Make-Buy Decisions in the U.S. Aircraft Industry

by

Robert K. Perrons

B.Eng., Mechanical Engineering
McMaster University, 1995

Submitted to the Technology and Policy Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science
in Technology and Policy
at the

Massachusetts Institute of Technology
September 1997
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Technology and Policy Program
August 8, 1997

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Abstract

The U.S. aircraft industry is going through a process of rapid and fundamental transformation on many levels. Drastic changes in both the level and composition of customer demand for commercial as well as military aircraft, a frenzy of consolidations in the industry, the emergence of lean manufacturing, and the “globalization” of supplier networks are making the aerospace sector very different from what it used to be. But the new realities of the industry go further than merely redefining the role of the independent aircraft company in its changing environment; they are also reshaping the very boundaries of each firm in the aircraft sector. It is therefore crucial for managers in the industry to understand one of the principal mechanisms by which a company controls the scope of its in-house activities: make-buy decisions.

This thesis approaches the topic of make-buy decisions in the U.S. aircraft industry in four ways. One, it offers insight into the circumstances and criteria behind make-buy decisions in the industry by examining two case studies involving commercial and defense products, respectively. The case studies focus as well on the vertical relationships among the companies examined, and how these relationships are realigned as a result of the prime’s make-buy decisions. Two, this thesis proposes a framework that explains ex post how managers in the industry decide to make or buy a particular component or process, and that provides guidelines for approaching future make-buy decisions. The framework concentrates on two major factors that play key roles in the aircraft sector’s make-buy judgments: the degree of technological maturity of the component or process, and the relative competitive market position of a firm with respect to the particular technology underlying the component or process. Three, this thesis recommends a make and buy strategy that large companies in the industry should consider for securing and maintaining a leading role in their respective core competencies. Four, it addresses the principal ways in which the aircraft industry’s make-buy decisions may be affected by or may eventually lead to changes in the policies of the U.S. government.

Thesis Supervisor: Kirkor Bozdogan
Research Associate, CTPID
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This thesis simply would not have been possible without the help of many people. In the footnotes of the pages that follow are the names of many kind souls who—let’s face it—had more important things to do, but who took time out of their busy day to answer my questions. This is especially true of Geary Long, Steve Coe, Leo Baldyga, Ed Lindgren, and John Gilliams. A nicer and more helpful bunch of guys cannot be found.

I also want to thank the entire LAI team for its helpful insights and good humor. One simply cannot sit down to write a one-hundred-and-some-odd page document without needing to chuckle and share with friends now and again. The team’s input was helpful, yes, but its geniality was necessary in finishing this work.

As well, I want to express my gratitude to my advisor, Dr. Kirk Bozdogan, who always asked for, well, more. No matter what one’s opinion of this thesis might be, it is undoubtedly better than I would have done if left to my own devices. Moreover, his fresh ideas and wealth of experience always seemed to shed light on the darkest of issues.

And finally, many thanks are owed to my wonderful girlfriend, Kristine, who more than once had to watch the 11 o’clock news alone because “I had a neat idea that I just had to get onto paper before it left my head.” I am one lucky fella.
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<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BCAG</td>
<td>Boeing Commercial Airplane Group</td>
</tr>
<tr>
<td>BD&amp;S</td>
<td>Boeing Defense &amp; Space Group</td>
</tr>
<tr>
<td>BMI</td>
<td>Bismaleimide</td>
</tr>
<tr>
<td>CDP</td>
<td>Concept Demonstration Program</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CTIPID</td>
<td>Center for Technology, Policy, and Industrial Development</td>
</tr>
<tr>
<td>DOD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DOJ</td>
<td>Department of Justice</td>
</tr>
<tr>
<td>Dow-UT</td>
<td>Dow-United Technologies</td>
</tr>
<tr>
<td>EMD</td>
<td>Engineering and Manufacturing Development</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<tr>
<td>FEM</td>
<td>Finite Element Modeling</td>
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<tr>
<td>FTC</td>
<td>Federal Trade Commission</td>
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<tr>
<td>GATT</td>
<td>General Agreement on Tariffs and Trade</td>
</tr>
<tr>
<td>GM</td>
<td>General Motors</td>
</tr>
<tr>
<td>IMVP</td>
<td>International Motor Vehicle Program</td>
</tr>
<tr>
<td>IPD</td>
<td>Integrated Product Development</td>
</tr>
<tr>
<td>IPT</td>
<td>Integrated Product Team</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
</tr>
<tr>
<td>JIT</td>
<td>Just-In-Time</td>
</tr>
<tr>
<td>JSF</td>
<td>Joint Strike Fighter</td>
</tr>
<tr>
<td>LAI</td>
<td>Lean Aircraft Initiative</td>
</tr>
<tr>
<td>Mil. Spec.</td>
<td>Military Specifications</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>MITI</td>
<td>Ministry of International Trade and Industry (Japan)</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
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<td>---------</td>
<td>-----------------------------------------------</td>
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<tr>
<td>NUMMI</td>
<td>New United Motor Manufacturing Inc.</td>
</tr>
<tr>
<td>POP</td>
<td>Purchased Outside Production</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>RTM</td>
<td>Resin Transfer Molding</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
</tr>
<tr>
<td>SPO</td>
<td>System Program Office</td>
</tr>
<tr>
<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>U.S.</td>
<td>United States</td>
</tr>
<tr>
<td>VPs</td>
<td>Vice Presidents</td>
</tr>
<tr>
<td>WPAFB</td>
<td>Wright-Patterson Air Force Base</td>
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CHAPTER 1: INTRODUCTION

The principal goals of this thesis are four-fold. One, it will offer insight into the circumstances and criteria underlying make-buy decisions in the U.S. aircraft industry. Two, it will propose a framework that explains *ex post* how managers in America’s aerospace sector decide to make or buy a particular component or process, and that offers suggestions for future outsourcing judgments in the industry. Three, it will recommend a strategy that large companies in the aircraft sector should consider for securing and maintaining a leading role in their respective core competencies. Four, it will address the principal ways in which the aircraft industry’s make-buy decisions may be affected by or lead to changes in the policies of the U.S. government.

1.1 MOTIVATION FOR RESEARCH

DEFENSE AIRCRAFT

The entire U.S. aerospace industry is going through a process of rapid and fundamental change. The collapse of the former Soviet Union has removed the principal threat to America’s security. And as the perceived threat to the country has diminished, so too has the U.S. government's willingness to pay for the nation's defense. This has resulted in drastic cuts in both the number of defense aircraft development programs and the number of units expected to be purchased under each program.1 Figure 1.1 underlines

the profound reduction in the aircraft procurement budget of the Department of Defense (DOD) since the end of the Cold War.

![Military Aerospace Industry Sales, 1987-1997](image)

**Figure 1.1: U.S. Military Aerospace Industry Sales, 1987-1997**

With sales being only a fraction of what they once were, defense aerospace companies are being forced to do more with less.

**COMMERCIAL AIRCRAFT**

Ironically, while the number of defense aircraft purchased by the DOD continues to fall, demand for commercial airplanes has been increasing steadily to meet the needs of the growing world economy. The number of worldwide passenger flights between 1992 and 1995 grew at approximately 6.5 percent per year. If unabated, this trend towards increased travel will result in a worldwide demand of about 16,000 new airplanes over the next 20 years, worth a total of more than $1 trillion in 1995 dollars.

Despite its glowing sales projections, however, the commercial aircraft sector is facing pressures of its own. The two major players in the market, Boeing and Airbus, are fiercely vying against one another for sales contracts around the world. As well, the

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3 The Boeing Company's 1995 annual report, p. 33.

4 Boeing 1995 annual report, p. 5.
deregulation of airlines in the United States has caused carriers to be more cost-conscious than ever. Air travel is becoming somewhat of a commodity, and airlines are facing lower profit margins as a result. Towards improving these margins, airlines are pressuring aerospace manufacturers to build airplanes that are cheaper and that have lower operating costs than before. This constant push to reduce costs has re-defined the industry significantly. In the words of one manager in Boeing’s Commercial Airplane Group (BCAG), “tomorrow’s leading commercial aerospace firms will probably be those that lead the way with... cost saving measures.”

EXTERNAL CUES FOR CHANGE

Indeed, changing customer needs in both the defense and commercial aircraft sectors are causing firms to change the way they do business. But there are also forces other than customer demand that are profoundly changing the face of the industry. Many firms in the aerospace sector have consolidated their operations with those of their suppliers or even their competitors. Information technologies have evolved to a degree that allows firms to communicate with one another almost instantly, thereby allowing several companies to coordinate their design and manufacturing activities. International borders have become less of a barrier to commerce, and companies have undergone a process of “globalization.” In short, the overall role of any one firm in the U.S. aerospace industry is very different in many ways from what it used to be.

However, the new customer demands of the aerospace market and the new realities of the business world go further than merely redefining the role of the independent aerospace company in its changing environment; they are also reshaping the very boundaries of each firm in the industry.

Towards redesigning the boundaries of their firms in the marketplace, and adapting to the rapid changes in the business world, U.S. aerospace companies in both the military and commercial sectors have begun to adopt the principles of the lean manufacturing system.

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5 Gilliams, John N. Mr. Gilliams is a Contracts Manager in BCAG’s Materiel Division. By interview with author, 28 August 1996.

1.1.1 The Lean Manufacturing System

To describe the remarkable new approach to manufacturing practiced by Japanese auto manufacturers, MIT's International Motor Vehicle Program (IMVP) coined the term "lean." "As a concept, 'lean' includes several of the popular concepts of management research, such as Total Quality Management (TQM), Continuous Improvement, Integrated Product Development (IPD), and Just-In-Time (JIT) inventory control—but lean manufacturing attempts to unite these niche topics into a unified philosophy for producing products."7 The lean manufacturing system is fundamentally different from the mass production system championed by North American and European manufacturers throughout most of this century insofar as it has:

a different operational framework, corporate culture, and organizational structure. The term "lean" manufacturing was selected because the associated techniques require significantly fewer resources than previous methods. For instance, compared to mass production, lean manufacturing uses less human effort in the factory, less manufacturing space,... fewer engineering hours to develop new products, and less inventory on-site. In addition, lean production results in fewer defects while producing a greater variety of products. From a philosophical perspective, practitioners of mass production set limited goals for "good enough" performance, while lean producers set their sights on perfection. This attitude is evidenced by the major goals of lean production, namely, perfect first-time quality, waste minimization, and continuous improvement. The corresponding desired outcome is lower production cost, improved product quality, higher productivity, efficiency at a lower scale of production, rapid product development cycle, and product mix diversity.8

1.1.2 Rethinking the Boundaries of the Firm

One of the key ideas of the lean production system is that of the "extended enterprise"—a group of closely knit firms that draws on the synergy of its members to create a highly productive corporate family. This concept is founded on the understanding that the combined resources, experiences, and ideas of several companies can, if managed correctly, outperform those of any single firm. Indeed, this cooperative

approach is quite different from the “arm's length” way of doing business that has traditionally been practiced in the West.

But there is more to the lean manufacturing system than how companies interact with one another. To become lean, a company’s managers have to re-evaluate on a fundamental level what the role of their firm ought to be in this new, more cooperative environment. In other words, a firm has to assess what it should do itself, and what tasks it should relegate to outside suppliers. The functions that once played an integral role in a company’s day-to-day operations might instead be outsourced to other companies as firms reconsider what their “core competencies” are. It is therefore crucial for managers in the industry to understand one of the principle mechanisms by which a company controls the scope of its in-house activities: make-buy decisions.

A single make-buy decision in and of itself may not seem to be of great consequence to a company. Among the many parts and processes that a firm needs to make a product, relatively few are of critical importance to the firm’s survival and success. But the aggregate of these decisions effectively defines the scope of what a company is and is not doing. In other words, “the resolution of [make-buy] questions defines the boundary of the firm.”


1.2 RESEARCH GOALS AND METHODOLOGY

1.2.1 Developing a Framework for Make-Buy Decisions

To be sure, there are already several bodies of work from disparate disciplines that deal with the topic of make-buy decisions. But while these efforts are a good starting point in thinking about outsourcing issues, they fail to address the key distinguishing characteristics that set the U.S. aerospace industry apart from other sectors of the economy. Moreover, previous outsourcing frameworks have typically approached the problem from more traditional points of view, such as transaction cost analysis and overhead allocation. And in the spirit of classical Western management techniques,

these attempts have embedded in them a philosophy of the single firm enterprise; that is, every firm is more or less a corporate island unto itself, constantly looking out for the maneuvers of its competitors and suppliers, but rarely working in concert with other companies. However, this approach does not reflect the more intimate inter-firm relationships fostered by lean manufacturers.

Towards understanding the aircraft industry’s make-buy decisions in a lean environment, this thesis will propose a framework that explains ex post how managers in the aerospace sector decide to make or buy a particular component or process, and that provides guidelines for approaching future make-buy decisions in the industry. As well, this thesis will outline a make and buy strategy that large companies should consider for securing or maintaining a leading role in their respective core competencies. Questions to be addressed include:

- What are the key determinants of current make-buy decisions in the defense and commercial sectors of the U.S. aerospace industry?
- How are make-buy decisions made within specific companies?
- How do make-buy decisions in the commercial aerospace industry differ from those in the defense sector?
- How do outsourcing judgments in today’s U.S. aerospace industry differ from those of classical lean manufacturers?
- What are the ramifications of “globalization” on the make-buy decisions of both defense and commercial aerospace manufacturers?
- How can the lean model’s more intimate inter-firm relationships be reconciled with America’s current antitrust legislation?

1.2.2 Research Approach

Outsourcing decisions are not always driven by numbers. Political and strategic forces often play key roles in a manager’s decision to make or buy a component or process. To develop an appreciation for all the factors—both formal and informal—that go into outsourcing judgments, a series of site visits and interviews was conducted with the managers and workers who were involved with the make-buy decisions analyzed in this study.
Two supply chains were examined. The first involves the development and production of the main landing gear for the Boeing 777, a key component for a high-profile commercial aircraft program. Also of principal importance to this study is the fact that the component is based on relatively mature technologies that are well understood by several companies within the industry.

The second supply chain looks at the development and production of the sinewave spars used in the wings of the F-22 strike fighter aircraft. The sinewave spars are markedly different from the 777’s landing gear in two regards. First, the F-22 is a high performance defense aircraft. Second, its development and production involves technologies that are relatively nascent. Thus, by examining these two case studies, this thesis will examine how make-buy decisions differ between commercial and defense projects, as well as how they differ between components that involve relatively nascent technologies and those that involve well-established technologies.

To find out how make-buy decisions vary at different tiers of the supply chain, interviews were conducted at three different levels within each chain: the prime contractor, a first-tier supplier, and a second-tier supplier. The participating companies and their respective locations in their supply chain are shown in Figure 1.2.

1.2.3 Outline of Chapters

Chapter 2 will review the existing literature on the topic of make-buy decisions, identify the major differentiating characteristics of the U.S. aerospace industry which set it apart from other sectors of the economy, and outline the research strategy followed in this thesis in light of these previous considerations. Chapters 3 will provide a detailed discussion of the circumstances surrounding the make-buy decisions involving the development and production of the 777’s main landing gear. Chapter 4 will examine the factors underlying the outsourcing judgments made throughout the development and production of the F-22’s sinewave spars. Chapter 5 will propose a framework that seeks to provide a more systematic explanation, ex post, for the make-buy decisions examined in Chapters 3 and 4, and by extension, in the U.S. aircraft industry more generally. Chapter 6 will address the principal ways in which the aerospace industry’s
make-buy decisions may be affected by existing policies of the U.S. government, and how these decisions may affect future policies. Finally, Chapter 7 will summarize main findings, put forth several recommendations regarding outsourcing decisions for aerospace contractors, and offer some directions for future research.

