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Analysis of Competition in the Defense Industrial Base: An F/A-22 Case Study

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Analysis of Competition in The Defense Industrial: Base: An F-22 Case Study

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Consolidation of the defense industrial base has led to concerns about whether enough competition exists between remaining firms to maintain needed cost reduction and innovation. We examine competition in the U.S. defense industrial base by performing an in-depth case study of Lockheed Martin and the F-22 program that considers multiple tiers of the industrial base. We find that defense firm specialization has led to outsourcing practices and arguably a more robust U.S. defense industrial base. Implications for government policy are identified. (JEL H57, O38, D43, L14)

I. Introduction

In the last decade, significant change has swept the defense industrial base. U.S. defense budgets related to the procurement of weapon systems fell by more than 65% in real terms following the end of the Cold War (Perry, 1993). Defense firms responded to decreased

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defense spending by either exiting the industry or concentrating their operations within the defense industry (Augustine, 1997; Deutch, 2001). The defense industry consolidation has resulted in primarily three firms, Boeing, Lockheed Martin (LM), and Northrop Grumman, serving as prime contractors to the U.S. government for major weapon systems. The move toward an oligopoly of defense firms has led to concerns about the level of competition (e.g., Birkler et al., 2003; Kovacic, 1999) and is recognized as an area requiring further research (Lorell, 2003).

Government policy is an integral part of the structure of the defense industrial base as the government plays both the role of regulator and the only customer (Sapolsky and Gholz, 1999). A policy implication related to the consolidation of defense firms is that it has diminished the viability of some traditional methods of government oversight. Specifically, the impact of barring prime contractors from government work may be untenable. Quite simply, the impact of excluding prime contractors from defense contracts for misconduct, even temporarily, could be counterproductive when it eliminates the only available firm to meet a given requirement. For example, a suspension of Boeing's space division for military contracts was waived multiple times, since it was the only firm that could provide space launch services in the required time frames (Merle, 2003). Still, as a result of identified transgressions, Boeing will lose approximately $1 billion in business and gain a stronger competitor in the space business as LM rebuilds its space launch capabilities (Wong, 2003).

An important policy question is whether defense industry consolidation has maintained levels of competition needed to encourage both cost reduction and innovation (Birkler et al., 2003; Cole and Squeo, 1999). Some research has questioned whether competition within the defense industry actually contributes to either innovation or cost reduction (Birkler et al., 2001; Kovacic and Smallwood, 1994). For example, innovation in combat aircraft historically occurs at times of increased demand, emergence of new component technologies (e.g., engines, guided weapons, radar, and stealth), and significant changes in government requirements (Lorell, 2003). The goal of the current article is to examine competition in the

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U.S. defense industrial base and make associated recommendations to address policy concerns.

We define ''defense firms'' as companies that have established capabilities and competencies in dealing with the Department of Defense. The defense industry is a niche market in that it involves small numbers where both buyers and suppliers have significant bargaining power. Defense firms have developed a scarce competence in dealing with a monopsony customer with regulatory oversight (Driessnack and King, 2004). The scarcity of this competence can be readily observed as foreign firms and firms not accustomed to defense procurement teaming with defense firms when competing for a new U.S. Navy shipbuilding contract (Squeo, 2003).

Although an important sector of a nation's economy, it is difficult to perform empirical analysis of the defense industry (Anton and Yao, 1990). The difficulty in performing research on the defense industry has resulted in existing defense industry research exhibiting multiple shortcomings. One shortcoming of existing research is that studies often do not go beyond prime contractors, or the largest firms within the defense industry (e.g., Birkler et al., 2003), when the role of small firms in industries, in general, (King et al., 2003) and the defense industry, in particular (Squeo, 2002), has been recognized as important.[1] To overcome the challenge of performing meaningful research in the defense industry, we perform a case study (e.g., Eisenhardt, 1989; Yin, 1994).

Applying a case study methodology provides an opportunity to explore competition in the defense industry in a way that adapts to the context of a small numbers market. Specifically, a case study allows examining the interaction among the defense prime contractors and their suppliers within the defense market. We use transaction cost economics (Williamson, 1975) as the foundation for our examination of the defense industry. By considering the exchanges within a firm and its external partners, we are able to consider conditions that fall outside the classic assumptions of a competitive market. In collecting information on the defense industry, we focus our attention on the fighter aircraft industry.

