a monopsony faces competitive suppliers, it faces the entire market supply curve because it is the only purchaser in the market;[34] when it purchases more of the product in question, price rises; and when it purchases less, price falls. It recognizes the effect of its purchases on price and so it purchases less than it would in a perfectly competitive market. Although the equilibrium price is lower than in a perfectly competitive market, the quantity is also lower.

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[33] For a small set of defense-related products, such as nuclear-powered aircraft carriers, pure monopsony and pure monopoly provide a reasonably accurate characterization.

[34] The monopsonist does not have a true demand curve; rather, it has a marginal valuation (MV) curve. This is analogous to the case of the monopolist, supply, and marginal cost.
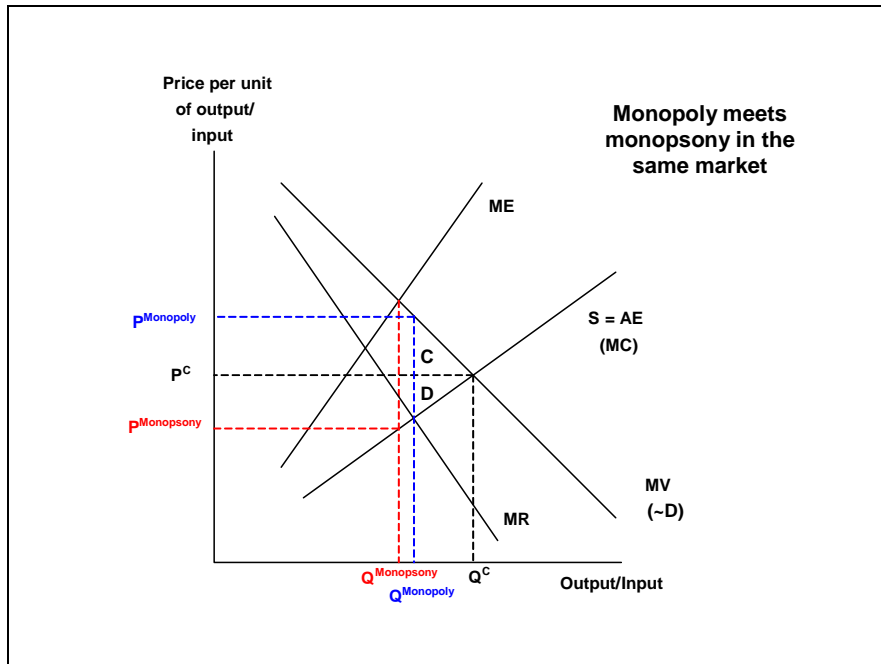
Notes: S = supply; AE = average expense associated with each unit of purchase or input, which is also the industry's supply (S) curve; MC = marginal cost; ME = marginal expense associated with each unit of purchase or input; MV = marginal value to the purchaser, which is shown as D = demand for the perfectly competitive market; MR = marginal revenue; Pc = the equilibrium price in the perfectly competitive market; Pmonopsony = the equilibrium price in the monopsony-only market; Pmonopoly = the equilibrium price in the monopoly-only market; Qc = the equilibrium quantity in the perfectly competitive market; Qmonopsony = the equilibrium quantity in the monopsony-only market; Qmonopoly = the equilibrium quantity in the monopoly-only market. Absent the monopoly, the monopsonist would equate ME and MV and sets price and quantity along AE, the industry's supply curve. Absent the monopsony, the monopolist would equate MC and MR and set price and quantity along D, the purchasers' demand curve. The deadweight loss associated with the monopoly, absent the monopsony, would be the area C+D, which in this depiction would be somewhat less than that which would be associated with the pure monopsony.