Figure 1.2: Supply Chains Examined in This Study
CHAPTER 2: LITERATURE REVIEW AND DISCUSSION OF U.S. AEROSPACE INDUSTRY'S DISTINGUISHING CHARACTERISTICS

This chapter will review the existing literature on the topic of make-buy decisions, identify the major differentiating characteristics of the U.S. aerospace industry which set it apart from other sectors of the economy, and outline the research strategy followed in this thesis in light of these previous considerations.

2.1 REVIEW OF LITERATURE ON MAKE-BUY DECISIONS

TRANSACTION COST THEORY

While most significant research focusing on make-buy decisions has occurred within the last 20 years, the topic dates back to at least 1937, when Coase put forth a theory explaining why companies elect to "make" some of their inputs in-house and "buy" the rest from outside firms. At the heart of his explanation was Adam Smith's "invisible hand": The degree to which a company is vertically integrated and in what ways are chiefly determined by the fundamental laws of supply and demand. But as Coase himself points out, if the invention and manufacturing of every input can be totally regulated by the price mechanism in an open market, why are there any "companies"—i.e., organizations in which several functions or activities are combined and orchestrated—at all? The answer to this question, says Coase, lies in the fact that there are costs to be incurred in any market transaction above and beyond the price of the
commodity being traded in and of itself. Simply put, there are hidden expenses, or transaction costs, that are associated with using the price mechanism.

The simple act of discovering what the relevant prices are behind a transaction requires some amount of effort, and because labor is itself an input, there is a cost associated with this gathering of information. Moreover, the costs of negotiating and concluding a separate contract for each transaction that takes place in a market must also be taken into account. The formation of an organization—like a company, for instance—in which transactions among parties occur outside of the open marketplace therefore seems like a clever way to reduce or avoid altogether the marketing costs associated with transactions that occur within the market.

However, Coase admits that there are limitations to this logic. If by organizing several activities into a firm one can eliminate certain costs and reduce the overall cost of production, one might wonder why there are any market transactions at all. All production, this theory would suggest, should be carried out by one big firm. But Coase explains that there are also expenses associated with monitoring what goes on within a company, and the costs of organizing additional transactions within a firm may rise as the firm gets larger. In other words, the larger a company is, the more difficult it becomes to organize all the information pertaining to its internal transactions.

Nearly 40 years after Coase’s transaction cost theory was first published, Williamson made a significant contribution towards rationalizing make-buy decisions by formally defining something most people take for granted in the marketplace: Human nature tends towards opportunism, and people frequently cheat, lie, and mislead one another to fulfill their own interests. This opportunism, Williamson contends, represents a significant “cost” in any business deal with an outside company or individual. As well, he underlines the fact that there is an expense associated with the uncertainty inherent in interfirm transactions. Williamson adds these unseen expenses to Coase’s original transaction costs to explain more completely how a firm comes to source supplies and services internally or externally to itself.

---

1 Coase, Ronald H. “The Nature of the Firm,” *Economica* (1937) 4, pp. 386-405. Coase actually referred to these costs as “marketing costs,” but Williamson renamed them “transaction costs”—the term used to describe the concept in recent literature on the topic.

Towards constructing a framework with which managers can rationally sort through make-buy decisions, Williamson identifies and categorizes transactions along two dimensions, frequency and asset specificity:

Frequency refers to how often a transaction occurs, either occasionally or recurrently... For example, the purchase of capital investments, such as machinery and buildings, is described as occurring only occasionally. The purchase of materials or supplies is characterized as recurring frequently.

Asset specificity refers to the degree of customization of the transaction. A transaction is highly asset specific if it cannot readily be used by other companies because of site specificity, physical asset specificity, or human asset specificity.³

In general, Williamson hypothesizes that any kind of transaction involving non-specific investments—whether the transaction occurs frequently or occasionally—should be outsourced. Non-specific functions can typically be carried out equally well by any one of several firms in the marketplace, and firms that specialize in these kinds of activities can usually do so for a lower cost than a vertically integrated production team can.

On the other hand, firms ought to retain in-house transactions that occur frequently and that involve skills or equipment that is highly specific. In instances such as these, Williamson reasons that “economies of scale can be as fully realized by the buyer as by the outside supplier.”⁴ However, if the transaction involves specific assets but only happens occasionally, Williamson recommends that the item be outsourced because “the production costs for an internal hierarchy are higher than for a market because the company must acquire capital and maintain a trained staff, even though these resources are only used periodically.”⁵

More recent research by Walker and Weber indicates, however, that while transaction costs have a significant effect on companies’ make-buy judgments, comparative production costs are the strongest predictor of outsourcing decisions.⁶ But Walker and

5 Lacity and Hirschheim, p. 32.
Weber underline the fact that their research, like that of Williamson and Coase, does not necessarily reflect the emerging realities of the corporate world. Their work to date has tended to model make-buy decisions in such a way that allows only two mutually exclusive outsourcing possibilities for a company: make or buy. However, today’s business environment offers procurement managers a spectrum of options ranging from preferred suppliers to joint ventures in which companies can work together without fusing every aspect of their operations.

**CORE COMPETENCIES**

Another principal school of thought in make-buy research believes that firms ought to define for themselves a set of core competencies—i.e., a group of capabilities at which the company can be regarded as the industry leader, and on which it focuses its efforts and resources—and outsourcing decisions should be orchestrated according to these. Prahalad and Hamel suggest that large companies that try to keep in-house an excessively sporadic repertoire of skills are doomed to fail.7 Unlike the corporations of yesterday which prided themselves in being able to do almost everything in-house, Prahalad and Hamel contend that the competitive corporation of the future will focus its resources on a select few core competencies. They also clearly underline the fact that a core competence is not a single technology for which a company has a particular knack. Rather, it is the result of collective learning within the entire organization, and requires the integration of several different technologies and production skills.

As an example, the authors showcase 3M’s competence with sticky tape. Underlying the company’s expertise in the production of tape is a host of technological capabilities in substrates, coatings, and adhesives. These same capabilities have allowed 3M to broaden its product line in several other directions that might seem to be quite unrelated to sticky tape, including Post-it notes, magnetic tape, photographic film, and coated abrasives. As disparate as these products might be, however, they stem from the same core competence in thin films.

Prahalad and Hamel also argue that core competencies should be difficult for prospective competitors to imitate—that is, a firm ought to become the preeminent expert in each of its competencies, and must actively maintain this leadership role. On

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the other hand, circumstances may arise in which it is prudent to let go of a core skill set. But this is often easier said than done. Venkatesan points out that "even though traditional competencies may have eroded or become commodities, organizations have a deep psychological reluctance to abandon what was a core subsystem to a supplier."

Just as the skills or techniques comprising a core competence should be abandoned when they become commoditized or outdated, a firm's core competence can grow to include new technologies. However, many new technologies are invented or first applied by firms other than those whose core competencies would benefit most from the innovation. But Prahalad and Hamel demonstrate with case studies that it does not matter where the technologies are first developed; they can be learned by other companies. Because a particular firm comes up with an innovation first does not necessarily mean that it will be able to develop the idea into a particular core competence.

To be sure, if supplier markets are totally reliable and efficient, a rational manager might outsource everything except those activities and technologies that constitute his or her firm's core competencies. But as Quinn and Hilmer point out, "most supplier markets are imperfect and do entail some risks for both buyer and seller with respect to price, quality, time, or other key terms." They therefore conclude that while managers ought to develop a few well-selected core competencies, they should also consider keeping other functions in-house to mitigate risk, or to improve the company's strategic posture in the marketplace.

Most research to date on the topic of make-buy decisions has tended to define a firm's core competencies in terms of the components and processes that directly affect the final product. For example, Honda's competence in engine design and manufacturing, and Philips' core expertise in optical media storage systems have both been well documented. But recent research by Fine and Whitney suggests that the main skills companies should retain in-house transcend those directly involving individual products or techniques, and are in fact the skills that support the very process of choosing which

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10 Many of the strategic considerations surrounding make-buy decisions such as access to distribution networks and product differentiation are outlined by Michael Porter in Competitive Strategy: Techniques for Analyzing Industries and Competitors. New York: The Free Press, 1980, pp. 300-323.
skills to retain. They demonstrate that several successful companies in Japan do not simply gauge make-buy decisions according to the characteristics of the components or processes themselves, but according to the amount of information and learning that can be gained by making a part or developing a process internally. For example, Japanese automotive companies are quick to outsource the production of automotive components like seats and braking assemblies, but often prefer to make infrastructural elements like robots and database software internally. American auto manufacturers have historically done exactly the opposite, readily outsourcing things like robots and software to companies that specialize in those areas while insourcing most design and production tasks directly pertaining to auto components.

The Japanese approach may indeed seem somewhat counter-intuitive to most Western managers. Automotive manufacturers are, after all, in the business of making cars. It might therefore seem obvious that U.S. auto producers’ core competencies ought to lie in the various technologies and processes needed to design and produce car components. But Japanese auto makers do not just consider the components within their vehicles; they put a very high value on the process of learning. Managers in Japan have two key reasons for wanting to learn about technologies and processes that have long been considered peripheral by U.S. companies:

- Companies that design and build manufacturing equipment know what modern equipment can do, allowing product development engineers to fit their designs more confidently and more readily to the process capability.

- Firms that build manufacturing equipment are better at buying equipment because they can competently specify their needs and knowledgeably evaluate suppliers.

Fine and Whitney conclude that a company’s management of its outsourcing process is a core competence in and of itself. Simply put, a successful company’s most fundamental asset is a thorough understanding of the many technologies and processes needed to design and manufacture its products. This knowledge base allows the firm’s managers to make intelligent and informed make-buy decisions.

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OVERHEAD ALLOCATION

Because overhead costs represent an important portion of the total cost of producing most products, how these costs are distributed plays a significant role in a firm's overall cost structure. One common method of dividing overhead among different products is to allocate it to each program according to how much direct labor was needed to manufacture it. For example, if 60 percent of all the direct laborers' time within the company is spent on a particular project, that project is charged 60 percent of the company's total overhead expenses. However, if all the costs incurred in making the products ultimately rest squarely on the shoulders of the company, it may not really matter how the company allocates its overhead; what expenses it takes away from one product are simply re-allocated to another.

There are, however, circumstances under which development and production costs for a product are not borne by the manufacturer, but by the customer. Many government defense acquisition programs are conducted in this manner because no company has the financial resources to design and develop many of the systems that the DOD needs. For instance, to develop a modern jet fighter typically costs on the order of billions of dollars. Moreover, the DOD frequently buys products that no typical private individual would wish to own, such as missile guidance systems, and there is therefore no impetus in the marketplace for companies to develop these kinds of products for private consumption. For such items, government agencies like the DOD have no choice but to pay for the development of many of the goods they need by way of "cost-plus" contracts, wherein the government agrees to pay, through competitive procurement, the costs that are incurred by the prime contractor plus a nominal profit.

But according to Rogerson, this approach to government procurement can be manipulated by contractors that also develop and sell commercial products. The optimal production strategy for a company that distributes its overhead among commercial and government sponsored projects is to make sure that it can assign as much of its overhead as possible to the government funded products. Accordingly,

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12 In 1996, the DOD—which is only one of several government agencies that routinely buys hardware from private contractors—had a procurement budget of nearly $49 billion (source: "National Defense Budget Estimates for FY 1996," issued by the Office of the Undersecretary of Defense, March 1995). How the allocation of overhead affects the make-buy decisions of government contractors is therefore worthy of attention.

Rogerson postulates that companies will elect to keep in-house the production of labor-intensive components for its government funded “cost-plus” products, while outsourcing parts and processes that require little direct labor. This strategy allows contractors to maximize their profit by charging the government for a disproportionately large proportion of the companies’ overall overhead.14

CAPACITY FOR INNOVATION

Another issue driving make-buy decisions is technological innovation. In today’s fast-paced market, a manufacturer of technologically sophisticated goods must take steps to ensure that it can—either through its own R&D efforts or those of its suppliers—create new processes and technologies that will keep its products competitive in the long run. Kumpe and Bolwijn argue that the recent shift by large manufacturers towards buying new technologies from smaller suppliers instead of insourcing them is harmful to the long-term strategic footing of incumbent firms.15 To manufacture components competitively for today’s sophisticated products, they argue, requires an enormous investment in R&D. Focusing on the pharmaceutical industry, Henderson and Cockburn arrive at this same conclusion. They contend that the research efforts of large companies that elect to “make” their own process developments “are more productive, not only because they enjoy economies of scale, but also because they enjoy economies of scope by sustaining diverse portfolios of research projects that capture internal and external knowledge spillovers.”16

HUMAN FACTORS & EXPERIENCE OF EMPLOYEES

Despite the fact that it is not prominently displayed on most corporations’ balance sheets, the value of employees’ experience plays an important role in many companies’ make-buy decisions. Several firms in both Japan and the United States have suggested that job security plays an important role in the success of a company.17 This is

14 This implies ex post (i.e., after contract award) profit maximizing behavior on the part of defense contractors that somehow escapes the attention of government auditors. To deter such behavior, the government has enacted a variety of regulatory provisions designed specifically to protect itself from the types of consequences flowing out of the information asymmetry between the government and defense contractors.


especially true in industries whose employees are highly trained and are consequently difficult to replace. Managers in these sectors of the economy cannot afford to re-train a perpetually inexperienced workforce, and are therefore often reluctant to outsource the production of a component simply to achieve marginal short-term cost savings. But the role of labor in make-buy decisions often extends beyond the cost of a particular component. Venkatesan points out that there are situations in which firms sometimes prefer to manufacture a part or system in-house simply to preserve jobs and maintain cordial relations with their unions.18

TECHNOLOGICAL MATURITY

Also of significance in assessing whether or not a component should be outsourced is the technological maturity of the component and/or the processes used to make it. Welch and Nayak recommend that if a component or one of the methods used to manufacture it is relatively nascent, a company ought to “internalize the technology and develop it, thus preventing the competition from benefiting from it as well.”19 Gutwald also recognizes the role of technological maturity, and suggests that a firm should outsource the production of a “cutting edge” component only if the item is not particularly important to the end user, and if the firm is at a competitive disadvantage compared to its suppliers in producing it.20

MULTI-DIMENSIONAL APPROACHES

Indeed, over the years there have been quite a few attempts to determine what ultimately drives make-buy decisions. Research efforts to date have highlighted several different factors, each one playing a major role in the outsourcing judgments of procurement managers. But as demonstrated by the previously discussed literature, there is little agreement about which of these factors—transaction costs, quality, overhead allocation, core competencies, organizational learning, etc.—are among the most important. With so many facets to the problem of outsourcing, many people charged with making make-buy decisions are not sure how they should approach the

18 Venkatesan, p. 100.
20 Gutwald, Paul M. Strategic Sourcing and Technology Supply-Chains. MIT Master’s thesis (Management), June 1996, p. 44.
task. In lieu of choosing among the various criteria put forth by previous researchers, some make-buy strategists have resigned themselves to trying to balance several of them.

Towards helping marketing managers decide if they should make or buy their marketing support teams—that is, whether marketing activities should be performed by the company’s own employees, or if they should be outsourced to independent agents—Anderson and Weitz develop a framework which delineates each of the major points a manager ought to consider as he or she goes through the make-buy decision process. The framework is essentially a checklist with 28 questions, each one requiring a check mark in the “make” column or the “buy” column. After finishing each of the 28 questions, the manager using the framework is left to weigh each factor as he or she sees fit, thereby arriving at an overall answer (Figure 2.1).