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Fighter aircraft production requires capabilities above general aerospace manufacturing with increased technological demands for materials, avionics, engines, and systems integration that push the limits of design and engineering knowledge (King and Nowack, 2003). Additionally, aircraft programs involve technology development that is sensitive to both changes in technology and defense funding. Technological change has led to a periodic change in the number of firms competing for fighter aircraft development and to changes in the firm that has tended to win those contracts. For example, after emphasis shifted to avionics and guided missiles in the 1960s, McDonnell established leadership with its F-4 and F-15 aircrafts (Simonson, 1968). LM became the current industry leader, after it developed innovative stealth technology first used with the F-117 stealth fighter (Lorell and Levaux, 1998) that has been subsequently applied to F-22 and F-35 aircraft. However, there have been no new entrants into manned U.S. aircraft production since World War II, and the award of the last two U.S. fighter programs (i.e., the F-22 and F-35) to LM has heightened concerns about what can be expected from a dwindling number of potential aircraft suppliers.

Whether surviving defense firms will sustain competition and innovation in fighter aircraft design and production remains an open question. Part of the U.S. Cold War military strategy was to use technology to counter the vast size of the Soviet military (Kitfield, 1995). While only the United States currently operates stealth aircraft, Russia and Japan are reportedly working on developing stealth aircraft (Lambeth, 1996), so continued technological leadership by the United States in fighter aircraft technology requires continued innovation. Since the leadership of LM in fighter aircraft is representative of concerns about competition in the defense industry, we perform an in-depth examination of LM's F-22 program. Before performing that examination, we outline our application of transaction cost economics.

II. Theoretical Foundation

Transaction cost economics (North, 1990; Williamson, 1975) holds that managers choose the least costly method of organizing. Market exchange is generally considered more efficient than internalizing transactions, as it allows parties of a transaction to be

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competitively selected and drives the most efficient pricing for buyers and suppliers. However, Williamson (1975) suggests that market failure precludes market exchange and drives internalization of exchanges within a firm. Williamson (1975, 39–40) originally outlined five situations that involve market failure:

- Bounded rationality: human beings tend to search for adequate and not optimum solutions,
- Uncertainty/complexity: conditions without readily discernable patterns or manageable number of interactions that would facilitate decision making,
- Information impactedness: information asymmetry involving situations where one party is better informed than the other, making contractual arrangements difficult or expensive to verify,
- Opportunism: power imbalances that allow one party of a contractual relationship to pursue self-interests, and/or
- Small numbers: reduction in business choices resulting from limited quantities of either buyers or suppliers.

Later, a sixth market failure involving ''asset specificity,'' or a condition created from recurring transactions that creates progressively stronger bilateral relationships, was identified (Williamson, 1979).

The defense industry, with a limited number of suppliers and a single, government buyer, represents a small numbers market that would normally disband due to market pressures (i.e., new entrants). However, government procurement regulations, designed to minimize the potential for defense contractor opportunism, act as an entry barrier that results in newcomers and small firms teaming with defense firms that are familiar with defense procurement. Additional entry barriers relate to the level of technology capability required and the requirement for government security clearances to participate in the market. For example, building the necessary skills and supporting infrastructure to support entry into technological demanding markets such as fighter aircraft can take decades (King and Nowack, 2003).

The role of defense prime contractors has evolved over time and increasingly involves providing ''system integration,'' or a coordinating role to ensure subsystems operate effectively together in an overall weapon system. Systems integration is crucial to fielding effective weapon systems within a reasonable time at an affordable price. In the past, the U.S. government provided selected subsystems as government finished equipment, and at times, the government acted as the final systems integrator. For example, the government played an active role in the integration of systems on the B-1B bomber. However, changing technology and increased reliance by the government on commercial practices has transferred the role of integrating subsystems to major defense firms (Lorell et al., 2000). At the same time, the increased emphasis on cost in a post–Cold War environment has contributed to major defense firms to allocate increased technical and financial responsibility to their suppliers.