Figure 8. Monopoly Meets Monopsony
(Based on data from Pindyck & Rubinfeld, 2001, pp. 347, 358-359, and 525-527)

In the bilateral monopoly, price can settle anywhere at or between Pmonopsony and Pmonopoly, including at the perfectly competitive level; however, if the firm has any negotiating leverage vis-à-vis DoD, the bilateral monopoly price will be higher than the monopsony-only price and possibly closer to the competitive price. Quantity will settle somewhere below the perfectly competitive level because neither the monopsonist nor the monopolist has an incentive to exceed it; however, depending on the relative slopes of the various curves, it may settle above or below the monopsony-only quantity. As depicted in Figure 8, the introduction of monopoly to the erstwhile-monopsony-only market could result in a higher price and higher quantity, but with different relative slopes; it could also result in higher prices and lower quantities.

The new-found market power of the monopolist firm would likely result in a transfer of some surplus from the purchaser (i.e., the DoD) to the firm, which, though not a "good thing" from the DoD's perspective in the short term, could have positive consequences if it implies the increased viability of the industry in the long term. The net effect on society-at-large is

ambiguous and context specific. Society may actually gain surplus from convergence to monopoly.

The model becomes more complicated with economies of scale, the promise of which provided some or much impetus for the DoD's promotion of consolidation in aerospace, shipbuilding, and elsewhere. In such instances, convergence to monopoly may result in lower prices and greater efficiency than would occur in the more traditionally-depicted bilateral monopoly. If firms consolidate, so that each produces at greater volume, they can move down their respective cost curves and capture those economies. By definition, unit costs drop with increases in output—the cost of production may be $2.2 billion per ship if two firms produce 4 ships each and only $2 billion per ship if one firm produces all 8 ships—so that one firm can produce the same total output at lower total cost than two or more.[35] The monopsonist bids-up prices with each additional purchase, but additional purchases also drive down cost. To the extent that the monopsonist can extract some of the benefits of the cost reductions, its purchases may have a less pronounced price-raising effect than in the simple case.

The foregoing model suggests that, *if* an increase in industry concentration results in less effective competition among firms, then the prices of affected defense-related products may rise and quantities may fall or rise. Ultimately, the price and quantity outcomes will depend partly on the DoD's negotiating abilities; it will have lost some but not all of its relative market power. The outcomes will also depend on whether firms in the defense industry experience economies of scale. Moreover, and perhaps surprisingly, society at large may find itself with more economic surplus than under conditions of pure monopsony, even in the absence of economies of scale.

Preliminary Empirical Assessment

The question remains, however, as to whether the market has become less competitive. Does an increase in concentration among top-ranked firms necessarily imply a loss of effective competition? One way to approach this question is to identify changes in the DoD contracting practices. Are fewer contracts awarded competitively now than in the past, particularly to industry leaders? Admittedly, a decrease in competitive awards may not be causally related to an increase in defense industry concentration, even if contemporaneous and highly correlated;[36] however a clear pattern in the data (or lack thereof) may lend credence to (or refute) a relationship.

This section evaluates the frequency and distribution of one DD350 variable, "Extent Competed" (A = Competed; B = Not Available for Competition; C = Follow on to Competed Action; and D = Not Competed), among top 100 firms; future analyses will also consider four additional variables: "Number of Offerors Solicited," "Number of Offers Received," "Solicitation Procedures," and "Authority for Other than Full and Open Competition." The DD350 provides reasonably complete coverage for "Extent Competed," with consistent documentation and formatting, starting in 1989, but provides only limited coverage for the other variables.

The evaluation begins with data in 5-year increments, comparing the shares of contract dollars awarded competitively, either directly ("Competed") or indirectly ("Follow on to Competed

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[35] From Pindyck & Rubinfeld (2001, p. 227), "output can be doubled for less than a doubling of price." A natural monopoly is said to experience "strong" economies of scale.

[36] Just as in the case of concentration itself, many "drivers" may explain the difference in practices.