![Figure 2.1: Anderson and Weitz’s “Checklist” Framework](image)

To be sure, Anderson and Weitz’s checklist framework is valuable in that it implicitly underlines the fact that there are several factors behind make-buy decisions, each one potentially playing an important role. But this approach may be quite cumbersome to a procurement manager who wants to use it. After all, 28 individual questions beget 28 individual answers, and organizing and prioritizing so many considerations might require an unreasonable amount of time. And with so many independent decisions to make, it is doubtful that a result from a 28-point framework would be repeatable.

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21 Anderson and Weitz, pp. 3-19.
More recently, Probert et al. have devised another methodology for making outsourcing decisions that also reflects the multi-disciplinary and multi-dimensional nature of make-buy issues. But unlike Anderson and Weitz's framework, the model put forth by Probert et al. consolidates the many questions facing procurement managers by breaking the problem down into three discrete components: a technology matrix, a cost model, and an analysis of the company's strategic issues (Figure 2.2). As in Anderson and Weitz's model, the final judgment about whether or not to outsource a particular component or process is still left to the discretion of the managers charged with making the decision. Nonetheless, this approach is helpful insofar as it pulls together many different criteria into three succinct outcomes that can be more easily organized by someone using the framework.

![Diagram](image)

**Figure 2.2: Consolidated Framework by Probert et al.**

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2.2 **Distinguishing Characteristics of the Industry**

As demonstrated in the preceding section, there are already a handful of make-buy frameworks and conceptual models available, each one approaching the issue of outsourcing in a slightly different way and some with a particular industry in mind. And to be sure, these efforts have helped immensely in bringing into focus many of the more or less generic criteria behind outsourcing decisions. But America's defense and commercial aerospace industries are markedly different in many respects from most other sectors of the economy, and face many distinct circumstances and challenges that have not been addressed in the make-buy literature to date.

**Small Customer Base**

For one, the aircraft sector is unlike most industries in that its customer base is quite small. There are less than 100 major airlines in the world that buy large commercial jets, and most of them only purchase a few units per year. Military aerospace contractors in the U.S. face an even smaller market for their new airplanes. They typically have but one customer: the DOD.

**Low-Volume Production**

Most manufactured goods are produced in relatively large volumes. For instance, tens of thousands of units of a particular car model may be manufactured in a given year. In contrast, aerospace products are typically produced in much smaller volumes. For example, Boeing's Commercial Airplane Group (BCAG) made a total of 220 airplanes in 1996.\(^{23}\) These low rates of output are also characteristic of military aircraft: Between 1998 and 2012, only 438 F-22's are currently scheduled for production.\(^{24}\)

**Large Capital Investment**

Perhaps one of the most outstanding features of the aerospace industry is its high level of capital investment per unit of output (i.e. high capital-output ratio). "There are a few

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industries—automobile manufacturing, for one—that consume as much capital." 25 Because of this large barrier to entry into the market, there are a relatively limited number of companies in the world that make complex airplane components, and only a handful that assemble medium or large-sized jet aircraft. With such a relatively small number of companies at the top tiers of the industry, it is not at all uncommon for several aerospace assemblers to rely on the same suppliers for comparable parts. 26 The lower tiers of the aircraft industry's supplier base, however, include thousands of smaller firms.

"INTEGRAL ARCHITECTURE" OF COMPONENTS

Citing earlier work by Ulrich, 27 Fine and Whitney draw a clear distinction between products that have a modular architecture, and those that have an integral architecture:

A product with a modular architecture has components that can be "mixed and matched" due to standardization of function to some degree and standardization of interfaces to an extreme degree. Home stereo equipment has a modular architecture; one can choose speakers from one company, a CD player from another, a tape deck from a third, etc., and all the parts from the different manufacturers will assemble together into a system. IBM-compatible computers are also quite modular with respect to [their] CPU, keyboard, monitor, printer, software, etc., as are adults' bicycles.

A product with an integral architecture, on the other hand, is not made up of off-the-shelf parts, but rather comprises a set of components and subsystems designed to fit with each other. Functions typically are shared by components, and components often display multiple functions... [T]he product must be developed as a system and the components and subsystems defined by a design process exerted from the top down, rather than the bottom-up design process that may be used by a bicycle manufacturer. 28

Fine and Whitney explicitly point to aerospace products as having integral architectures. "One cannot take a wing off the shelf from one supplier, and engine from another, avionics from a third, and expect to end up with a (flyable) system." 29 The design and

26 For example, when Menasco recently acquired Bendix, a former competitor in the landing gear business, it was discovered that the two companies relied on the same suppliers for many of their components (source: interview by author with Menasco managers in Euless, Texas, 16 May 1996).
28 Fine and Whitney, p. 10.
29 Fine and Whitney, p. 10. However, this is not to suggest that there is no flexibility in the manufacturing of jet aircraft. In the case of the Boeing 777, for example, customers can choose from a variety of engines from
production of airplanes is therefore different from many other industries in that
designing a single component requires a high degree of communication and concurrence
among design teams working on different parts of an airplane. For example, there are no
industry-wide standards for how landing gears are connected to an airplane’s fuselage
and wings, and a landing gear team must communicate frequently with engineers from
the wing and fuselage teams to make sure that the eventual design of one system does
not violate design criteria for any of the others.

HIGH-TECHNOLOGY CONTENT AND RELATIVE IMPORTANCE OF TECHNOLOGICAL
MATURITY

One of the key features that sets airplane manufacturers apart from many other sectors
of the economy is that their products contain many components that are remarkably
complex. In fact, "no other industrial product embodies as much refinement in the
combined techniques of metallurgy, electronics, and computers as a jet aircraft."\(^{30}\) This
high degree of sophistication and novelty, which is typically more pronounced in defense
aircraft than in commercial ones, presents a broad array of technical challenges that
most sectors of the economy simply do not have to face.\(^{31}\)

Because the aerospace industry utilizes many different advanced technologies, a make-
buy decision for a particular airplane component is especially sensitive to the maturity
of the technologies underlying it. Indeed, several research efforts before this one have
pointed to technological maturity as one of the criteria that play a role in make-buy
judgments. But the frameworks constructed thus far have failed to reflect the relative
importance of this criterion in an aerospace environment, relegating it to a more or less
secondary status relative to other factors affecting outsourcing decisions. Whether or
not a technology is "cutting edge" weighs heavily on the minds of procurement managers
in the aerospace sector, and any framework intended to model make-buy decisions in
the industry ought to reflect this.

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\(^{30}\) Newhouse, p. 49.

\(^{31}\) Hoult, David P. "Product Development with Suppliers—The Role of Database Commonality," Society of
Automotive Engineers (SAE) Technical Paper #970766, 1996.
CRITICALITY OF COMPONENTS

Generally speaking, manufacturers in most industries are concerned with the quality of the components in their products. Brand reputations and market shares are routinely won and lost according to how well a consumer product stands up to the rigors of daily use vis-à-vis the durability and quality of competing brands. But if a standard, run-of-the-mill component is defective or breaks, there are typically few casualties. For example, very few people suffer because of injuries resulting from faulty refrigerators or lawn sprinklers that failed to perform. While manufacturers in most sectors of the economy aspire to make their products as good as they can be, the consequences of any lapse in the quality of their wares may be relatively minor.

Companies in the aircraft industry, however, do not have this luxury. Many of the components and systems in an airplane are “mission critical”—that is, if they fail to perform, the performance of the entire airplane is seriously jeopardized, which can easily lead to catastrophic losses in terms of equipment and human life. Aerospace manufacturers—whether on their own initiative or at the insistence of a regulating government agency—are therefore extremely sensitive to the quality of the materials and components used in their airplanes, and generally prefer to use the safest and highest grade parts and materials whenever possible. To that end, a company’s competitiveness in any of the technologies used to manufacture an airplane is of paramount concern in its make-buy decisions. If another firm can produce a component that is demonstrably superior in terms of quality and safety, a prime is usually reluctant to keep the process or component in-house unless it is confident that it can improve its in-house resources to meet or surpass the other firm’s levels of excellence.

2.3 CHAPTER SUMMARY

This chapter has examined previous work in the area of make-buy decisions. Among the different approaches explored to date are:

☞ transaction cost theory
☞ core competencies
☞ overhead allocation
☞ capacity for innovation
human factors and experience of employees
technological maturity
and multi-dimensional approaches, which combine several of the previously
mentioned approaches.

Additionally, this chapter has outlined several ways in which the U.S. aerospace
industry is appreciably different from many sectors of the economy:

- small customer base
- low-volume production
- large level of capital investment required to enter the market
- the mostly "integral architecture" of aerospace components
- the importance of technology maturity to firms' competitiveness
- the criticality of many airplane components and systems

Because the aircraft industry is in many ways distinct from most others, its managers
often contend with a decidedly different set of issues than do their colleagues in other
industries. Accordingly, existing make-buy models do not sufficiently explain why
managers in this sector elect to make or buy a particular component or process.
Towards constructing a framework that more accurately explains how aircraft
manufacturers make outsourcing decisions, the following two chapters explain in detail
the circumstances surrounding the design and manufacturing of two components: the
main landing gear for the Boeing 777, and the sinewave spars for the F-22.

The hypothesis underlying this investigation is that make-buy decisions in the aerospace
industry are largely influenced by two factors that have not been reflected or have been
underemphasized in other make-buy models to date: the technological maturity of the
component or process, and the firm's competitiveness with respect to the particular
technology. The case studies presented in the next two chapters are particularly useful
in analyzing the effect of technological maturity on make-buy decisions because the first
documents the outsourcing decisions surrounding a technologically mature component,
while the second focuses on a component that is technologically nascent. As well, the
case studies examine situations in which a firm is an industry leader in developing and
using a particular technology, and others in which the firm is not. Thus, the cases
documented in the following two chapters are useful in assessing the effect of a
company's technological competitiveness on its outsourcing decisions.

The two case studies also differ in that one of the components is from a commercial
airplane project, while the other is for a military airplane. These examples therefore lend
themselves to a direct comparison between make-buy decisions in civilian and military projects.
CHAPTER 3: CASE STUDY A—THE 777'S MAIN LANDING GEAR

The goal of this chapter is to document a case study detailing the circumstances underlying the make-buy decisions behind the Boeing 777's main landing gear. One of the more outstanding features of landing gears is that although they have evolved somewhat over time, the basic technologies behind them have remained largely unchanged for many years. Therefore, because of their slower rate of technological evolution, they are particularly useful as a point of reference in assessing the impact of the rate of change of technology on make-buy decisions.

3.1 BACKGROUND AND INTRODUCTION

By the end of the 1980s, it was clear that the Boeing Commercial Airplane Group (BCAG) was not completely addressing the needs of its customers:

The airlines of the world told us they wanted an airplane that was bigger than the 767 and smaller than the 747. And we said, "Why don't you buy 767s," and they said, "We want an airplane that's bigger than the 767 and smaller than the 747, because on some of the city pairs that we fly we cannot get enough people to fill up a '47 and we have too many for a '67." It took us two years to figure out that they really wanted an airplane that was bigger than the '67 and smaller than the '47. So we decided to make a new airplane.¹

To attend to the growing “mid-size” jet airliner market, BCAG set out to develop the 777, or “triple seven” as it is commonly known.

The new airplane’s design was markedly different from the other members of BCAG’s product line in several regards. For one, the main landing gear had a wheel base that was quite unlike the conventional four-wheel design that had been standard before the 777. The new model featured a six-wheel unit that could better distribute the weight of the aircraft on runways and taxi areas. As well, it was the largest landing gear ever to be incorporated into a commercial airplane. This clearly represented somewhat of a challenge for the three companies charged with the main landing gear’s design and production: BCAG, which ultimately installs the landing gear in the 777; Menasco, a division of Coltec Industries, which manufactures many of the landing gear’s principal components; and Wyman-Gordon, which forges the titanium and steel used by Menasco. This supply chain, whose members had already worked together several times before over a period of decades, is illustrated in Figure 3.1.

3.2 The Technology Behind the 777’s Main Landing Gear

3.2.1 Major Components and Their Functions

Landing gears are absolutely critical to the taxiing, take-off, and landing stages of every flight an airplane undertakes. In addition to absorbing a large proportion of the shock imparted to the wheels during landing and taxiing, the main landing gears of an airplane provide braking capability. To bear the many different loads applied throughout its operation, the 777’s main landing gear is composed of several fundamental components, shown in Figure 3.2:

- The inner and outer cylinders bear the weight of the aircraft. The inner cylinder fits inside the outer cylinder to form the main shock strut. This

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3 Source: BCAG’s 777 web site.
strut is also one of the principal mechanisms of shock absorption for the entire landing gear assembly.

⇒ The torque links provide the wheels with additional torsional stiffness to prevent the wheels from "shimmying"—that is, they prevent the wheels from oscillating about their swivel axis when the plane is in motion on the ground.

⇒ The drag strut helps the landing gear bear the longitudinal loads applied in the direction of the airplane's motion.

⇒ The side strut helps to maintain the lateral stability of the landing gear. Simply put, it helps to keep it from moving from side to side.

⇒ The axles are the links by which the landing gear's wheels are connected to the truck beam assembly.

⇒ The retraction arm pulls the landing gear back into the airplane after take-off.

![Diagram of the landing gear supply chain]

Figure 3.1: The Flow of Materials in the 777 Landing Gear Supply Chain

3.2.2 The Evolution of Landing Gear Technologies

Compared to many other of the functional systems in commercial airplanes, landing gears have remained relatively unchanged since World War II.\(^5\) Indeed, there have been

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\(^5\) This point was generally agreed upon by several of the design engineers at Menasco, a landing gear manufacturer based in Texas. By interview with author, 16 May 1996.
some minor developments in the state of the art. Because of its superior strength-to-weight ratio, titanium has replaced strengthened steel in some components. But this shift to a new material has not represented much of a change to most of the firms within BCAG’s landing gear supply chain. By virtue of the fact that both strengthened steel and titanium are metals, many of the basic and well-established techniques and tools used for forging and machining steel can be applied to titanium with relatively little extra effort or expense.

Figure 3.2: The Boeing 777's Main Landing Gear\textsuperscript{6}

\textsuperscript{6}Courtesy of Charles Campbell, the Project Manager for the 777 main landing gear at Menasco.
Also, the advent of finite element modeling (FEM) allows today’s engineers to remove from their landing gear designs every last bit of non-critical material. This development has been useful in reducing the weight of landing gears and allowing engineers to test their ideas without actually having to build a physical prototype.

But neither the switch to titanium nor the introduction of FEM has done much to improve the fundamental architecture of landing gear designs. The same basic components come together in more or less the same way they have for decades, and the processes by which the components are manufactured are fundamentally similar to those used a generation ago.

3.3 BCAG’s Make-Buy Decision Process

3.3.1 BCAG’s General Outsourcing Policies

In the Early Days of the 777

When BCAG started to develop the 777, its make-buy decisions were often “stand-alone” judgments that were made at the division level, and that did not take into account BCAG’s overall long-term strategy. As well, outsourcing decisions rarely deviated much from what they had been in previous projects. If a particular task or component had historically been relegated to outside suppliers, there was a good chance that the job would be outsourced again. This patterned approach to procurement was not without exceptions, though. If a supplier’s situation changed, and it suddenly did not have the capacity to handle a job in a timely fashion, BCAG’s in-house team would take on the responsibility. Or, conversely, if an in-house team could not handle a task that it had traditionally done, the job was outsourced to a supplier.