The combined impact of increased integration responsibilities and sharing of risk is a distribution of work within a technology market (i.e., Arora et al., 2001). This can be observed in an increased use of teaming by defense firms (Kovacic and Smallwood, 1994) (see Figure 1). Additionally, the amount of work performed by defense prime contractors in-house has decreased over time. For example, in the early 1960s, aircraft firms performed approximately 45% of work in-house (Hall and Johnson, 1968). Currently, LM with the F-22 contract performs 25% of the work in-house, or roughly half the work that was performed in-house on earlier programs.[2]

The transaction costs associated with the difficulty of exchanges between prime contractors working to integrate subsystems into a working weapon system helps determine the governance structure the prime contractor uses to develop and produce a weapon system. The more problematic a transaction, the more likely it will be internalized (Williamson, 1975). Less problematic transactions, where technical and financial risk can be shared, will lead to closer supplier relationships, such as alliances or joint ventures. However, long-term relationships are expensive to maintain, so organizations tend to have no more partners than necessary (Humphries and Wilding, 2001). Meanwhile, market-driven exchanges allow greater competition for part and component suppliers, and a greater number of potential

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suppliers will allow a prime contractor to either identify preferred suppliers or use full-and-open competition. The anticipated impact of transaction costs on a prime contractor's governance structure of a weapon system is shown in Figure 2.

III. LM F-22 Raptor

A. Background

The initial requirement for an Advanced Tactical Fighter (ATF) to replace the F-15 Eagle was identified by the Air Force in 1981, and, in 1985, seven manufacturers were awarded initial concept definition contracts (Wall Street Journal, 1985). The field of seven was later narrowed to two contractor teams for building ATF prototypes with a partnership of Lockheed, General Dynamics (GD), and Boeing on one team and Northrop and McDonnell Douglas on the other (Charles, 1987). A competitive fly-off of the competing designs with Lockheed's YF-22, emphasizing maneuverability, and Northrop's YF-23, emphasizing stealth and speed, was used to determine the winner of the ATF development contract (Wartzman, 1991).

Formal teaming in the ATF competition allowed firms to share the risk of developing a prototype, and, in 1991, the Lockheed-led team won the ATF design competition (Schine, 1991). The F-22 design incorporated multiple technology advances, including super cruise (the ability to exceed the speed of sound without using afterburner) and vectored thrust engines, providing improved maneuverability.[3] Lockheed subsequently acquired GD's aircraft division for $1.52 billion, in 1993, procuring its portion of the F-22 contract and F-16 production (Wall Street Journal, 1993). The GD acquisition increased Lockheed's share of the F-22 program to 67.5%, while Boeing maintained a 32.5% share. After winning the design competition, the F-22 program entered Engineering Manufacturing and Development (EMD) with a focus on establishing a stable, cost-effective design that further validates system capabilities through testing.

During EMD, the F-22 program experienced several noteworthy events. Although delayed due to minor technology problems common to new aircraft development, the first flight of an F-22 took place on

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September 7, 1997 from Lockheed's Marietta, GA, facility (Kandebo, 1997). The F-22 program experienced additional turbulence because of concerns over the cost of having three aircraft programs (i.e., F-22, F-35, and F/A-18E/F) under development at the same time, leading to the F-22 program to experience political criticism. For example, in 1999, the House of Representatives voted to eliminate funding for the F-22 program (Squeo, 2003).[4] Most recently, the 2006 Quadrennial Defense Review reviewed and reversed recent reductions to F-22 procurement (King, 2006). Further, the F-22 program has recently met several milestones, including Full Rate Production (April 2005), Initial Operational Capability (December 2006), EMD completion (March 2006).

B. Governance Structure

From the beginning of the F-22 program, LM took a collaborative approach to ensure that their ATF design was the most competitive, with Boeing having considerable experience with integrating avionics systems (Kovacic and Smallwood, 1994) and composite materials (Lorell, 2003) and GD having the most recent production experience with the literally thousands of F-16 aircraft produced.

The distribution of work across Boeing and the divisions ofLMdoes not explain the extent of the industrial base supporting F-22 development and production. Other firms in the defense market make significant contributions with over 1100 suppliers in more than 40 states supporting the F-22 program.[5] The result—less work is performed by LM and Boeing on the F-22 than would generally be assumed. This facilitates a division of innovative labor and allows firms to exploit industry-wide economies of scale in technology (e.g., Arora et al., 2001).