Action") to firms operating at different market levels, e.g., top 4, top 8,… top 100, and overall, in 1989, 1994, 1999, and 2004. It then provides additional detail for the years between 1989 and 1994. It also considers the extent of competition in each year in relation to industry concentration. The results are preliminary for at least two reasons: first, because of coding issues in the underlying data and, second, because of mechanical difficulties sorting the data that could lead to error. Future rounds of analysis will address both concerns.

Table 2 shows the share of DoD contract dollars competitively awarded, either directly or indirectly (hereafter the "competitive share"), by year and market level.

Table 2. The Extent of Competition over 5-Year Intervals
(Based on data from DD350 (DoD, SIAD, 2008b, from 1989-2004))

	Top 4	Top 8	Top 20	Top 50	Top 100	All
1989	60.72	64.71	65.00	64.51	64.86	68.06
1994	53.83	49.96	51.50	53.92	56.56	63.22
1999	52.20	51.40	55.16	56.04	58.21	65.13
2004	48.40	49.86	52.41	56.80	57.39	64.16
	Top 1-4	**Top 5-8**	**Top 9-20**	**Top 21-50**	**Top 51-100**	**101+**
1989	60.72	71.74	65.56	62.72	67.61	74.50
1994	53.83	41.59	55.14	62.63	74.56	74.24
1999	52.20	48.42	70.53	60.55	74.05	75.67
2004	48.40	53.46	61.97	75.99	61.84	75.99

Note: This table shows the percentages of DoD contract dollars competitively awarded, either directly or indirectly, in aggregate categories and for marginal market-level breakouts.

The results for the incremental years (1989, 1994, 1999, and 2004) indicate a consistent downward trend in the extent of direct and indirect competition among the DoD's top-most suppliers (i.e., the aggregate top 4); however, as previously, the results across and within market levels are mixed. Each of the top 8, top 20, etc., aggregate categories experienced a decline in competitive awards from 1989 to 1994 and a partial rebound in 1999. The differences among the breakouts are more pronounced: the top 21-50 became more competitive over time and the top 51-100, after experiencing a substantial increase in competitive awards in the 1990s, saw a large drop in 2004.

Figures 9 and 10, which show the competitive shares for the top 4, 8, 20, etc., aggregate categories (top panel) and for the top 4, top 5-8, top 9-10 etc., marginal market-level breakouts (bottom panel), starkly illustrate the relative and absolute "mixedness" of the results across and within market levels.
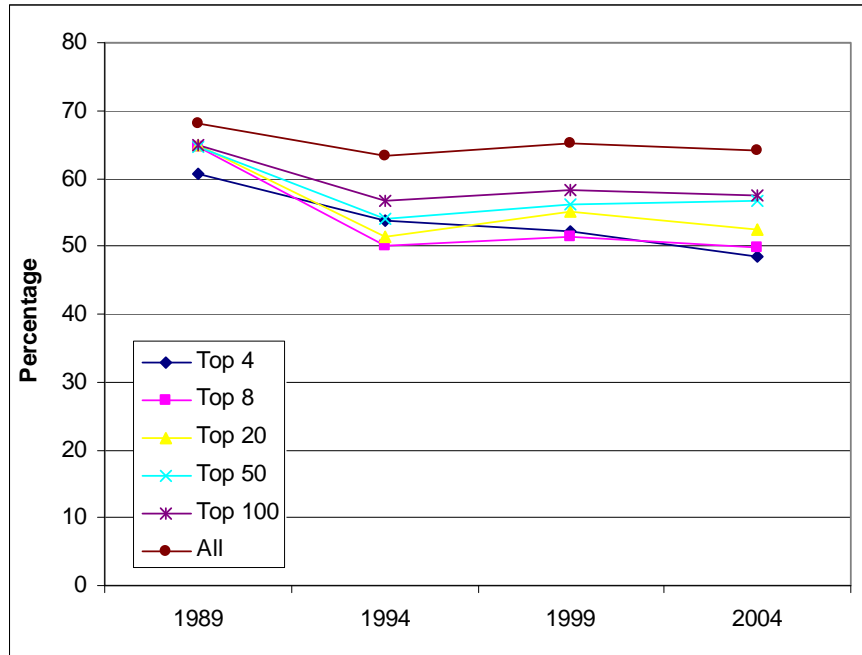
Note: This figure shows the percentages of DoD contract dollars competitively awarded, either directly or indirectly, in aggregate market-level categories.