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7 Lindgren, Edward. Mr. Lindgren is a Senior Manager in BCAG’s Materiel Division. Personal communication with author, 11 July 1997.
BCAG'S OUTSOURCING POLICY TODAY

But BCAG's make-buy decision process today is significantly different from what it was in the early days of the 777. Four years ago, BCAG's Senior Executive Management decided that BCAG's outsourcing policies needed to be revised to concentrate better on its core competencies. To that end, BCAG enlisted the help of Booz, Allen and Hamilton, a management consultant, to assist in developing a more streamlined make-buy plan.

The resulting plan formalized and clearly outlined an approach to outsourcing decisions that applied to all of BCAG's projects. For instance, if the make-buy policy recommends that BCAG should outsource the manufacturing of a particular component, it will try to do so for each and every one of its programs. This outsourcing policy is summarized in the Group's Operating Procedure Directive, and provides for BCAG's procurement managers step-by-step instructions regarding the criteria that should be used to assess make-buy options, and by whom such judgments should be made.

The principal factors that shape BCAG's new outsourcing strategy are: core competencies, costs, capital investment, labor relations, and market access.

CORE COMPETENCIES

Certain functions and assemblies are regarded as core competencies by BCAG, and are never outsourced. For instance, BCAG views wing structures as one of the most critical parts of its airplanes, and does not even consider the possibility of handing off the design and/or production of these components to a supplier. It also insists on maintaining a high degree of control over the design of every major assembly and component in its aircraft. A supplier may be invited to participate in the design process, but BCAG considers these functions as part of its core competencies, and retains an in-house team of design experts for each major assembly.

EXTREME SENSITIVITY TO COSTS

Air travel has been "commoditized" by the deregulation of the civil aviation industry in the United States, heightening the cost pressures on both airlines and aircraft producers. Consequently, the cost of components has become one of the primary considerations in
BCAG’s make-buy decisions. This extreme sensitivity to prices has not only changed what BCAG buys, but how it buys it. Whereas it used to work with its suppliers on a competitive bidding system for developing components for new projects, it now treats cost as a more or less independent variable; that is, BCAG managers tell the landing gear supplier how much they are willing to pay. It is then up to the supplier to work with BCAG’s in-house engineers to make a landing gear that fulfills all the necessary specifications while remaining under the cost limit. The deregulation of the industry has therefore been somewhat beneficial to the industry as a whole in that the increased cost pressure has led to greater efficiency.

CAPITAL INVESTMENT

Another make-buy issue of primary concern for BCAG is capital investment. BCAG would have to devote a significant amount of its resources to acquire the many large, specialized machines needed to manufacture landing gears—and because landing gears are not a core competence for BCAG, this is an investment that it does not want to make if it can avoid it. The burden of such large investments is further amplified by the industry’s highly cyclical nature. BCAG cannot buy machinery according to its maximum capacity needs during the “boom times” because the next downturn in the aerospace market might be right around the corner. To have a lot of money tied up in expensive capital equipment that is sitting idle would prevent the company from investing its resources in something more fruitful.

LABOR RELATIONS

BCAG’s workforce factors heavily into its outsourcing decisions. Boeing’s union representatives are quite concerned that BCAG’s managers might try to outsource an unnecessarily large amount of its production to subcontractors. In fact, the union’s objections to BCAG’s new outsourcing policy was one of the key issues in its last round of contract negotiations with its employees. But the two sides eventually reached a

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8 While it is true that BCAG's decisions are largely driven by cost considerations, it is important to note that the company does not merely consider the immediate, “up-front” price of a component when deciding whether to make or buy it. Rather, the decision is based on long-term analyses, such as the net present value (NPV), return on investment (ROI), and internal rate of return (IRR). Moreover, BCAG’s cost analyses take into account indirect costs, such as the additional administrative costs incurred in dealing with suppliers.

mutually agreeable solution: If an outsourcing decision will significantly affect 50 or more employees, the union must be briefed about the rationale behind the decision.\textsuperscript{10}

\textbf{Market Access}

For many years, BCAG sold most of its airplanes to customers in the United States. But as illustrated in Figure 3.3, a large part of Boeing’s commercial sales today are to foreign airlines. And as Asia’s economy rapidly expands over the years to come, it is expected that foreign carriers will constitute an even larger fraction of BCAG’s sales in the future.\textsuperscript{11} This dramatic shift in BCAG’s customer base has had an effect on its make-buy decisions.

Commercial aerospace manufacturing companies and their suppliers are a welcome addition to any country’s economy. The industry is a user and driver of many advanced product and process technologies, and there is an element of international prestige to be enjoyed by nations that take part in the development and production of such large, complex products.\textsuperscript{12} Moreover, commercial aerospace producers have a noticeable impact on any economy in which they operate. BCAG, which is based in the U.S., employed nearly 66,000 employees and earned $16.85 billion in revenues in 1994.\textsuperscript{13} The economic effects of commercial aerospace manufacturing are indeed large enough to be felt on an international level. In 1987 large commercial aircraft were the single largest net contributor to the U.S. balance of payments, accounting for seven percent of America’s total exports.\textsuperscript{14} With so many obvious advantages to having a domestic commercial aerospace manufacturing base, many countries have taken steps to develop one for themselves.

But these same foreign governments that are working towards establishing a domestic aerospace manufacturing sector also own or substantially support the air carriers in their respective countries.\textsuperscript{15} This brings about a somewhat unique situation for commercial

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\textsuperscript{10} Gilliams, John. 28 August 1996.
\textsuperscript{11} The Boeing Company’s 1995 Annual Report, p. 33.
\textsuperscript{13} Boeing 1995 Annual Report, p. 4.
\textsuperscript{14} Dertouzos, \textit{et al.}, p. 207.
\textsuperscript{15} Dertouzos, \textit{et al.}, p. 205.

48 \textit{Make-Buy Decisions in the U.S. Aircraft Industry}
Figure 3.3: Projected Market for Commercial Aircraft, 1996-2015\textsuperscript{16}

aerospace manufacturers like BCAG in that several of their customers—i.e. the governments of countries that own and operate state-owned airlines—are not merely interested in getting the best airplanes for the lowest possible price. Some of them want to get involved in their production, too. They may therefore use the allure of a large sale to entice BCAG to produce a component or family of components outside of the United States.

Purchasing airliners according to their amount of domestic input is not, however, the only means by which a foreign government can convince large aerospace manufacturers to set up production facilities outside of their home countries. A government might offer the prime contractor handsome incentives that make the prospect of overseas production a genuinely attractive alternative in and of itself, without directly tying future sales to the deal at all. The Japanese government’s contribution to the design and production of the 777 is one of the more outstanding examples of this kind of strategy.

As early as 1970, Japan’s Ministry of International Trade and Industry (MITI) designated aerospace as one of three key technology areas for the 21st century. However, the aviation business differs structurally from the types of industries the Japanese have traditionally targeted for investment and development,\textsuperscript{17} and Japan’s manufacturers had less experience than their U.S. counterparts in the design and production of aerospace products. It was clear to MITI that instead of building a domestic aircraft manufacturing industry from the ground up, it would be much easier to draw on the skills of a company that already had experience in the field—a company

\footnotesize{\textsuperscript{16} Boeing 1995 Annual Report, p. 4.}

\footnotesize{\textsuperscript{17} Dertouzos, et al., p. 213.}
like BCAG. To that end, the Japanese government offered to pay for a substantial portion of the development costs for any major component or system that BCAG would outsource to Japanese firms. Unable to refuse such an attractive offer, BCAG contracted about 20 percent of the design and development of the plane’s airframe structure to Japanese subcontractors.\footnote{Source: BCAG’s 777 web site.}

\textbf{PERIODIC REVIEW OF MAKE-BUY PLAN}

A recurring theme throughout BCAG’s outsourcing policy is its long-term commitment to ensuring “that World Class levels of performance are met and maintained by both internal and external sources.”\footnote{BCAG Operating Procedures Directive #6-1000-202, issued 15 April 1995 by R.B. Woodard, President, p. 1.} Whether through its in-house facilities or those of its suppliers, BCAG strives to use the best products and processes—compared not only to other aerospace companies, but across all industries—in everything it does.

However, it is clearly unreasonable to expect that a single “World Class” procurement plan will continue to be so indefinitely. The business world is in a constant state of flux, and what was the best decision only a few years ago may not be appropriate today. Accordingly, BCAG reviews and re-assesses its make-buy decision for each major assembly and subassembly at least every two years. Investigations regarding the outsourcing strategy can also be initiated at any time by any one of several teams and organizations within BCAG if there is a significant technological development in a process or product, a new program is being introduced, or if a supplier’s performance has been deemed unacceptable.

\textbf{TRANSITION FROM OLD MAKE-BUY PLAN TO NEW ONE}

BCAG’s procurement managers are indeed committed to making outsourcing judgments according to its new make-buy policy, but they cannot simply change the way they do business overnight. There are still many instances in which their outsourcing practices do not—and cannot—adhere to the new plan.

This is largely due to the fact that several of the airplanes BCAG is producing today are “derivatives,” which are successive generations or modified versions of older designs.
BCAG’s managers often award production contracts for derivative components to the same suppliers who produced them in the original program. The tooling used by a supplier to manufacture components for a totally new aircraft can cost several millions of dollars. Derivative models of an airplane, on the other hand, often vary only marginally from the original design, and many of the tools used to make components for the original aircraft may require only minor adjustments to accommodate the derivative version. Thus, even though BCAG’s new make-buy plan suggests that its procurement managers ought to retain the production of a derivative component in-house, it might be outsourced to take advantage of the existing tooling. However, as BCAG moves on to completely new design platforms in the future, its make-buy decisions will more closely match the new plan.

3.3.2 Make-Buy Decision for the 777 Main Landing Gear

The process of manufacturing landing gears can be broken down into three principal tasks: designing the gear, producing its components, and putting the components together. There are of course strong interdependencies among the three functions. For instance, the production team relies on information from the design team, and the assembly team has to coordinate closely its efforts with those of the production team. Nonetheless, the three functions are mature enough and the definition of the tasks well defined enough that they can be decoupled quite successfully; that is, the design, production, and assembly of the landing gear can be handled as largely independent functions. A separate make-buy decision therefore had to be made for each.

DESIGN

Perhaps even more profound than the uniqueness and size of the landing gear itself is the novelty of the design process behind it. BCAG tried an approach to planning that was a notable departure from its traditional style in two significant ways. First, the 777 was the first jetliner to be 100 percent digitally designed using three-dimensional solids technology. The entire airplane was “pre-assembled” on computers, eliminating altogether the need for a costly, full-scale mock-up.20 Second, BCAG fostered a more

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20 Source: BCAG’s 777 web site.
cooperative environment between its own engineers and those of its suppliers than it had in previous projects. Before the 777, BCAG retained nearly all of the design responsibilities for its landing gears in-house, and the majority of the specifications needed to make the landing gears were handed down to suppliers like Menasco and Wyman-Gordon in what was basically a “build-to-print” arrangement. To be sure, BCAG still retained the design responsibilities for the 777’s landing gear in-house—that is, it continued to “make” the design—but it did so in a way that involved a much higher degree of interaction with its suppliers than was the case in previous projects.

After BCAG’s in-house design team put together a basic design concept for the 777’s main landing gear, the company asked a select group of landing gear contractors to send a team of their engineers to BCAG’s design facility in Washington State. The contractors’ engineers then worked together with BCAG’s own in-house landing gear experts to develop a detailed design that would improve the “ producibility” of the original design concept, thereby helping the contractors to achieve the cost targets set by BCAG. The proposal submitted by the Menasco team was eventually chosen over those of the other contractors by a process of competitive bidding. But even though Menasco’s engineers contributed significantly in developing the landing gear, BCAG still owns the proprietary rights to the design.

**PRODUCTION**

One of the most glaring technical challenges in machining the 777’s landing gear is its size. The steel forgings from which the inner and outer cylinders are manufactured are approximately four meters long and weigh nearly 17,000 pounds.\(^1\) Just to mount one of these forgings on a lathe takes 2.5 man-shifts, and to machine it takes another 1.5 man-shifts.

Machining on such a grand scale requires equipment quite unlike that found in the machine shops of most other industries. To make landing gear cylinders requires machines and tools that are highly specialized and very expensive—so expensive, in fact, that it is quite difficult for new businesses to enter the market. Other companies in the landing gear’s value stream are acutely aware of the potential profits that could be had by machining the components themselves, but “there’s simply too much capital

\(^1\) Escowlas, Rich. Mr. Escowlas is a forging design engineer at Wyman-Gordon. By personal communication with author, 4 June 1997.
involved with getting into that part of it." For this reason, BCAG decided to "buy" the manufacturing capability for major components like the inner and outer cylinders.

ASSEMBLY

While the inner and outer cylinders are among the largest and most visible parts in the 777's landing gear assembly, there are also many other smaller yet critical components such as wheels, actuators, brakes, and hydraulic systems. For the 777, BCAG receives from Menasco an assembly consisting of large landing gear structural components like cylinders, trucks, and axles. The rest of the smaller components are shipped directly to BCAG from their respective manufacturers, and BCAG's in-house assembly team puts all the components together in its "build-up shop."

This approach to assembling landing gears is quickly changing, though. For instance, in the case of the 757, Menasco now buys the smaller components itself, assembles the landing gears, and then sends them to BCAG as a complete unit. And beginning in September of 1997, Menasco will also assume all the assembly responsibilities for the 777's main landing gear.

In addition to the direct time savings that have resulted from this move, BCAG also has to devote fewer resources to handling the many different parts. A complete assembly is much easier to transport than many smaller subassemblies. Because of the criticality of landing gears in the day-to-day functioning of any airplane, however, some managers within BCAG were somewhat apprehensive about relinquishing control of the assembly process to outside companies. Landing gears are of primary importance to the final assembly and performance of an aircraft, and several managers believed that BCAG ought to maximize its control over such critical elements. But in the end, it was decided that the gains to be had by focusing on BCAG's core competencies outweighed the added risk. Moreover, the concept of purchasing fully assembled landing gears was not without precedence: Airbus Industrie, BCAG's largest competitor for large-scale commercial aircraft, has been receiving its landing gear systems completely assembled from Messier-Dowty of the United Kingdom for quite some time.

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22 Creed, J. Rick. Mr. Creed is the Director of Wyman-Gordon's Structural Business Division. By interview with author, 18 November 1996.
3.3.3 Who Makes BCAG's Make-Buy Decisions?

In addition to redrawing the boundaries of what processes and components should be kept in-house and what should be outsourced, BCAG's new make-buy strategy also redefines who should make such judgments. Outsourcing decisions used to be made independently within each of the Group's divisions, allowing managers in different parts of BCAG to have dissimilar and even conflicting make-buy policies. As noted earlier, however, BCAG now makes such decisions at the Group level, which means that outsourcing judgments are generally applied in the same way throughout all of BCAG's programs. It was thought that this move would synchronize BCAG's activities, thereby allowing its many procurement managers to make decisions that are complementary to one another and in line with the BCAG's overarching objectives.

BCAG's Make-Buy Hierarchy

The BCAG Leadership Team, whose members are directly appointed by the Group's President, have ultimate authority over BCAG's make-buy decisions. Essentially, the Team is charged with making sure that every proposed procurement plan is congruent with the long-term objectives of the Group. Despite the fact that the Leadership Team has the power to question any make-buy decision, though, it does not actually make these judgments itself. Rather, it has the authority to initiate an investigation if there is a change in BCAG's overall strategy that is not reflected in the current make-buy plan. But as noted before, the Leadership Team is not the only team that has the authority to initiate an investigation into BCAG's make-buy policy. Several different teams and organizations, shown in Figure 3.4, may initiate an inquiry into the policy if they feel the current plan does not accurately reflect BCAG's situation in the marketplace, or if the existing strategy is not in BCAG's best interests.