LM's formal corporate policy on ''make or buy'' decisions involves the application of competitive principles in order to make ''best-value'' decisions and does not provide preferential treatment to LM business units. Development of major F-22 subsystems was competed by Lockheed during the ATF competition. Key ATF suppliers were carried over from the prototype phase to EMD based on a

competition sensitivity analysis performed by LM. Major subsystems were designated as sole source based on cost or the complexity of the work. These observations are consistent with our framework that exchanges on the F-22 program are driven by transaction costs. The actual distribution of work on the F-22 program is shown in Figure 3, and it shows that LM acts as the final systems integrator, performing a minority of work on billable materials. Billable materials represent the summation of all supplier costs (i.e., raw material, recurring labor, direct product engineering, factory support, overhead, general and administrative, and profit) to the prime contractor that performs final assembly. Using this measure allows examining relationships below the prime contractor level that have not been examined in extant research.

Internalized Transactions. Fighter aircraft manufacture is demanding, and work retained by LM entails complex tasks. Only a quarter of work on the F-22 program has been kept internal to LM, with retained work primarily involving core competencies based on stealth technology and manufacture of major structural components (see Figure 4).[6] Additionally, Lockheed[7] acted to internalize key fighter production capability with its acquisition of GD's aircraft division, in 1993.

Though initially criticized as a potential misstep (Cole, 1994), there is little doubt that the acquisition of GD's aircraft division enhanced LM's capabilities as a defense firm and had a positive impact on LM's subsequent cash flow and earnings. Through the acquisition of GD's aircraft division, Lockheed gained access to an additional 32.5% of the F-22 contract and to F-16 aircraft contracts. Based on the dollar value of current and planned F-22 contract awards, it is estimated that LM will or has received an additional $10.5 billion in cash flows resulting from the acquisition of GD's aircraft division. Additionally, since 1993, LM has been awarded $13 billion in F-16 contracts by U.S. and foreign governments and is expected to gain up to $5 billion in cash flows related to sustaining F-16 U.S. military operations through 2018. For a $1.52 billion investment, LM gained access to cash flows valued at $1.6 billion.[8] In addition to benefiting LM, it is also reasonable that the acquisition benefited the defense

industrial base by reducing surplus capacity and putting excess resources to more productive work (Duetch, 2001).

Long-Term Relationships. Competition has forced prime contractors to specialize their technology portfolios and develop strategic alliances with other firms that can more efficiently provide needed products and expertise. LM continues to maintain a long-term teaming relationship with Boeing for F-22 aircraft, where Boeing is responsible for the F-22's avionics and the manufacture of F-22 wings and rear fuselage (see Figure 4). The management of Boeing's F-22 work is similar to LM and is consistent with minimizing transaction costs. For example, the manufacturing of wings for the F-22 represents a complex, labor-intensive process in that involves building a web of carbon fiber and titanium spars by hand (Gates, 2003); therefore, Boeing performs this work internally at its Seattle plant. However, Boeing also uses external suppliers to streamline production and ensure costs remain competitive.

For its share of the F-22 contract, Boeing distributes work between itself and suppliers (see Figure 3). In comparison to total F-22 billable materials, Boeing only performs 12% of F-22 work internally, and an additional 14.3% goes to Boeing's strategic suppliers. Boeing's largest subcontract representing 5.3% of F-22 billable materials was awarded to a Northrop Grumman and Raytheon team to build the F-22 radar. Boeing also competitively awards 5.8% of F-22 billable materials to suppliers.

Single-Source Suppliers. LM has developed relationships with key suppliers with eight out of the ''top 10'' F-22 subcontractors representing competitive selection of sole-source suppliers. For example, BAE supplies the electronic warfare system for the F-22 and Northrop Grumman supplies the F-22's navigation system, which represent 5.7% and 5.0% of billable materials on the F-22, respectively. Together, the top 10 F-22 subcontractors perform roughly 18% of the billable materials on F-22 production.