Figure 9. A Comparison of Competitiveness by Aggregate Market Levels
(Based on data from DD350 (DoD, SIAD, 2008b, from 1980-2004))
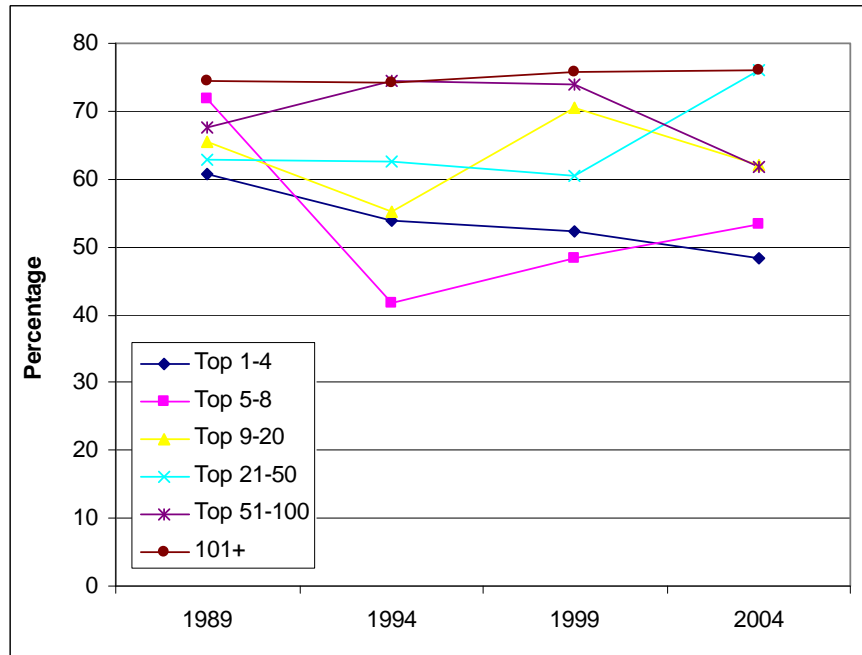
Note: This figure shows the percentages of DoD contract dollars competitively awarded, either directly or indirectly, for marginal market-level breakouts.

Figure 10. A Comparison of Competitiveness for Marginal Market Levels
(Based on data from DD350 (DoD, SIAD, 2008b, from 1989-2004)).

Even within the top 4, the results are mixed. Though not show in Table 2 or Figures 9 and 10, the first-ranked firm's competitive share was 49, 39, 65, and 55% in each of 1989, 1994, 1999, and 2004, respectively.[37] Contrary to expectation, the firm's competitive share peaked just as its market share was cresting (its share of the DoD market was over 10% in 1999 and reached over 11% in 2000).

Recalling the earlier finding of an increase in diffusion among the top 5-8, 9-20, and 21-50 firms over the 1990s, the data speak inconsistently to the extent of competition at those levels. The top 5-8 firms saw a dramatic decline in the share of competitive awards from 1989 to 1994 and then a substantial rebound from 1994 to 1999 and again from 1999 to 2004; the top 9-20 saw large fluctuations over the same period; the top 21-50 saw an overall increase; and the top 51-100 saw an increase in the 1990s and a decline in the 2000s. Moreover, whereas the market-share results previously suggested "business as usual" for the top 51-100 firms throughout the 1990s and into the 2000s; these competitive-share results seem to shift "business as usual" to the next market level (i.e., to the 101st firm) and those ranking behind it.