The responsibility for actually making final make-buy decisions is vested in the Produce Macro-Process Team, better known as the Produce Team. The Produce Team is responsible for coordinating the investigations for make-buy decisions for new components and subcomponents, and for validating current strategies for existing ones.

Carrying out these investigations is indeed a demanding endeavor, often requiring input from many people in several different divisions and teams from all over BCAG. To help the Produce Team with this daunting task, BCAG's Make/Buy Organization collects the
data and draws together the input needed for the investigations from several managers throughout BCAG (Figure 3.4). Upon collecting the data it needs, the Make/Buy Organization provides the Produce Team and/or Leadership Team with a make-buy recommendation. If a "buy" recommendation is made, the Make/Buy Organization also investigates and validates the requirements that must be met by subcontractors vying for the contract.

--- Information flow

Denotes teams that can initiate a make-buy investigation

Figure 3.4: BCAG's Make-Buy Hierarchy
However, when putting together a recommendation, the Make/Buy Organization may not be aware of some of the global issues—market access, political conditions within countries from which BCAG buys components, etc.—that surround major outsourcing decisions. For this reason, make-buy plans submitted to the Produce Team by the Make/Buy Organization must first be reviewed by the Steering Committee, which is responsible for making sure that the proposed plan is congruent with BCAG’s international and regional strategies.

3.4 MENASCO’S MAKE-BUY DECISION PROCESS

3.4.1 The Company’s General Outsourcing Policies

CONSTRAINED BY CAPACITY

Menasco’s managers take pride in the fact that their company is capable of making in-house nearly every sub-component that goes into any one of its landing gears. However, the company simply does not have the capacity to make in-house everything that it needs, and must therefore outsource the production of some components. To manufacture the many parts that the company decides not to make in-house, Menasco relies on 158 suppliers for approximately 30 to 35 percent of the value of the landing gears it ships to BCAG.

COST SENSITIVITY

In addition to its in-house capacity constraints, a principal motive underlying most of the company’s make-buy decisions is cost. If a subcontractor can manufacture a part at a significantly lower cost than Menasco’s own production team, the company’s

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23 Snow, Ralph H. Mr. Snow was the Director of Menasco’s Design Engineering Department. Personal communication with author, 21 April 1997.

24 This number is probably lower now. Menasco’s managers were extremely proud of the fact that they were actively paring down their supplier base. Three years ago, the company had 386 suppliers, and it projected that it would have less than 150 by the end of 1996.

25 According to several Menasco engineers, this number is growing. It is important to note, too, that Menasco retains in-house a larger proportion of the production value for larger landing gears. This is due to the fact that many of Menasco’s suppliers simply do not have the facilities and machines to manufacture very large components. Because of its unprecedented size, this was particularly true for the 777’s landing gear.
managers are very reluctant to manufacture it in-house. Also, Menasco’s managers prefer to make larger and more complex components that require the company’s highly specialized skills and equipment because the production of these components entails the utilization of many “high value-added” processes. Smaller components, by comparison, typically represent a less significant proportion of the overall value of a landing gear, and are therefore more likely to be chosen as “buy” items. For example, in the case of the 777, Menasco manufactured the cylinders, trucks, and axles, but left BCAG to purchase the wheels, tires, and brake systems from other suppliers.

Also taken into consideration are the quality of the components that its suppliers can produce, and the timeliness with which they can deliver them.

PROBLEMS WITH SUPPLIER INVOLVEMENT IN DESIGN AND DEVELOPMENT

Menasco’s managers are acutely aware of the advantages of early supplier involvement in design and development activities. To that end, the company has provided several incentives for its vendors to participate in the earliest stages of the design process. Despite its efforts, however, Menasco is experiencing a great deal of difficulty in spurring its suppliers to commit their employees to Menasco’s major projects in the same way that Menasco does for BCAG. At the root of the difficulty is the fact that like Menasco itself, the company’s lower tier vendors are faced with capacity constraints. Many of Menasco’s suppliers are small companies, and are therefore unable to dedicate a project-specific design engineer to spend most of his or her time working face-to-face with Menasco’s engineers.  

3.4.2 Menasco’s Make-Buy Decision for Forged Titanium

WHAT IS FORGING?

Forging is the name for processes whereby metal workpieces are shaped by compressive forces applied through various dies and tools. It is one of the oldest metalworking

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26 Starkey, Tim. Mr. Starkey is the Group Vice President of Materiel and the Vice President of Program Management at Menasco. By interview with author, 16 May 1996. It is important to note, though, that Wyman-Gordon (which has over $500 million in annual sales) can afford to devote employees to Menasco.
operations, dating back to at least 4000 B.C. Simple forging can be done with a hammer and an anvil, as was routinely done by blacksmiths for centuries.\(^7\)

The forging process is an essential step in the manufacturing of landing gears because of the tremendous improvements in the mechanical properties that it brings about in most metals. The metal from which a landing gear is manufactured can be made significantly stronger by "cold working" it—that is, by permanently deforming the metal without heating it. Forging is also useful in that it shapes the metal into a shape more like that of the eventual component, which can sometimes result in significant savings in the overall production costs of the landing gear.

**Overall Cost Savings Due to Forging**

To make a landing gear as large as the 777's requires thousands of pounds of forged metal, most of which is cut away during the machining process. There is, however, quite a bit of judgment involved on the part of manufacturing engineers with regards to how much metal winds up as scrap. By making a forging that is "just big enough," engineers can significantly reduce the amount of material that needs to be cut away from the landing gear. As with most decisions in a manufacturing setting, though, there is a trade-off: The process of minimizing the amount of scrap by designing sophisticated forging dies that are "just big enough" is neither cheap nor straightforward, often requiring a lot of know-how. An advanced forging design must therefore result in significant cost savings in materials for it to be worthwhile. For instance, it makes little sense to expend a lot of time and money meticulously designing a die in an effort to remove every last bit of unnecessary material from a forging made of an inexpensive grade of steel.

**Decision to Use Titanium Instead of Steel in Selected Components Within the Landing Gear**

But as noted earlier, some of the components in the 777's main landing gear—specifically, the torque links and the truck beam—are not made of steel. After conducting a thorough trade study that took into account the long-term costs of the landing gear, Menasco's design engineers recommended to BCAG that they should make

these components out of titanium instead. Titanium does indeed cost several times more than steel, but with its superior strength-to-weight ratio, the change in material offered a significant weight advantage that made titanium a better alternative overall. However, with the decision to move to titanium came an additional design responsibility. Unlike forgings made of inexpensive grades of steel, titanium is expensive enough to warrant the design and production of sophisticated dies for the forging process. The forging for the truck beam is nearly 3500 pounds, so even a modest improvement in the design of its forging die can reduce the price of the landing gear by thousands of dollars.

The responsibility for forging the titanium was decoupled into two parts: designing the forging dies, and actually forging the metal. A separate make-buy decision was made for each.

DESIGN

In the early days of the 777, BCAG directly handed down explicit designs for the forgings it wanted Wyman-Gordon to make. Designs presented in this fashion frequently had to be sent back to BCAG and/or Menasco for modifications, and subsequently bounced back and forth among the design teams at all three companies several times before they converged on a final design. This years-long tradition of passing design details "over the wall" to the other companies' engineers was for the most part rooted in the fact that, even though all three companies had worked together fairly frequently on design problems, Wyman-Gordon did not have any technical personnel stationed at either BCAG or Menasco's design facilities. In the opinion of a manager at Wyman-Gordon, the old design process was frustratingly inefficient, and often resulted in designs that were far from optimal in terms of cost and performance. For example, he is convinced that if BCAG had consulted Wyman-Gordon at the outset of the 777 program, Wyman-Gordon's engineers could have shaved 800 pounds off the weight of the forging, thereby saving BCAG several thousands of dollars per landing gear.28

28 The techniques used by Wyman-Gordon's design engineers to make forging dies are typically not state-of-the-art technologies. To be sure, the company does have on staff several Ph.D.-level researchers, but many of the day-to-day skills used to make forgings "just big enough" are manifest in rules of thumb and tacit know-how shared among Wyman-Gordon's employees. "There's a lot of well-known standards and 'tricks of the trade' in this business," said one engineer. "It's not that BCAG couldn't do this themselves; it's just that forging is our business, and we have the experience."
But things are done much differently these days. Instead of directly overseeing every detail of the entire design and development process, BCAG has empowered its suppliers with the ability to figure out for themselves many of the finer points of a component. For instance, BCAG now sends to Menasco the performance specifications of the landing gear—what weight it has to support, what its overall dimensions have to be, etc.—and Menasco’s engineers have a significant amount of say in the rest of the design details. Menasco in turn hands down to Wyman-Gordon the performance specifications and critical dimensions for the forging, leaving Wyman-Gordon’s engineers to work out the more specific technical details themselves. To be sure, BCAG still has several in-house forging design experts, but it now regularly draws on the expertise of companies like Wyman-Gordon to improve the producibility of the forgings used in its landing gears. But as in the case of the landing gear designs that Menasco’s engineers work on for BCAG, Boeing still retains ownership over any of the designs that Wyman-Gordon’s engineers come up with—that is, they may be borne of Wyman-Gordon experience and know-how, but they are “on Boeing paper.” Wyman-Gordon’s managers also indicated that this new approach is also used by Boeing’s Defense & Space Group.

**INFORMATION FLOW AND CO-LOCATION OF PERSONNEL AMONG MEMBERS OF THE SUPPLY CHAIN**

Just as significant as the change in what Wyman-Gordon’s employees are able to do is the change in where they are doing it. Unlike before, Wyman-Gordon now has an employee permanently based at Menasco’s Texas facility whose job is to attend to the details of the interactions between the two companies on a full-time basis. This move towards co-locating employees is becoming more pronounced with time. In the early stages of the 747X, which was an updated version of BCAG’s popular 747 model, BCAG’s managers expressed a desire to have a representative from both a forging company and a landing gear manufacturer at BCAG’s design center in Washington State on a full-time basis. BCAG eventually canceled the entire 747X program, citing lower expected sales than had been anticipated earlier. However, Wyman-Gordon’s managers are convinced that BCAG’s approach to the 747X will set the tone for supplier selection and inter-firm communication in subsequent programs (Figure 3.5).
PRODUCTION

The same strength that makes titanium and strengthened steel so appropriate for aerospace components also makes it difficult them forge. The hydraulic press used to forge the pieces of metal from which the 777's landing gears are machined exerts nearly 50,000 tons of force, stands 16 stories tall, and costs on the order of $100 million. It is therefore quite understandable that there are only a few companies in the Western world that have forging equipment of this magnitude.

There are few significant differences among the methods and equipment of the five forging companies, and prime contractors like BCAG therefore regard the forging process

![Diagram of BCAG, Menasco, and Wyman-Gordon]

two-way substantial sharing of information, co-location of employees

three-way substantial sharing of information, co-location of employees (proposed for 747X, seen as emerging model for future).

Figure 3.5: Emerging Model of Information Sharing Among Companies in 777 Landing Gear Supply Chain
in and of itself as somewhat of a commodity. Accordingly, BCAG has no intention of devoting the massive amount of capital necessary to set up an in-house forging center in the foreseeable future. Menasco, with a much smaller capital pool to draw from than BCAG, is also not interested in acquiring forging as a core competence.

CHOOSING A FORGING SUPPLIER

BCAG left it up to Menasco’s managers to choose where and how it got forgings to make the landing gears, so long as the forgings complied with BCAG materials specifications. However, BCAG still maintains a high degree of “hands on” control over each and every one of the forgings that will eventually be used in a BCAG airplane. For example, BCAG’s own quality control engineers thoroughly inspect all the raw titanium that Wyman-Gordon intends to use in BCAG components before Wyman-Gordon’s employees even start to work on it.

PRIME CONTRACTORS’ LIABILITY FOR MATERIALS AND PROCESSES

BCAG’s attention to almost every detail throughout the entire manufacturing stream of its airplanes is not without foundation. The company’s customers demand world class quality in the aircraft delivered to them, and rely on BCAG to ensure that the airplanes being introduced into their fleets are of the highest possible standard.

Moreover, responsibility for the Federal Aviation Administration’s (FAA) very stringent requirements—which cover everything from minimum standards for on-board data storage devices to acceptable specifications for microphones—rests squarely on the shoulders of the prime contractors. No matter how many tiers of suppliers BCAG might work with, and no matter how many firms are involved in the design and manufacturing of an airplane, BCAG is ultimately held accountable for the final product. For this reason, BCAG has traditionally maintained a high degree of direct involvement in the materials and process details of all the subcontractors and vendors throughout its supplier network.

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29 Donoghue, Robert J. Mr. Donoghue is the Vice President of Wyman-Gordon’s Sales & Marketing—Forging Division. By interview with author, 18 November 1996.
A significant part of BCAG’s “hands-on” control over its supplier network is its rigorous certification system, whereby suppliers are certified if their materials and processes meet or exceed BCAG’s standard. Because of the very high costs associated with certifying companies and maintaining their certification status, however, BCAG is actively working to reduce the number of firms in its supplier base.31

MOVE TO GREATER CONTROL OVER LOWER-TIER VENDORS

Whereas subcontractors like Menasco have traditionally been charged with the responsibility for procuring raw materials themselves, BCAG’s managers are actively working towards organizing the acquisition of major inputs in the future.32 Driving this change in strategy is a phenomenon referred to as the “bullwhip effect,”33 (Figure 3.6) in which misinformation and inter-supplier gaming results in amplified exaggerations in levels of demand at lower-tier vendors. This occurrence is best described in the following scenario: BCAG informs two independent landing gear manufacturers of its intention to design and build a new airplane, complete with landing gears made from aerospace-grade steel. Each landing gear manufacturer then communicates to its steel

31 Gilliams, John. 28 August 1996.
32 Lindgren, Edward. 28 August 1996.
suppliers that it might require a large shipment of steel in the near future. However, the quantities of steel ordered by the landing gear manufacturers may not reflect the exact amount needed.

Because of the high degree of information asymmetry among the firms involved, a process of “gaming” begins: “Will my vendor ration his deliveries to me? Would it therefore be prudent of me to order too much intentionally?” This miscommunication is further amplified down the supply chain as each steel vendor, somewhat unaware of what its competitors are doing, then stocks a large quantity of steel in anticipation of the major contract. In this way, a single order for landing gears at the top of the supply chain can inadvertently result in a signal for lower-tier steel vendors to order collectively much more steel than is needed. By organizing the procurement of major inputs for all of its first-tier subcontractors, BCAG hopes to prevent such exaggerations in the demand of a particular item or commodity, thereby averting wild fluctuations in the prices of inputs for its airplanes.34

3.4.3 Who Is Charged With Making Menasco’s Make-Buy Decisions?

Make-buy issues are dealt with on a case-by-case basis at Menasco. Representatives from several departments within the company—finance, quality, engineering, and any other parts of the company that may be significantly affected—meet informally to assess the company’s current capacity limitations, and to decide if a supplier can do the job for less money than Menasco’s in-house production teams.

3.5 Chapter Summary

When BCAG started to develop the 777, its make-buy decisions were often “stand-alone” judgments that were made at the division level, and that did not take into

34 As well, BCAG will probably be able to achieve quantity discounts by purchasing its inputs in larger batches. General Motors has also started to consolidate its purchasing by using a top-level buyer to procure components for all of its international production centers (source: Stanford Business School Case #S-OIT-6, February, 1995). One of the major drivers behind this move by GM was a desire to achieve greater economies of scale. But while economies of scale might be a positive outcome of top-level planning for lower-tier vendors, Mr. Lindgren was quite sure that it is not BCAG’s fundamental motive.
account BCAG's overall long-term strategy. Since that time, however, BCAG has developed a new make-buy strategy that better focuses on its group-wide core competencies, and that delineates explicitly when and by whom such judgments should be made. In addition to core competencies, the principal determinants underlying BCAG's outsourcing decisions are: costs, capital investment, labor relations, and market access.