Both BAE and Northrop Grumman supply LM subsystems for the F-22 and the F-35. For example, Northrop Grumman performs around

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10% of the work on the F-22 radar under Boeing and the F-22 navigation system for LM, even though it lost the ATF competition and the company represents a competitor to both LM and Boeing. Additionally, Northrop Grumman has a 20% share of the work on the F-35 program led by LM (Lorell, 2003). An implication of LM selecting the most competitive suppliers on major subsystems for its aircraft programs is that it helps maintain the market for technology in the defense industry.

Competition. Consistent with transaction cost theory,LMuses competition for general material (e.g., sheet metal, machined parts, and electromechanical hardware) that involve less uncertainty/complexity and where multiple suppliers exist. When only considering the F-22 prime defense contractors, close to 17% of billable materials for F-22 production is competed on an on-going basis (see Figure 3). Including work performed by additional tiers of the defense industrial base would only increase the amount of work on F-22 production that is still exposed to market forces.

LM has used innovative approaches to ensuring competition, where appropriate. For example, LM has embraced electronic commerce to ensure competed work is awarded at the lowest possible cost through improved information flow. Although skepticism about applying electronic commerce to the aerospace industry have been voiced (Mecham, 2001), LM in a single example of employing a reverse auction online saved over $2.2 million in material costs as their electronic marketplace led to reduced prices through competitive forces.

IV. Conclusion

Even though the government awarded the F-22 contract to LM, winning the contract required that LM team with other defense contractors to offer the best performance at the lowest price. Further, the government's continuous emphasis on cost has driven competition into the F-22 program. Figure 3 shows that LM and Boeing compete 16.9% of F-22 work—a number that would be higher if additional competition held by subcontractors was included.

Simply assuming that a greater number of defense firms in the past resulted in greater competition may not be valid. First, the ability of defense firms to charge unreasonable prices is checked by the government's role as both the sole customer and regulator. In fact, there is no reason to conclude that the level of competition in the defense industry has decreased or that costs charged to the government are not fair and reasonable, as analysis indicates that defense firms exhibit lower financial performance than commercial firms (Bowlin, 1999). Second, it could be argued that the level of competition in past fighter programs was actually lower. For example, only four defense firms competed for the F-15 contract that was awarded without a competitive fly-off (King and Massey, 1997), while seven firms competed for the F-22 contract that was awarded after a competitive fly-off. Third, advancing technology and specialization has required teaming between defense firms so they can offer the most competitive design solutions and share risk. This suggests that it may be more reasonable to say that the level of competition in the defense industry has increased because its market for technology is more developed.

The end result of specialization by surviving defense firms and current teaming and outsourcing practices is arguably a more robust U.S. defense industrial base (Heinrich, 2002). A side effect of increased teaming is that a greater number of firms gain experience dealing with key technologies, such as stealth, increases competition for subsequent contracts (Kovacic and Smallwood, 1994). Therefore, even though the number of prime defense firms has decreased overtime, competition still exists as remaining firms compete for a larger share of procurement efforts at the second tier and below.

A. Policy Implications

Policy makers need to realize that applying the classic assumptions of a competitive marketplace with multiple buyers and sellers to the defense industry will result in suspect policy recommendations (Langlois and Robertson, 1995) and could have consequences other than those intended (King and Driessnack, 2003). For example, policy recommendations to shore up competition by maintaining two sources of supply may be misguided. For example, a

recent RAND study examining whether to maintain two suppliers for the F-35 program concluded that the cost associated with that option would outweigh any anticipated benefits (Birkler et al., 2001). Instead of a fixating on maintaining a second source of supply for weapons systems, policy makers may be better served by focusing on competition within the market for technology within the defense industry.

Our findings indicate that policy makers in evaluating the efficiency of transactions (i.e., cost-effectiveness) should use a transaction cost perspective that considers the structure of the defense market and related transaction costs and then consider whether any feasible, superior alternatives exist (Williamson, 1985). Ensuring work is delegated to appropriate tiers of the defense industrial base will help maintain needed competition and innovation, while allowing prime contractors to leverage their core capabilities of systems integration and interfacing with a government customer at reduced overall cost.