The one nearly consistent pattern to be found in the data is the dramatic change—mostly a drop—in the extent of competition between 1989 and 1994. The change raises questions about the usefulness of 1989 as an anchor point (was it an outlier?) and about the nature of the transition (if 1989 was not an outlier, was the transition smooth or sudden, e.g., did it occur in close proximity to the Last Supper). Table 3 includes data for 1989 and 1994 and the years between them.

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[37] Note: The first-ranked firm in 1989 and 1994 was McDonnell Douglas; the first-ranked firm in 1999 and 2004 was, as it is today, Lockheed Martin.

Table 3. Competitive Contract Awards in a Transition Period?
(Based on data from DD350 (DoD, SIAD, 2008b, from 1989-2004))

	Top 4	Top 8	Top 20	Top 50	Top 100	All
1989	60.72	64.71	65.00	64.51	64.86	68.06
1990	57.77	61.09	60.06	61.38	62.27	65.85
1991	53.75	59.22	59.24	59.75	61.35	64.88
1992	64.65	57.72	57.34	58.59	59.67	63.45
1993	52.67	50.89	51.51	54.92	56.62	61.78
1994	53.83	49.96	51.50	53.92	56.56	63.22
	Top 1-4	**Top 5-8**	**Top 9-20**	**Top 21-50**	**Top 51-100**	**101+**
1989	60.72	71.74	65.56	62.72	67.61	74.50
1990	57.77	66.85	58.22	65.80	69.05	72.95
1991	53.75	69.92	59.26	61.45	72.12	70.73
1992	64.65	47.72	56.67	63.01	67.64	69.65
1993	52.67	47.27	52.79	65.49	68.79	70.48
1994	53.83	41.59	55.14	62.63	74.56	74.24

Note: As above, this table shows the percentages of DoD contract dollars competitively awarded, either directly or indirectly, in aggregate categories and for marginal market-level breakouts.

Looking more closely at the data for 1989 through 1994, the results for the top 4, 8, 20 etc., aggregate categories suggest a reasonably smooth glide path from 1989 to 1994 for all but the top 4, but not for the marginal market-level breakouts.

The data for the 1989-1994 transition suggest that 1989 was not necessarily an outlier and that competition dropped off at some market levels in the years between 1989 and 1994, but that the path from 1989 to 1994 was neither entirely smooth nor tied to a particular event, be it the Last Supper or any other policy action.

Lastly, and perhaps somewhat more concretely, an analysis of the correlation between competition and concentration—via an analysis of the correlation between the shares of DoD contract dollars competitively awarded and the market shares of DoD's suppliers—suggests a negative relationship between competition and concentration for the top 4 firms, in aggregate, but not necessarily for the others (see Table 4).

Table 4. Correlations between Competition and Concentration
(Based on data from DD350 (DoD, SIAD, 2008b, from 1989-2004))

Top 4	Top 8	Top 20	Top 50	Top 100	
-0.5599	-0.3211	0.5675	0.8261	0.7834	
Top 1-4	Top 5-8	Top 9-20	Top 21-50	Top 51-100	101+
-0.5599	0.4420	-0.4021	0.0027	0.5513	0.0890

Note: This table shows the correlations between the competitive shares and market shares at each market level, both for aggregate categories and marginal market-level breakouts.

With data for a small number of years it is difficult, if not impossible, to pull a clear and compelling story from the statistical results.[38] Even within the top 4, the results are mixed. Recalling the noteworthy increase in the first-ranked firm's competitive share after 1994, the correlation between competition and concentration appears to be moderately positive at 0.5034.

On balance and notwithstanding the unexpected results for the first-ranked firm, it seems that competition declined among the top-most firms in the 1990s, but at other market levels the trends in competition are less clear. The lack of clarity may stem from a lack of data, as the analysis currently "misses" the years 1995-1998, 2000-2003, and 2005-2006, or from the underlying methodology. The analysis works with concentration ratios for firms in a buyer-defined (DoD) industry that do not necessarily produce like goods and services; thus, the ratios provide, at best, imperfect proxies for concentration among producers of particular product lines. To the extent that purchases of particular types of items drive the data on competition, the analysis may fail to identify the relevant relationships between concentration and competition.