Menasco is capable of making in-house nearly every sub-component that goes into any one of its landing gears, but frequently elects to outsource components and processes because of capacity constraints and/or costs. Make-buy issues are dealt with on a case-by-case basis at Menasco by a team of representatives from several departments within the company.

The three firms charged with the landing gear's design and production—BCAG, Menasco, and Wyman-Gordon—have begun to co-locate their employees, allowing the firms to interact frequently and work more cooperatively on designs.

BCAG maintains a high degree of control over most aspects of any design or production process pertaining to its airplanes. It has, however, recently empowered Menasco and Wyman-Gordon with the ability to figure out for themselves many of the finer points in designing and producing specific landing gear components or subassemblies.
CHAPTER 4: CASE STUDY B—THE F-22 SINEWAVE SPARS

This chapter provides a detailed discussion of the details surrounding the make-buy decisions involving the development and production of the sinewave spars for the wings of the F-22 by the Boeing Defense and Space Group (BD&Ś). Whereas the case study presented in the preceding chapter focuses on a major component from a commercial aircraft program, this case study examines an important part from a defense aircraft program. However, more important than the difference in the end users of the products—i.e. commercial airlines vs. the Department of Defense (DOD)—is the difference in the rates of change of the technologies behind the components: The materials and processes used to make the sinewave spars are more recent, and are evolving much faster than those of the 777 landing gear.

4.1 BACKGROUND AND INTRODUCTION

In 1991, Lockheed Martin and BD&Ś jointly won the contract to develop the F-22 as a replacement for the aging F-15. Although still in the Engineering and Manufacturing Development (EMD) phase, the F-22 is expected to become “the air-superiority fighter of the 21st century. It has first-look, first-shot, first-kill capability against any potential

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1 It is important to note that Boeing’s defense and commercial operations are independently operated, and the strategies of one do not necessarily have any direct effect on the policies of the other.

2 Lockheed Martin is the official prime contractor for the F-22, and BD&Ś was officially selected as a "subcontractor" for the design and production of the wings, aft fuselage, avionics, and many support systems. However, BD&Ś's role in the F-22 is in many ways more like that of a co-contractor. BD&Ś was left to manage many aspects of its part of the airplane by itself, including many of the materials and processes used therein.
enemy aircraft. But these ambitious objectives had to be met at an affordable cost, both in terms of its design and development and its subsequent full-scale production. One of several cost-cutting approaches examined at the outset of the project by BD&S was to make several of the airplane's wing spars out of advanced composite materials instead of aluminum or titanium, the traditional materials for spars. In addition to the expected cost reductions, the switch to composites would also result in significant weight savings in the aircraft. As depicted in Figure 4.1, this ambitious solution required the combined expertise and resources of three companies: BD&S, which is responsible for designing and constructing the wings; Dow-United Technologies (Dow-UT), which produces the resin transfer molded (RTM) spars; and Cytec Industries, which produces specialty resins used by Dow-UT in the RTM process.

Figure 4.1: The Flow of Materials in the F-22 Sinewave Spar Supply Chain

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4.2 The Technology Behind the F-22's Sinewave Spars

4.2.1 What Is a Spar?

Spars are one of the primary load-bearing structures within the wing of an airplane, and are therefore of paramount importance to the entire aircraft. As illustrated in Figure 4.2, spars are one of the principal means by which the wings lift the rest of the airplane. They also bear the torsional loads exerted on the wing. This is important in that the success of the airfoil—and therefore the upward lift of the wings—is dependent on the wing's angle of attack. By maintaining torsional rigidity, the airfoil is not free to move about, and the pilot is better able to control the aircraft.

![Diagram of a front view and top view of an airplane showing spars](image)

**Figure 4.2: The Role of Spars in an Airplane**

To be sure, wing designs have evolved such that the spars do not bear all the lift forces of the wing. Many of today's airplanes are designed with a rigid skin so that the wing's covering shares the load with the spars. Nonetheless, spars are still responsible for bearing a significant portion of these loads, and are therefore still critical to modern wing structures.

The spars used in the F-22's wings (Figure 4.3) are essentially I-beams, consisting of two parallel flanges separated by a web in the middle. The variety of spar used in the F-22

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4 This figure is merely a generic representation to explain what a spar is and what it does. For an illustration of the F-22's wing structure, see Appendix A.

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is known as the "sinewave" design because the web between the two flanges does not run in a straight line like many I-beam designs, but rather in a sinusoidal pattern. Although more complex to design and manufacture than a flat web, a sinusoidal web provides the spar with a higher degree of mechanical stiffness, thereby eliminating altogether the need for additional stiffening elements in the wing.

Figure 4.3: A Sinewave Spar

4.2.2 The Use of Composite Materials In Spars

Spars for defense aircraft have been machined out of aluminum and titanium for many years. However, because of the complex geometry of the F-22's sinewave spars, it would have been very expensive and difficult to machine each of the spars out of metal. And composite materials offered a weight advantage over metal in this application. In fact, by making the spars out of composite materials instead of metal, BD&S projected savings of over 50 percent on the long-term cost of each spar,\(^6\) a weight savings of 25 percent, and a reduction in the number of individual components in the wing.

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\(^5\) Courtesy of John Archer, the principal engineer in BD&S's Internal Spars IPT.

\(^6\) Long, Geary L. Mr. Long headed BD&S's integrated product team (IPT) for the F-22's wings. By interview with author. 24 August 1996.
"PRE-PREG" COMPOSITES

At the onset of the EMD phase in August 1991, BD&S proposed to make the sinewave spars out of pre-impregnated composites. Pre-impregnated, or "pre-preg," composites are fabricated by saturating graphite fibers with liquid resin and then manually applying them on top of one another on a set of matching mold dies. BD&S has used pre-preg on complex and critical components many times in the past, so the company's in-house composite materials team was reasonably familiar with it. But the sinewave spars were quite different from the parts it had fabricated before, and the BD&S team ran into a great deal of difficulty with the first units made with this process. High porosity and large voids in the spars resulted in rejection rates as high as 80 percent, thereby eroding the cost advantage that composite materials offered over metals.\(^7\) Such quality problems might have also created problems for BD&S throughout the life of the aircraft inasmuch as the F-22 wing was designed so that no inspection will be required for at least 20 years after the wings are assembled.

Because of the quality problems encountered in making the spars out of pre-preg composites, another composite process was considered with which BD&S’s engineers were less familiar, but that had the potential to fulfill their needs: RTM.

4.2.3 What is RTM?\(^8\)

RTM is not a new idea. The concept had been around for many years before the earliest stages of the F-22 project, and a handful of companies around the world were already making consumer products such as bicycle parts and automotive panels with this process. Moreover, the raw materials needed for RTM had already been used several times by aerospace manufacturers in pre-preg components. Nonetheless, the state of RTM technology at that time was nascent enough that it could not be trusted for critical aerospace parts. The finer details of the process and tooling had not been developed to a degree that would provide the high quality spars that BD&S needed. To that end, a

\(^7\) Welnick, Rich. Mr. Welnick was a quality engineer for BD&S who was working on the F-22 project at the time of this study. By interview with author, 28 August 1996.

new and decidedly more sophisticated process using graphite and bismaleimide (BMI) resin was contrived that could consistently produce the results that BD&S was looking for (Figure 4.4).

The process, which is patented by Dow-UT, begins with woven graphite fabric. The fabric is put into a "tackifier" where a small quantity of powdered resin is sprinkled onto the sheets of graphite and heated in an oven. The purpose of "tackifying" is to ensure that the fibers stick together so that they hold their shape and orientation during the resin injection stage. This prevents the occurrence of wrinkles in the tackified fabric, thereby making it possible to manufacture components with more complex shapes than could be achieved otherwise. The sheets of tackified graphite fabric are then cut with an automated ultrasonic knife, and placed on top of one another, forming a "flat pack."

![Diagram of the RTM process](image)

Figure 4.4: The RTM Process Used in Making the Sinewave Spars

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9 Lussier, Glenn R. Mr. Lussier is Dow-UT's F-22 Program Manager. By interview with author, 21 August 1996.

But unlike the manual lay-up process used to arrange pre-preg plies on top of one another, the new RTM process uses an automated "pick & place" system to put the flat pack's plies in exactly the right position. Correctly aligned and pressed onto a preform mold, the flat pack is then heated in an oven to re-melt the tackifying resin. When the resin cools, the flat pack is removed from the preforming mold in the same shape it will be inside the finished sinewave spar.

The preformed flat pack is then sandwiched between two stainless steel matched metal tools which close to form the mold cavity inside the flexible molding cell. The resin is injected at high pressure, and cured by heat. For the F-22, BMI #5250-4 resin was used because of its ability to endure temperatures that would cause most other resins to break down chemically. After the resin is injected, the mold is opened, and the component can be trimmed and holes can be drilled as required.

Despite the brevity of the preceding description, however, RTM is not a simple process. The matched metal tooling that defines the shape of the spar must be painstakingly designed so that the resin flows properly within the cavity. The matter is further complicated by the fact that there are few widely accepted standards for the RTM process in the industry. Because RTM is used for such a broad range of products which vary substantially in terms of size, shape, and criticality, supplier companies that manufacture RTM products differ significantly in the materials and methods they use.

4.2.4 Barriers to Using RTM

The F-22 System Program Office (SPO), based at Wright-Patterson Air Force Base (WPAFB) in Ohio, saw BD&S's move from pre-preg to RTM composites as an unnecessary risk, and did not share BD&S's enthusiasm for this bold step forward. While RTM had been applied several times before in previous airplane projects, it had never been used in mission-critical components such as spars. But the top-level managers in BD&S who were in charge of the company's work on the F-22 eventually convinced the SPO that the potential production cost savings justified the change in composite technologies.

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11 Gibbons, Martin. Mr. Gibbons was the IPT focal for the F-22, and worked alongside Geary Long. By interview with author, 26 August 1996.

Robert K. Perrons 73
Also, BD&S's engineers were not totally certain that RTM could be used in an application such as this, and there was not time to develop that option in-house to a point of technical viability within the project's original time frame. However, a 19 month slip in the F-22's development schedule afforded the BD&S team the additional time it needed to pull together a plan of action to use RTM spars in the project.

4.3 BD&S's MAKE-BUY DECISION PROCESS

4.3.1 BD&S's General Outsourcing Policies

In the preliminary stages of the F-22, a general methodology was in place to guide BD&S's materiel managers through their make-buy decisions. This system was well documented and distributed to all of the company's procurement managers in an attempt to align their actions with BD&S's long-term strategic goals. Essentially, "make or buy planning [was] performed to aid in establishing and achieving the long-range business strategy of [the] Boeing Defense & Space Group and to produce the best value for [its] customers." Flowcharts defined in explicit detail the steps that the "define and produce" teams were to follow en route to preparing an outsourcing strategy, and laid out very clearly the order in which these steps should be undertaken. BD&S also supplied its program managers with a product matrix, which is:

... a document... to be used by programs in identifying the various types of products (hardware, software, functions, and services) that relate to critical core competencies. It lists those products [BD&S] is distinctively good at making and must Make, those we have the capability to Make but have the option to Buy depending on capacity, and those products we must Buy because suppliers have a definite comparative advantage.

In addition to the product matrix, there are other principal factors that shape BD&S's outsourcing decisions, such as total cost, risk, capital investment, and personnel.

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11 BD&S Group directive #AD-DBS-003, issued 16 June 1995 by J. Schmit, Senior Vice President of Operations, p. 2. This directive was issued after a decision was made about the F-22's sinewave spars, but it accurately reflects the view held by senior level managers at that time.

12 BD&S internal memorandum draft, issued 3 March 1997 by J. W. Evatt, Executive Vice President.
TOTAL COST

As noted earlier, the Air Force is definitely interested in achieving its tactical objectives at affordable prices. BD&S accordingly pays a lot of attention to the cost of every component and process that it uses in its defense products. But there is more to such cost assessments than the "up-front" per unit cost put forth by a prospective supplier. For example, if a particular task is outsourced to an outside firm, BD&S has to devote some resources to ensure that things are moving smoothly with the outside company, and that the components being shipped to BD&S are on time and of an acceptable level of quality. The financial analyses conducted by BD&S therefore take into account the support costs that are inherent in any outsourcing decision. For these types of analyses, finance estimators use BD&S's Make or Buy Cost Model, which comprehensively assesses all cost factors inherent in make-buy decisions, including all BD&S support costs associated with buying a component or process from a supplier. The cost model is used prior to any decision to outsource items listed as either make or make-or-buy in the product matrix.

RISK

Many of the processes and technologies used to make BD&S's products are neither standard nor commonplace. There is therefore a high degree of risk incurred by BD&S in outsourcing the design and production of components to a subcontractor. Do the subcontractors really know what they are doing? Are there variables or uncertainties that might have an adverse effect on the quality of the components, but of which BD&S's procurement managers are unaware? To insulate themselves from undue degrees of risk, BD&S's managers prefer to keep in-house any component or process that is shrouded in technological uncertainty or that is deemed as proprietary.

CAPITAL INVESTMENT

Like most companies, BD&S has at its disposal finite resources with which to enhance or develop new in-house capabilities. BD&S managers therefore have to choose among competing products and processes to decide which ones should be outsourced to subcontractors and which ones BD&S should make in-house. To minimize the degree of uncertainty brought about in situations where BD&S simply does not have the capacity to make a part in-house, it frequently engages in Purchased Outside Production (POP).
contracts, in which other firms are hired solely for their production capacity, and not for their design capabilities. The design details and process specifications behind these components are put together by BD&S’s in-house engineers, and handed down to the subcontractors in a “build-to-print” fashion.

PERSONNEL

“Probably no other industrial product embodies as much refinement in the combined techniques of metallurgy, electronics, and computers as a jet aircraft.” Indeed, a great many skills go into making an airplane, especially one that utilizes as many “cutting edge” technologies as the F-22. Consequently, a large portion of BD&S’s employees—from the shop floor laborers to the engineers—are highly skilled in their trade, and would surely be difficult to replace. Because it cannot afford to forego the massive investment it has made in its employees, BD&S’s make-buy decisions are very sensitive to the company’s workforce capability and the impact such decisions will have on BD&S’s employees.

RELATIVE INSENSITIVITY TO FOREIGN MARKET ACCESS

One of the more noteworthy differences between BD&S’s make-buy policy and that of BCAG is that BD&S’s managers pay relatively little attention to the prospect of foreign sales in the initial planning stages of a defense program:

Foreign sources on the front end of advanced military hardware programs are usually not considered prudent. That’s partly because the customer normally has specifications (via “Mil. Spec.”) that explicitly say that all critical components and materials need to come from sources under the jurisdiction of the U.S. government. The other part of the consideration is that we are typically trying to convince Congress that the program would be good business in each of their districts, and no Congressman gets elected by foreign constituents.15

The situation changes, however, when a program is being jointly funded by the DOD and a foreign government. The Joint Strike Fighter (JSF), for which Britain’s Royal Navy

15 Coe, Steven L. Mr. Coe is the Manager of BD&S’s Central Manufacturing Engineering Department. As well, he co-led the F-22 Wing IPT with Geary Long during the project’s initial stages of development. By personal communication with author, 5 May 1997.
has been a customer from the onset, is a recent example of this kind of arrangement. The design and production of the JSF will be divided between contractors in both countries.