Additionally, history indicates that innovation is sustained as long as credible rival firms (Lorell, 2003) or technologies are present. The emergence of Unmanned Aerial Vehicles (UAVs) may represent a new innovation that may change the structure of the defense industry. For example, after the initial market entry by General Atomics Aeronautical Systems with Predator, in 1994, the market for unmanned aircraft is expected to reach $10 billion (Johnson, 2003). It is reasonable to expect that vigorous competition will transform the leadership of the aircraft industry with new entrants competing for future UAV development projects (Birkler et al., 2003). Policy makers need to encourage the development of rival technology to maintain competition and innovation.

B. Summary

Researchers (e.g., Quinn, 2000; Womack et al., 1990) have identified outsourcing as a means for firms to achieve faster and lower cost innovation, as long as managers focus on their firm's core competencies and have established outsourcing management practices. Prime contractors in the defense industry and LM, in particular, appear to have taken this information and made it central

to their business strategy. We find that LM has focused on leveraging its core capabilities and experience of interfacing with its government customer in managing F-22 contracts. Specifically, LM focuses on manufacture, integration, and final assembly of aircraft, while outsourcing other systems through teaming (e.g., Boeing and F-22 avionics), supplier relationships, or competition. The defense firms specializing in integration are decreasing costs by increasing the level of competition and innovation in the defense industry through increased outsourcing, and government policy should encourage its continued practice on the F-22 and other programs.

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Notes

[1] In fiscal year 2003, LM exceeded government on small business mandates by awarding over 5% of the dollar value of F-22 work to small businesses on 500 procurement actions.

[2] The authors were provided in-depth access to information on LM's subcontract management.

[3] The F-22's F119 engine is provided by Pratt & Whitney as government finished equipment and is not included in our analysis.

[4] The threat of program cancellation has acted as an incentive to lower program costs. This is not an idle threat as major programs such as the Navy's A-12 and the Army's Crusader weapon systems have been cancelled due to cost overruns and changing requirements respectively (e.g., Jaffe et al., 2002; Pasztor, 1991).

[5] LM contracts with approximately 600 subcontractors while Boeing contracts with roughly 500 subcontractors.

[6] LM manufactures the mid- and forward fuselage and performs final assembly of the F-22 aircraft.

[7] At the time of the acquisition of GD's aircraft division, Lockheed's merger with Martin Marietta, which resulted in the current firm name of Lockheed Martin, was still to come.

[8] The value of anticipated cash flows was calculated with a discount rate of 3.95% using the procedure described by Copeland (2000) with the exception that operating income is estimated to be 12% of cash flows, as the U.S. government limits the profit earned on defense contracts.

Abbreviations

ATF: Advanced Tactical Fighter
EMD: Engineering Manufacturing and Development
GD: General Dynamics
LM: Lockheed Martin
UAV: Unmanned Aerial Vehicles

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Figure 1
Teaming of Aircraft Prime Contractors by Program.
Updated from Birkler et al., 2003