Consolidation, Productivity, and Innovation

This section offers a brief discussion of the issues surrounding consolidation, productivity, and innovation, while addressing some initial observations on trends in consolidation and productivity in the aircraft industry, as a rough proxy for the larger industry.[39] Future research should look more closely at both the theoretical and empirical relationship between consolidation and productivity and between consolidation and innovation.

In considering productivity and innovation, the case can be argued for or against negative relationships with consolidation. The case "for" may be more familiar: a reduction in competition (e.g., via an increase in consolidation) would result in reductions in productivity (or its growth) and innovation because firms have less need to improve either. The case "against" may be less familiar: post-consolidation firms have more profits to allocate to productivity and innovation-enhancing activities and have incentives to do so because they fear the threat of future competition. In the extreme, firms may undertake productivity and innovation-enhancing activities, such as R&D, until they have fully expended the "excess" profits they are seeking to preserve.

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[38] The correlation calculations include data for 1995, bringing the total number of observations to nine (1989-1995, 1999, and 2004) for each market level.

[39] BLS publishes annual data on labor productivity in the aircraft industry but does not publish such data for a more broadly defined defense-aerospace or defense industry.

A cursory look at the data on aircraft labor productivity (available from 1972-2000) and defense industry concentration[40] (available from 1984-2006) shows an overall upward trend in both (in the period of overlap from 1984-2000), with some opposing movement. A closer look at correlations between aircraft labor productivity and defense industry concentration, controlling for steady increases in manufacturing productivity, lends some statistical weight, albeit far from conclusive, to a negative relationship between aircraft labor productivity and industry concentration.

Figure 11 traces aircraft labor productivity and the 4-firm defense industry concentration ratio from 1984 through 2000.
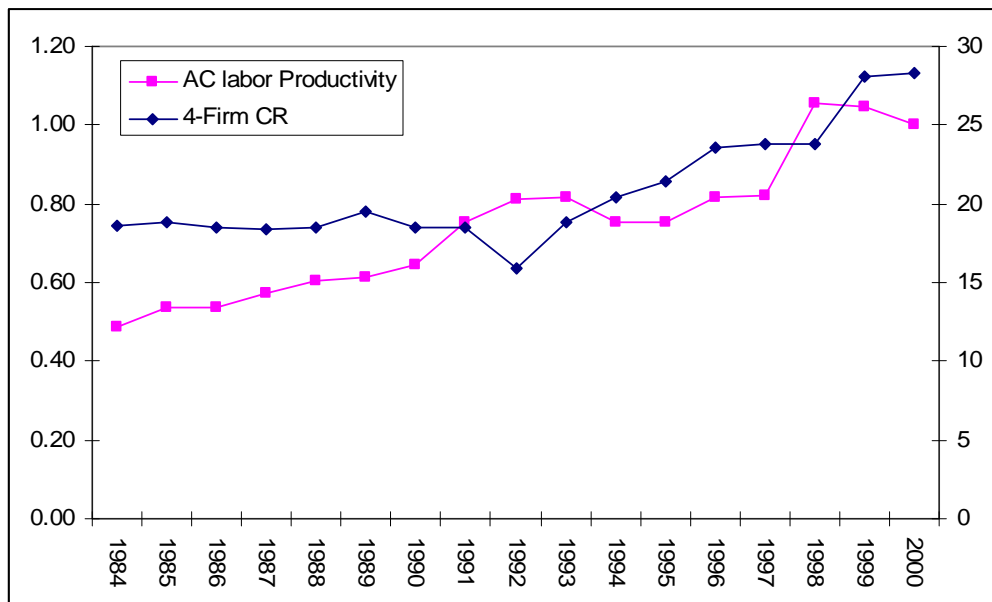

Note: The aircraft labor productivity variable is an index (2000 = 1).