PROGRAM SPECIFICITY OF MAKE-BUY PLANS

Even though BD&S’s program managers were expected to adhere to the company-wide make-buy policy when putting together outsourcing plans for the sinewave spars, the process of the day was much less formal than the Group’s current policy. But like Boeing’s Commercial Airplane Group, BD&S is actively transforming the way it handles its make-buy decisions, and is instituting more structure in its make-buy strategy to help its program managers communicate and balance program and company interests. However, as in the early days of the F-22 program, the particular details of make-buy decisions within BD&S are determined on a program-by-program basis. In fact, the revised process is not fundamentally different from the procedure used throughout the design and development of the F-22’s wings.

BD&S still recognizes that many of the salient issues surrounding any program are very case-specific, and that there will always be limitations and details that could not possibly be accounted for in a common company-wide policy. Thus, while the new make-buy policy does not prevent program managers from deviating from the company-wide product matrix, it requires them to rationalize their decisions to an Executive Make/Buy Committee, which is comprised of senior-level executives. By providing a forum for its program managers to explain formally their make-buy strategy to an executive committee, BD&S balances program risk, performance, and economics with company strategic interests in its new business programs. However, the Make/Buy Committee only focuses on new business programs, and did not review the F-22’s make-buy plan because the program was already under contract.

In addition to recognizing the program-by-program variations inherent in outsourcing decisions, BD&S’s make-buy policy also reflects the fact that outsourcing strategies will surely vary over time. “The individual technologies behind core competencies have a shelf-life,” remarked one manager, “and that shelf-life can be pretty limited.”16 In a dynamic environment like the defense aerospace industry, the mix of skills and capabilities needed for tomorrow’s products might be radically different from those

16 Baldyga, Leo. 8 April 1997.
used by the industry leaders of today. Therefore, when a company’s core competencies no longer offer a competitive advantage over other firms, "it’s time to start outsourcing those activities to other companies."

4.3.2 Make-Buy Decision for the RTM Sinewave Spar

**THE SOURCE SELECTION PROCESS**

To develop a working RTM process within the confines of the F-22 schedule, BD&S’s managers set up four programs with different manufacturers of RTM products. One program was with BD&S’s own in-house RTM group, and the others were with outside firms that also had prior experience with the process. Members of BD&S’s F-22 wing IPT were assigned to each team to help them devise a system that could consistently deliver high quality spars. At the end of the development phase, each project was judged according to its cost and the ability of the team to deliver the units on time.

BD&S’s in-house composites group had used RTM on a few different projects for components ranging from missile tail fins to drain masts on airplanes, but these applications were not nearly as complex or critical as the sinewave spars. The team consequently lacked the depth and breadth of experience that was needed to apply the technology in this new and more demanding direction. Essentially, BD&S’s own RTM experience was caught in too many little pockets that it could not integrate. There was no broad perspective at BD&S to apply the process to bigger, more complex parts. In this way, BD&S’s in-house team—which had been experimenting with RTM components for longer than some of the competing companies had been in existence—did not really have much of an advantage over the less established contenders that lacked significant production experience and the necessary capital equipment.

**AWARDING THE CONTRACT**

By the end of the development phase, a winner had emerged: Dow-UT, which was based in Connecticut. BD&S’s in-house capability was significantly behind that of

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17 Baldyga, Leo. 8 April 1997.
Dow-UT, and the BD&S team could not develop its tooling and process in time. As well, Dow-UT had made significant capital equipment purchases, and had developed its unique "tackifying" process, which allowed it to make cost-efficient RTM spars in time for the program’s EMD phase.

BD&S would have preferred to let its own team handle the RTM spars for the F-22. Indeed, if not for the time constraints placed upon the project, it is almost certain that BD&S would have done the work in-house. BD&S sees wing designing as a core competence, and prides itself in being a leader in the application of composite materials.19 Several members of BD&S’s in-house RTM team were disappointed with their higher-level managers’ decision to give the contract to an outside supplier.20 But time was of the essence, and despite the BD&S team’s efforts, the F-22 wing IPT “had to move fast to fit RTM into the schedule”21—and that meant letting Dow-UT do the job.

**DOW-UT’S OBJECTIVES**

Dow-UT was understandably quite happy to get the contract from BD&S. Over the next fifteen years, over 450 F-22 fighters were being planned for production, each one containing 46 unique spars. Dow-UT does indeed make other pre-preg and RTM components, but the sinewave spar contract represents an important part of the company’s expected future revenues.

There was, however, more to the company’s motives than the allure of profits from the F-22 program. Dow-UT had a long-term goal in mind when it vied for the F-22 sinewave spar contract: It wanted to establish a foothold for complex RTM components—specifically, its RTM components—in the aerospace industry.22 Other airplane manufacturers, including BCAG, do not currently trust RTM for mission-critical

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18 Dow-UT is a joint venture in which Dow and United Technologies are equal partners. It is not a subsidiary of either parent company, but rather a stand-alone joint venture that must "sink or swim" on its own. In 1989, the two companies came together—UT with its aerospace experience, and Dow with its experience in composite technologies and a sizable infusion of cash for the new venture.

19 Coe, Steven. By interview with author, 29 August 1996.

20 Claudette Gordon, Kevin Lee, and Brian Laliberte, all of whom are from BD&S's Materials and Process Division, agreed that many of the Division’s engineers were extremely disappointed by the fact that the in-house RTM team was not funded for further effort on RTM products. By interview with author, 27 August 1996.

21 Smith, Matt. Mr. Smith was a tooling engineer with BD&S who worked on the tooling for the RTM spars. By interview with author, 27 August 1996.

22 Lussier, Glenn. 21 August 1996. BD&S's Geary Long also mentioned that Dow-UT was looking forward to developing RTM sales above and beyond the F-22.
components. Dow-UT’s managers hoped that by having critical RTM parts on a high profile project like the F-22, managers and engineers in other aerospace companies would give RTM a second look. This in turn would expand the range of application possibilities for the technology, and leave Dow-UT with a sterling reputation in the industry.

**Risks Borne by Dow-UT**

Dow-UT’s belief in the importance of the F-22 project to the company’s future is clearly demonstrated by the risks it incurred to obtain the contract. When BD&S started soliciting bids from potential RTM sources, Dow-UT had already been using the technology for years, and had experience in making and selling rotating aircraft engine components made from RTM. But manufacturing a component like a spar is another matter entirely, and Dow-UT could not simply use the equipment it already had. To be able to produce the sinewave spars, the company had to invest approximately $8 million in new installed equipment. And while this amount might pale in comparison to the billions of dollars that routinely changes hands in defense contracts, it was a significant sum for a company of Dow-UT’s size. Moreover, the company undertook this investment without knowing for certain if it would be selected for the contract. BD&S’s managers were not willing to make any promises to Dow-UT until they could see some evidence that the company was indeed capable of manufacturing reliable aerospace-grade RTM components with non-trivial geometric shapes.

Upon winning the contract for the sinewave spar, Dow-UT had to take yet another gamble. The company’s managers certainly realized that if BD&S’s engineers learned all the “tricks of the trade” from their experience with the sinewave spars, it would no longer need Dow-UT for its expertise in manufacturing RTM components. Moreover, with its sheer size and capital resources, BD&S might then be able to supplant Dow-UT as the industry expert in RTM aerospace component technology. It was clear that Dow-UT had to take steps to protect its long term strategic interests.

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23 Many innovations in the aerospace industry are developed and first implemented in defense projects, and then adopted later on by commercial airplane manufacturers. For example, jet engines were used in civilian airliners only after their reliability was first proven in defense aerospace projects.

24 Lussier, Glenn. 21 August 1996.
THE "TWO HATS" PROPRIETARY KNOWLEDGE CONTRACT

To prevent BD&S from using Dow-UT's proprietary knowledge in subsequent projects, BD&S prepared and signed a proprietary agreement as part of the contract that binds BD&S employees, effectively preventing them from ever applying Dow-UT's proprietary ideas and techniques outside of the F-22 program. Figuratively speaking, BD&S employees assigned to the project wear two hats: one as a BD&S employee, and the other as a member of the F-22 team. While they are in and around other F-22 project members, they are free to talk openly about their work. But when they leave the confines of a sinewave spar project area, they are not allowed to talk about the technical, proprietary details of Dow-UT's RTM process with fellow BD&S employees who are not working on the sinewave spars themselves.\(^{25}\)

THE DESIGN AND FABRICATION OF TOOLING

A major cornerstone of Dow-UT's RTM process is the tooling, which can be divided into three parts: the forming tools, the installed equipment, and the part-specific tools. As mentioned before, one of the principal motives behind BD&S's decision to award the sinewave spar contract to Dow-UT was that the company was the first to develop its tooling system. But ironically enough, the tools and equipment so key to the company's process were largely based on the expertise and capacity of other firms for which tooling was a core competence. The installed equipment, which holds the part-specific tools in place during the RTM process, was developed by Dow-UT with a lot of help from a company that usually makes tooling equipment for the automotive industry. Also, the forming tools needed to shape the fabric before the resin is applied was developed jointly by Dow-UT and Draper Laboratories in Massachusetts.

The basic tooling used by Dow-UT to produce the test coupons\(^{26}\) was sufficient to win the contract, but only a handful of part-specific tools, which are machined out of stainless steel, had to be made for this. To manufacture each of the 46 individual spars inside each F-22, Dow-UT needed first to produce that many unique sets of part-

\(^{25}\) There is, of course, a very high degree of "good faith" in a contract such as this. It would surely be difficult to prove whether or not any proprietary Dow-UT techniques were ever used by BD&S outside of the F-22. However, Dow-UT's managers have remained quite convinced that BD&S personnel assigned to the F-22 wing project have conducted themselves in the spirit of the agreement, and they have not yet encountered any problems.

\(^{26}\) A "coupon" is a dummy component of specified dimensions made for the sole purpose of testing.
specific tools. And because the tools are so crucial to the RTM process, Dow-UT wanted to control their design and fabrication. But as with the forming and installed tools, the company would have relied on subcontractors for the fabrication of the part-specific tooling. BD&S’s managers thought that the project would be exposed to an unnecessarily high degree of risk by relying exclusively on outside contractors for such a critical task, and were therefore adamant about controlling the design and fabrication of the part-specific tools.

Since developing and maturing the RTM process to the F-22’s requirements was such a daunting undertaking, the design and fabrication of the highly sophisticated tool set required the combined expertise of Dow-UT and BD&S. To draw on the available first-hand knowledge of Dow-UT’s process requirements and capabilities, BD&S’s engineers worked with Dow-UT personnel in an IPT fashion. After developing a contract and working agreement on the tooling design requirements with Dow-UT, BD&S proceeded to design and fabricate the tools in-house. But due to internal capacity commitments to other F-22 production and tooling hardware, approximately 66 percent of the tooling fabrication work was outsourced. A proven supplier, UCAR Composites of California, was selected for the task based on its excellent history with regards to cost, schedule, and quality throughout the fabrication of similar tools for BD&S in the past.

**BD&S’s Continuing In-House RTM Efforts**

Despite BD&S’s decision to subcontract the production of the F-22’s spars to Dow-UT, it is still aggressively developing its own in-house RTM capability. The qualities that made RTM parts such an attractive option for the F-22 wing—low per unit costs, tight tolerances, and high quality—will also make the technology an excellent candidate for components in subsequent projects. And composites are indeed playing an increasingly important role in BD&S’s designs. A large proportion of the JSF’s wing design, for which BD&S won a Concept Demonstration Program (CDP) contract in November 1996, consists of composite materials. Moreover, now that it has been demonstrated that RTM is a reliable alternative for critical components like spars, it is quite possible that BD&S’s design teams will use the technology in those types of applications in future contracts. BD&S regards the design and manufacturing of composite parts as a core

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27 Gesell, Terry. Mr. Gesell was an engineer with BD&S’s MR&D Department. By interview with author, 28 August 1996.
competence, and because RTM will probably play a key role in future projects, the company is eager to develop its own RTM in-house production capability.

4.3.3 Who Makes BD&S’s Make-Buy Decisions?

When a make-buy decision is made and by whom is very much dependent on the product or process in question. Some end items and major systems are earmarked for separate consideration by senior executives in the early stages of the concept formulation phase. These parts are outsourced or kept in-house according to not only the company’s core competencies, but also the company’s strategic objectives, and strategic alliances with another companies. As well, BD&S may elect to insource a product or process because it is trying to venture into a new technology area.\textsuperscript{28} The components behind these types of decisions are typically very large in both scope and cost, and must be justified to the Executive Make/Buy Committee if the proposed strategy deviates from the make-buy strategy delineated in BD&S’s product matrix.

However, all products and processes must conform to the make-buy decision process shown in Figure 4.5. The program manager is responsible for figuring out an appropriate strategy for each product, and is supported by a large team consisting of as many as 50 people who are charged with thinking through the circumstances surrounding every make-buy decision. The team is comprised of a broad array of employees, including manufacturing and test personnel, project engineers, and materiel managers.

4.4 DOW-UT’S MAKE-BUY DECISION PROCESS

4.4.1 The Company’s General Outsourcing Policies

By virtue of its size, Dow-UT is somewhat reliant on outside suppliers for materials that are critical to the company’s day-to-day operations. No matter how strategically

\textsuperscript{28} Hopp, Gerald S. Mr. Hopp is a Procurement Manager in BD&S’s Materiel Department. Personal communication with author, 8 April 1997.
important a material might be to Dow-UT’s business, it might be that the company simply cannot afford to develop an in-house production center to provide it. A single make-buy judgment at Dow-UT is therefore more critical than any one decision at BD&S in that each major conclusion typically requires Dow-UT’s managers to commit a significant portion of the company’s capital resources to a single purpose. Simply put, when making an outsourcing decision, the stakes are relatively higher for small suppliers than for large contractors.

THE ROLE OF PRIME CONTRACTORS IN DOW-UT’S MAKE-BUY DECISIONS

Despite the fact that these decisions have a tremendous impact on Dow-UT, the company often has surprisingly little say in such matters. Prime contractors routinely tell Dow-UT what materials it has to use, and from what firms it has to buy them. In

Figure 4.5: BD&S’s Make-Buy Hierarchy

STEP 1: Some larger components and systems are designated “make” or “buy” according to top-level strategic objectives.

STEP 2: Program manager, system level, and component level personnel discuss circumstances of specific situations and define options together.

STEP 3: Program manager must rationalize to Committee major decisions that deviate from BD&S’s product matrix.

STEP 4: Program manager executes make-buy plan.

- Execution of make-buy decision
- Information flow

Denotes that Committee did not review make-buy plan for F-22 sinewave spars.
fact, there are functions that Dow-UT is perfectly able to perform which the prime contractors require to be provided by another supplier. For example, Dow-UT has its own loom, and is quite capable of weaving its own graphite fibers for RTM components. However, Dow-UT is not certified by all prime contractors for this function, and it cannot use graphite cloth manufactured at its in-house facility for the F-22. Moreover, the company has no intention of changing this. To meet all of the prime contractors’ certification standards would entail investing a lot of time and money, and Dow-UT’s managers simply do not think it is worth it.

**Prime Contractors’ Liability for Materials and Processes**

This extreme sensitivity to matters of certification by the prime contractors stems from the fact that it is the contractors, and not their suppliers, who are held accountable for the materials used in defense aircraft. This meticulous attention to detail extends beyond the materials themselves. The contractors are not simply concerned with the end result put forth by a supplier; they also pay close attention to the processes. For example, Cytec Industries, which produces the BMI resin used in the sinewave spars, is contractually bound to adhere closely to volumes of explicit process specifications laid out by BD&S. These specifications include such minute details as the mixing time for chemicals used in the resin, and the temperatures at which they are processed. Any deviation from these specifications, no matter how minor, must first be approved by BD&S’s material engineers.