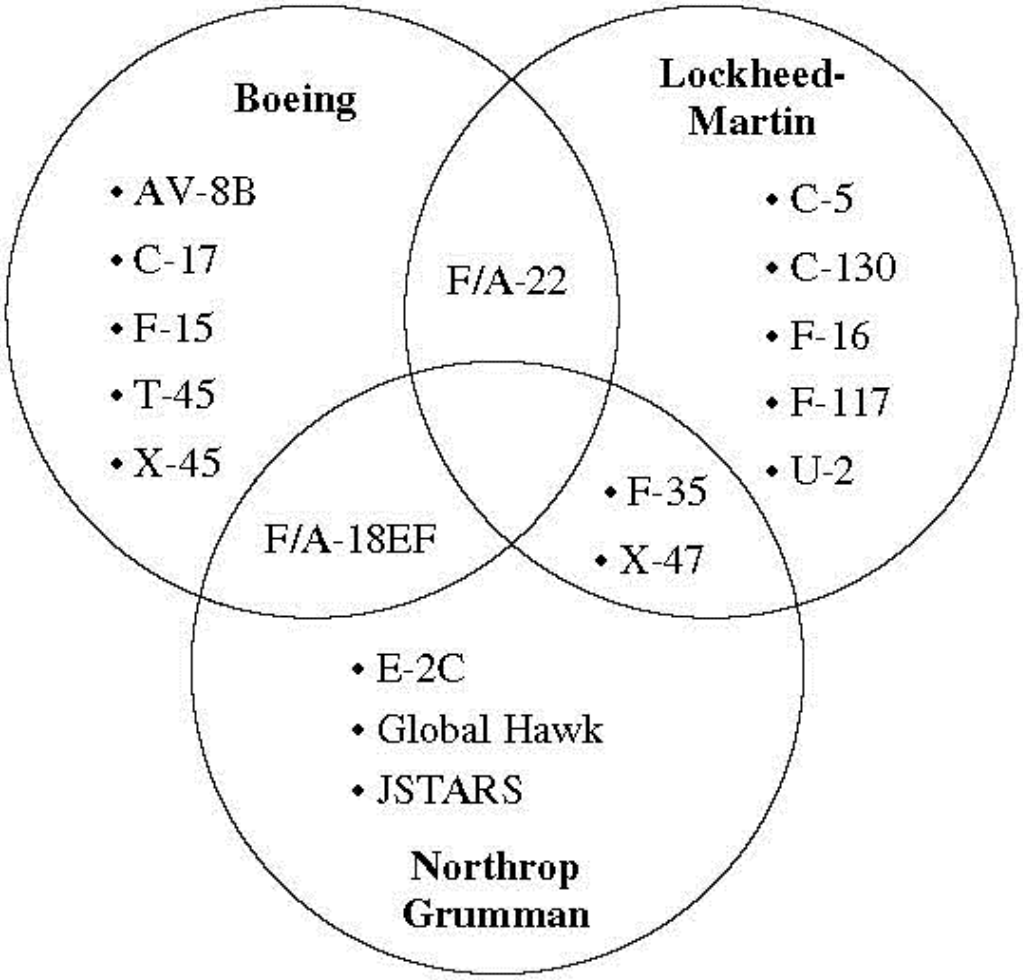

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FIGURE 2
Impact of Transaction Costs on Governance