Figure 11. Aircraft Labor Productivity and Defense Industry Concentration
(Based on data from US Department of Labor (2005) and DD350 (DoD, SIAD, 2008b, from 1984-2004))

The correlations among the three variables are all strongly positive, ranging from 0.753, between aircraft labor productivity and the 4-firm concentration ratio, and 0.947 between aircraft labor productivity and manufacturing productivity. But, the partial correlation between aircraft labor productivity and the 4-firm concentration ratio, after controlling for the contemporaneous rise in manufacturing labor productivity, is actually negative, -0.572, and moderately significant

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[40] This analysis uses the 4-firm concentration ratio as a proxy for aircraft industry concentration, both of which have been trending upward; however, the defense industry—writ large, in terms of DoD contract awards—is considerably less concentrated, in absolute terms, than the aircraft industry. The Census Bureau (see http://www.census.gov/epcd/www/concentration.html) typically publishes estimates of aircraft industry concentration every five years. In the US market, the four largest aircraft manufacturers accounted for over 80% of shipments in the late 1990s and just less than 60% in the late 1950s; the top eight accounted for well over 90% in the late 1990s.

An even more cursory look at the data on R&D expenditures (more precisely, company-funded applied research and development or AR&D) in the aircraft industry and defense industry concentration shows a stronger negative correlation, i.e., about -0.73 (see Figure 12); however, a careful analysis of the relationship between innovation and concentration would require a much closer examination of all R&D expenditures and other measures of innovation, such as patent awards, in relation to industry concentration, holding a host of other industry and economic variables constant.
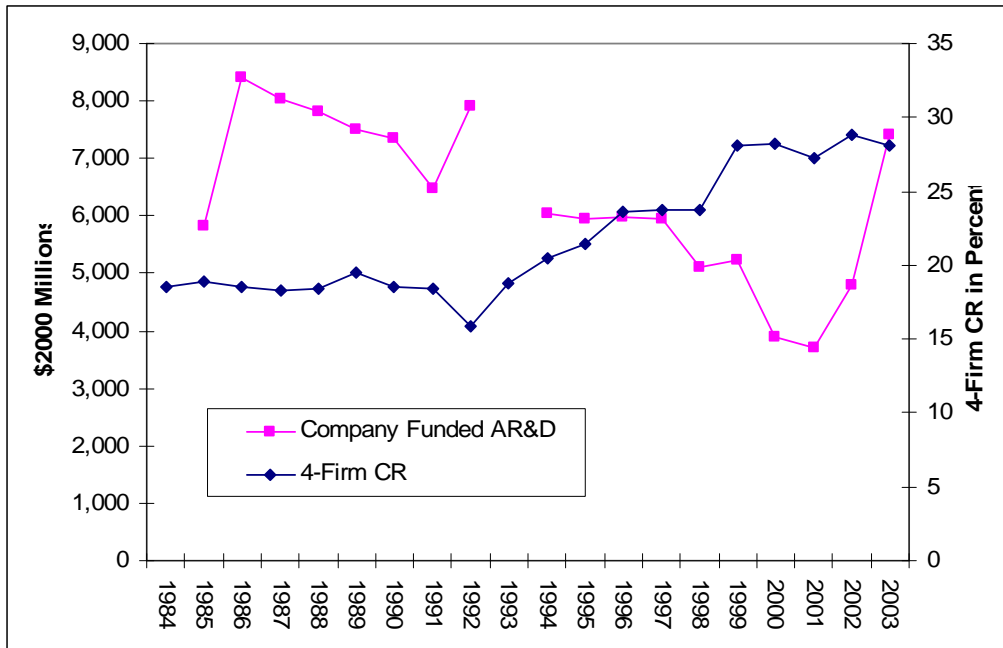
Note: AR&D = applied research and development; CR = concentration ratio.

Figure 12. Aircraft AR&D Expenditures and Defense Industry Concentration
(Based on data for company funded applied research and development from the Aerospace Industries Association (2005, p. 105) and DoD DD350 (DoD, SIAD, 2008b, from 1984-2003), using a BEA deflator)

The data on concentration and competition do not paint a clear picture of negative or positive relationships across and among market levels; however, for the top 4 aggregate category, they generally seem to move in opposition. To the extent that this can be taken as a sign of less competition at that level, the relationships between productivity and 4-firm concentration and innovation and 4-firm concentration, may reflect underlying relationships between both variables and competition. At risk of overreaching with inadequate data, the correlations hint at the possibility of negative relationships and provide no immediate evidence to the contrary.

Conclusions and Suggestions for Future Research

In some respects, the "eye chart" is right. It speaks a simple, plausible, and possibly self-evident truth. The DoD's top-most suppliers (i.e., the top 4), in aggregate, have increased their market share and become less competitive since the mid-to-late 1980s. However, the "truth" of the chart is less evident beyond the top 4 and even within the top 4. For example, the

first-ranked firm may hold a larger share of the market now than in the 1980s; indeed, it has held a larger share of the market over the past 10 years than at any time since 1958, but it also faces competition, either directly or indirectly, for a larger share of its DoD dollars. Underlying differences in the first-ranked firms in each era may help explain the result. In the 1980s, McDonnell Douglas may have produced a narrower range of products that were not competed openly; whereas, Lockheed Martin may now produce a wider range of products that are competed openly.

Together, the concentration ratios and competitive shares provide an aggregate view of an industry defined in terms of a single buyer: the DoD. In so doing, they enable consideration of the forest; however, it may be helpful to begin to view the trees. Future research will fill in the missing years in the analysis of competition (i.e., 1995-1998, 2000-2003, and 2005-2006) and complete the assessment of competition and concentration, looking more closely at product lines.

The eye chart also fails to fully capture the dynamism of the market. For example, it fails to recognize new entrants and the role of globalization, which are sometimes one and the same. (For example, BAE, a British-founded firm has dramatically increased its presence in the US market through a combination of direct investment in the United States and trade. It broke the top 8 in 2005.) Another new-entrant issue involves the changing composition of defense spending and the increasing prominence of service providers, especially post 9-11 and in Iraq. Noting that the top 51-100 firms and the 101st and beyond have largely experienced "business as usual," the data suggest both continuity and churn: some firms may be absorbed—as may be their fondest desire—and others may enter the market anew. As above, consideration of industry concentration in terms of particular product lines may be fruitful.

To the extent that the top-most level of the market has become less competitive, the simple, static bilateral monopoly model suggests that DoD may be paying more for some products, but the quantity implications are ambiguous. Moreover, if DoD's suppliers experience economies of scale, then the DoD may actually be paying less for some goods and services post-consolidation. Perhaps surprisingly, society-at-large may be economically better off with consolidation even without economies of scale.

However, dynamic concerns about productivity and innovation suggest a need for a closer examination. A cursory look at data on labor productivity and R&D in the aircraft industry suggests the possibility of a negative relationship vis-à-vis consolidation. A rough-and-ready look at correlations among pertinent variables is no basis for conclusions, but it is a reason to look more closely in the future.

Lastly, the statistical analysis of industry concentration and contributing factors suggests, on the one hand, the shared authority of DoD and the larger economy in determining the fate of the industry and, on the other hand, the relative lack of importance of policy proclamations, even when they come with changes in policy processes and potential cost reimbursements. DoD may have a significant say in what happens in the defense industry, but it cannot control the market altogether.

Looking to the future, the implications of the statistical assessment are striking. At present, the defense industry—as it is reflected in the 4-firm concentration ratio—is more closely tracking defense spending (in the sense that spending is rising and the 4-firm concentration ratio is still substantially below peak) than the larger economy; however, were spending to

decline (e.g., at the end of the war in Iraq) the conditions might be right for an increase in consolidation.

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