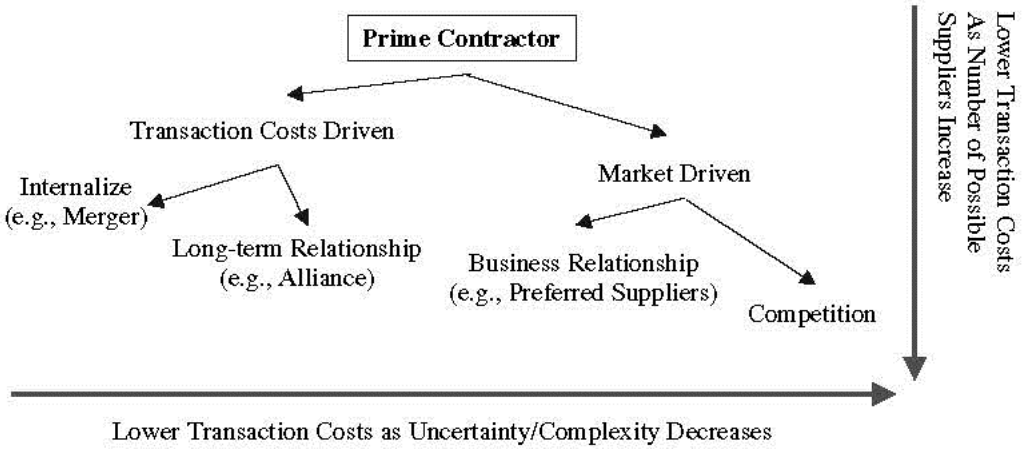
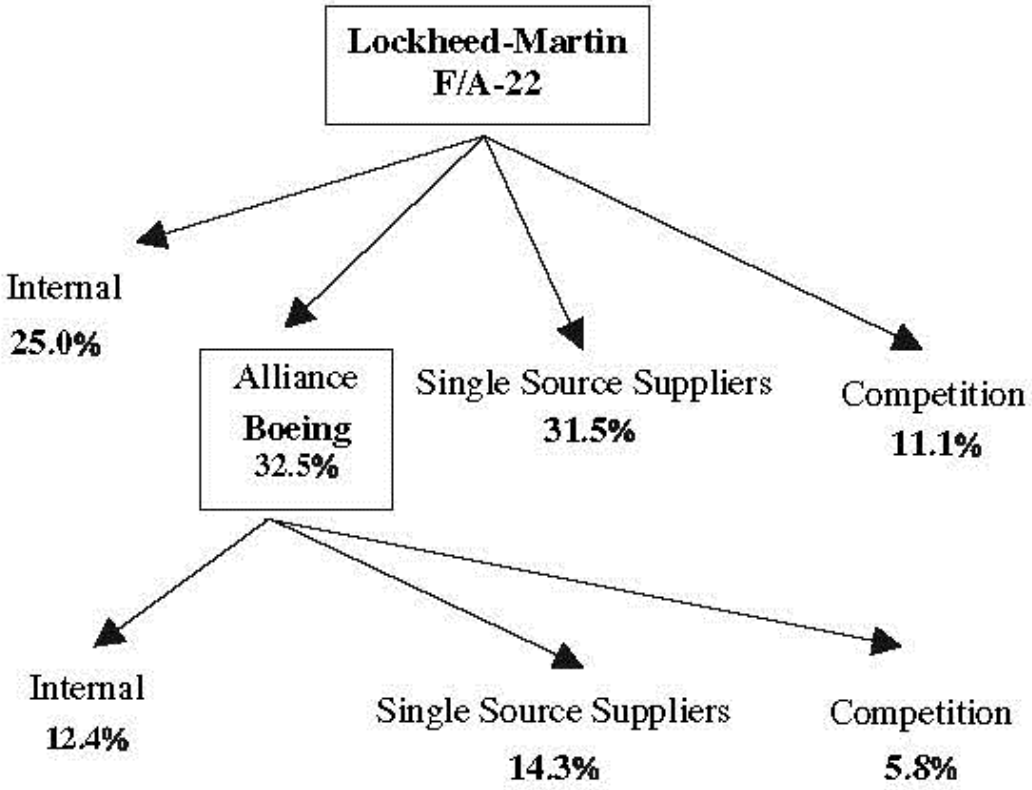


FIGURE 3
Governance of F-22 Raptor



Source: LM Corporation; percentages represent portion of total billable material.

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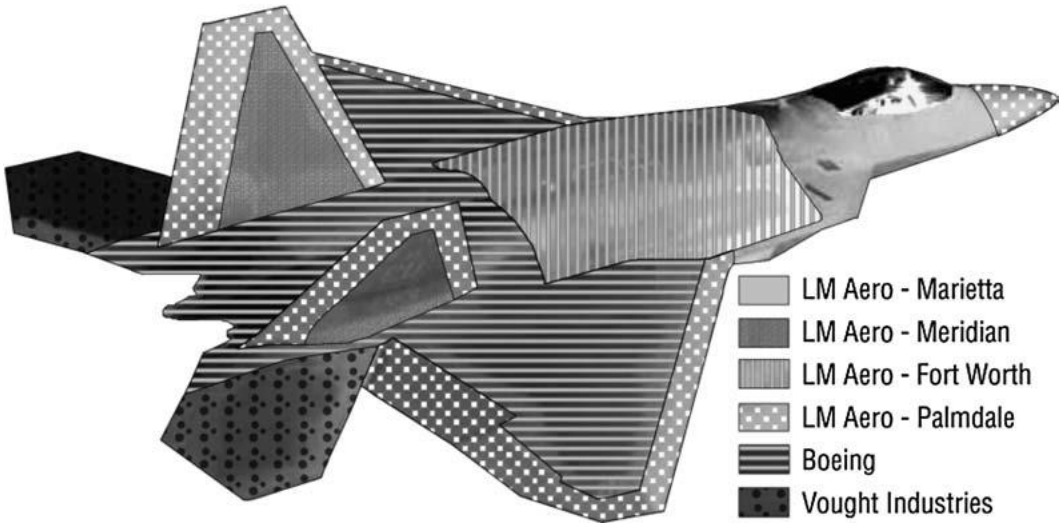
Figure 4
Distribution of Work on F-22 Production



Source: LM Corporation.