**Advantages of "Hands-On" Involvement by Prime Contractors**

There are, however, distinct advantages to letting prime contractors play an active role in the procurement of materials and processes for smaller suppliers. One manager recalled how a supplier of graphite fabric once told Dow-UT that it simply had to wait for more of the particular fabric it wanted. Dow-UT in turn explained the situation to the program’s prime contractor, which immediately phoned the lower-tier supplier directly to straighten out the problem. Because primes are much larger and have much more influence than their smaller suppliers, they can get things done that otherwise might not get done. In this way, BD&S frequently uses its size to overcome obstacles encountered by its suppliers.

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29 Harrison, Patricia. Ms. Harrison is a marketing manager with Cytec Industries in Havre de Grace, MD. Personal communication with author, 16 April 1997.
CRITERIA FOR DECISIONS LEFT TO DOW-UT

For those materials and processes not directly controlled by the prime contractor, the company's primary criterion in deciding whether to make or buy is price. To be sure, there are instances in which Dow-UT decides to retain a skill or capacity in-house when there are suppliers who would be able to do it at a lower cost. But if the lowest cost is not awarded the contract, the company's senior managers require that there be a compelling explanation as to why. Among the other issues that play an important role in the company's make-buy decisions are:

- Quantity—will Dow-UT need so much of a particular material that it is worthwhile to make it in-house?

- Strategic position of the company—if a process or material is vital to one of Dow-UT's more important products, the company would rather keep that skill or material in-house to make itself less vulnerable to the potential competition of its suppliers.

- Trust and familiarity also play a significant role in outsourcing decisions—Dow-UT is more likely to outsource the production of a material or process to a supplier that it has worked with before.

- Maturity of the technology behind the material or process—if the company cannot locate a supplier that already knows exactly what needs to be done and exactly how to do it, Dow-UT would prefer to do the job itself.

4.4.2 Dow-UT’s Make-Buy Decision for BMI Resin

COMPLEXITY OF MANUFACTURING PROCESS BEHIND BMI

BMI #5250-4, the resin used in the RTM process to make the sinewave spars, is based on a patented formula, and is able to withstand higher temperatures than those used in other composite applications. Manufacturing it requires a great deal of knowledge about the chemical reactions underlying the production process. It is not sufficient for a company simply to buy the necessary chemicals and mix them together. Because of the high degree of expertise and experience necessary to manufacture the resin, neither Dow-
UT nor BD&S sees the production of BMI as a core competence, and neither company is currently working towards having an in-house production facility in the future.

"HANDING OFF" RESPONSIBILITY FOR MATERIALS SPECIFICATIONS

As noted earlier, Lockheed Martin, the prime contractor for the program, is officially responsible for selecting all the materials used in the airplane. Nonetheless, the decision to use Cytec's BMI resin over those of its competitors was made by BD&S's managers, and not Lockheed Martin's. Because of BD&S's long-standing focus on composite technologies as a core competence, its chemists were more familiar with the resin and its properties than Lockheed Martin's composites experts. Moreover, from their dealings with Cytec in previous programs, BD&S's engineers were already well acquainted with Cytec's patented process. Realizing that BD&S's experts were better qualified to attend to the technical details of the BMI resin than Lockheed Martin's in-house composites team, the program manager at Lockheed Martin informally handed off to BD&S the responsibility for authoring the material and process specifications for the resin. But Lockheed Martin is still formally in charge of the specifications. To that end, the materials and process guidelines put forth by BD&S were officially documented by Lockheed Martin, although they were authored by BD&S's engineers.\(^{30}\)

"BASELINING" THE RESIN

One of the principal motives for using Cytec's BMI resin was that it was already "baselined"—that is, many rigorous certification tests had already been done by Cytec's engineers for Lockheed Martin and BD&S, and the resin's characteristics had been carefully and thoroughly documented in a database shared by both Lockheed Martin and BD&S.

Conducting the certification tests necessary to baseline the BMI resin was both a time-consuming and expensive process for Cytec. The contractors are very protective of the information in their database, and they scrutinized very closely every detail of Cytec's testing methods. It was not enough for Cytec to volunteer the data that its in-house engineers had compiled. If the testing was not done under the watchful eye of one or both of the contractors, it was usually rejected.

\(^{30}\) Long, Geary. Personal communication with author, 5 May 1997.
Because of the rigorous testing requirements behind baselining a particular material, prime contractors are extremely averse to using new materials whose characteristics are not already in their database. Cytec’s BMI is the only resin of its kind whose characteristics are documented in the materials database, and there is therefore little direct competition from other resin manufacturers in this product line.

**INFORMATION FLOW AMONG MEMBERS OF THE SUPPLY CHAIN**

A consequence of BD&S’s direct procurement of the resins on Dow-UT’s behalf is that Dow-UT has very little direct contact with Cytec. In fact, Dow-UT’s managers and engineers rarely speak directly to Cytec personnel, and have only met in-person with Cytec employees six times over the last seven years. BD&S, on the other hand, contacts Cytec by telephone almost daily, and meets face-to-face with Cytec’s managers and engineers almost every three months. The communication pathways among the three companies in the supply chain are illustrated in Figure 4.6. Because Cytec deals with Dow-UT so infrequently, Cytec’s managers see their company more as a supplier to BD&S than to Dow-UT.

One of Cytec’s managers was quite confident that Dow-UT’s sinewave spar team could have benefitted tremendously from the experience and know-how of Cytec’s engineers. However, much to the disappointment and puzzlement of the manager, Cytec was never invited to join any kind of IPT specifically dealing with the sinewave spars. She also remarked that BCAG, which uses Cytec’s resins in several of its composite components, deals with Cytec in almost the same way—that is, Cytec’s managers communicate more or less exclusively with BCAG personnel, and Cytec is never called on to nominate IPT members to assist in the product development process.

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31 Harrison, Patricia. 16 April 1997.
4.4.3 Who Makes Dow-UT’s Make-Buy Decisions?

Dow-UT’s make-buy decisions are made by a multi-functional group of senior level personnel, including the program manager and representatives from the procurement, engineering, and operations departments.

As noted earlier, the small size of the company creates a situation in which the consequences of any one decision are relatively much more significant than a similar decision in a large company like Boeing. For that reason, the company does not feel comfortable with trusting its make-buy decisions to a company-wide plan; rather, the multi-functional group makes its outsourcing decisions by assessing each make-buy option according to the specific circumstances surrounding the situation.\textsuperscript{32}

![Diagram](https://via.placeholder.com/150)

**Figure 4.6: Communication Pathways in RTM Spar Supply Chain**

\textsuperscript{32} Lussier, Glenn. 21 August 1996.
4.5 **CHAPTER SUMMARY**

To guide its managers through make-buy decisions, BD&S has put together a comprehensive methodology that defines in explicit detail the steps that its managers ought to follow en route to preparing an outsourcing strategy for new aircraft programs. An integral part of the methodology is a product matrix that identifies the products that BD&S must make in-house, those that it has the capability to make but has the option to buy depending on capacity, and those that it must always buy. In addition to the core competencies delineated in its product matrix, BD&S’s make-buy decisions are also determined by total cost, risk, capital investment, and personnel. It is important to note, too, that foreign market access does not play a key role in BD&S’s make-buy strategy because of the DOD’s insistence that all critical components and materials come from sources under the jurisdiction of the U.S. government.

Dow-UT has surprisingly little say in many of its make-buy “decisions.” Prime contractors routinely tell Dow-UT what materials it has to use, and from what firms it has to buy them. For those materials and processes not directly controlled by the prime contractor, the company’s primary criteria for assessing make-buy options are: price, the quantity of the good required, the strategic position of the company, familiarity with the supplier, and the maturity of the technology behind the material or process.

Because BD&S directly procures the resins needed for RTM on Dow-UT’s behalf, Dow-UT’s managers and engineers have very little direct contact with their counterparts at Cytec. Thus, Cytec’s managers see their company more as a supplier to BD&S than to Dow-UT.

The next chapter will draw on the observations put forth in Chapters 3 and 4, and propose a make-buy framework for the U.S. aircraft industry.
CHAPTER 5: A MAKE-BUY MODEL FOR THE U.S. AIRCRAFT INDUSTRY

As discussed in Chapter 2, America's defense and commercial aerospace sectors are markedly different in many regards from most other industries. Accordingly, existing make-buy models fail to explain sufficiently how managers in the industry make outsourcing decisions. Drawing on the observations discussed in Chapters 3 and 4, this chapter proposes a framework that explains ex post how managers in the aerospace sector decide to make or buy a particular component or process, and that offers suggestions for future outsourcing judgments in the industry. This chapter also outlines a make and buy strategy that large companies should consider for securing or maintaining a leading role in their respective core competencies.

5.1 THE MAKE-BUY FRAMEWORK

5.1.1 The Importance of Technological Maturity in Make-Buy Decisions

The make-buy policies of the primes and suppliers examined in the preceding chapters almost never explicitly point to technological maturity as a prime consideration in the outsourcing judgments of those firms. Nevertheless, the technological maturity of a component or process is indeed of principal importance, and is manifest in their make-buy policies and practices.
As noted earlier, prime contractors in both the commercial and defense aircraft sectors are ultimately responsible for the quality and performance of everything that goes into their airplanes. It is therefore understandable that primes typically prefer to have at least a working familiarity with every aspect of their aircraft, from the raw materials to the processes by which the components are manufactured. As an extension, the technological maturity of a component is a major consideration in the industry’s make-buy decisions inasmuch as both primes and key suppliers are typically quite familiar with established technologies, and are more inclined to outsource components whose production is based on materials and processes that they know and trust. For example, there is only a minimal degree of uncertainty involved with the design of forgings for landing gear components. The designing of forgings is in many ways a mature technology, and comparable forging design techniques are employed by a handful of companies. BCAG therefore perceives very little need to make forgings in-house when firms such as Wyman-Gordon have well-established capabilities to perform such tasks.

BD&S also considers technological maturity in its make-buy decisions. Because of the criticality of aerospace components, extensive theoretical proof may not be enough to convince BD&S’s managers that a component or process that makes use of a new technology is perfectly safe; there is often little substitute for experience and old fashioned “trial by fire.” Thus, a prime incurs a considerable amount of risk by outsourcing components whose underlying technologies are relatively nascent. It therefore follows that by pointing to risk as one of the principal criteria in its official make-buy policy, BD&S implicitly regards a component’s technological maturity as a major factor in its outsourcing policy.

But BD&S’s reluctance to outsource components involving cutting-edge techniques or materials is not just manifest in its policies; it is also evident in its actions. BD&S opted to retain in-house the design of the part-specific tools for the F-22’s RTM spars because outsourcing this task would have exposed the project to an unnecessarily high degree of risk. Unlike forging designs for landing gears, the tooling designs associated with the spars were based on relatively new technologies and processes with which BD&S was not completely familiar even though it had already developed an in-house capability in these areas.

Thus, a strong conclusion emerging from the case studies reported earlier is that technological maturity is a principal factor behind outsourcing decisions in the U.S.
aerospace industry, particularly in cases of major critical components where the degree of technological maturity also serves as a reliable indicator of the degree of technical risk faced by the customer company making the outsourcing decision.

5.1.2 The Significance of a Firm's Competitiveness

As noted in Chapter 2, prime contractors in the aircraft manufacturing industry are rarely able to use components that are "just good enough." Because many of the systems in an airplane are "mission critical," aerospace manufacturers are extremely sensitive to the quality of the materials and components used in their airplanes. Whether on their own initiative or at the insistence of a regulating government agency, primes typically prefer to use the safest and highest grade parts and materials whenever possible. This commitment to using top-quality inputs plays a pivotal role in the outsourcing decisions of aircraft manufacturers.

For example, on the first page of BCAG's make-buy directive is a mandate for its managers to "ensure that World Class levels of performance are met and maintained by both internal and external sources." But this insistence by BCAG's senior managers to use only top-of-the-line components and processes does not just include other aerospace manufacturers; rather, to be "World Class is to be one of the best in the world... across all industries." BD&S is also committed to using only the highest quality goods and processes in its airplane components. But like any military contractor, BD&S's insistence on top grade inputs and techniques is largely a result of the fact that its dominant customer, the DOD, has traditionally handed down innumerable military specifications, or "mil. specs," that define in overwhelming detail exactly how and with what a product is to be made. The parameters issued for the production of the BMI resin for the F-22's sinewave spars are a shining example of the extremely meticulous detail of mil. specs. Cytec Industries, the company that makes the resin used in the spars, must adhere

closely to such minute DOD-issued particulars as mixing times and exact processing temperatures.

Commercial and defense aerospace contractors alike therefore consistently use components and processes that are of the highest possible caliber. Accordingly, if a company involved with the manufacturing of an airplane is not among the best in the world in using a particular type of material or in performing a manufacturing process, it will either try to improve its in-house efforts to meet the standards of the world leaders in that field, or outsource the component to a firm that is among the best.

5.1.3 Developing a Framework

These two factors—the technological maturity of the component or process, and the competitiveness of a firm with respect to the particular technology—play significant roles in the aerospace industry's outsourcing decisions, but are not reflected or are underemphasized in current make-buy models. What follows is a framework that is distilled from the foregoing case studies, and that will address these characteristics. Moreover, in addition to rationalizing *ex post* the make-buy strategies of the companies studied, this framework will serve as a guide that managers in the aerospace industry can use *ex ante* when formulating a make-buy strategy for their companies.

**Framework Overview**

The framework is summarized in the matrix shown in Figure 5.1, which divides the field of potential make-buy situations into four principal categories:

1) the component or process involves a technology that is quickly evolving, and the company is substantially behind the leading firms with respect to its technological competitiveness (top left quadrant)

2) the component or process involves a technology that is quickly evolving, and the company is among the leading firms with respect to its technological competitiveness (top right quadrant)

3) the technology behind the component or process is relatively mature, and the company is substantially behind the leading firms
with respect to its technological competitiveness (bottom left quadrant)

4) the technology behind the component or process is relatively mature, and the company is among the leading firms with respect to its technological competitiveness (bottom right quadrant)

Each quadrant of the framework is further divided according to whether or not the company regards the particular design or manufacturing activity as critical to one of its core competencies.³

The next four sections discuss the circumstances surrounding each of these scenarios, and construct an appropriate course of action for each by examining the make-buy decisions of the firms described in Chapters 3 and 4.

5.1.4 Quickly Evolving Technology, Behind Leader in Use and Development

INNOVATIVE IDEAS FROM OTHER FIRMS

Despite a company's best efforts to develop or implement a new technology, an outside supplier can sometimes do it first. This is not necessarily a shortcoming on the part of the company's in-house research personnel; many fantastic breakthroughs in science and engineering do not occur because of well thought out, highly focused research projects, but through a series of serendipitous and unpredictable interactions between seemingly unrelated fields and disciplines.⁴ Simply put, it is often difficult to see how, where, or when the next big breakthrough in a particular field will occur. Therefore, among the thousands of individual skills and techniques that will be utilized to design and produce the next generation of airplanes for any aerospace company, many will be invented or first applied not by the company itself, but by its suppliers or potential suppliers.

³ Of course, many firms—including some of those examined in this study—have at best a loose definition of what their core competencies are. It is therefore both understandable and reasonable for a manager to regard any of his or her company's activities as part of its core competencies simply because the company is doing it. Nonetheless, managers from each of the firms studied seemed to have an opinion about what functions were a part of the company's core competencies and which ones were not. The classification of each activity as a core competence or non-core competence is inferred here from their actual decisions and/or assessments.

Figure 5.1: Field of Potential Make-Buy Scenarios

Accordingly, any aerospace manufacturer will sometimes find itself "following the leader" in adopting new technologies, and a manager will frequently be faced with the challenge of implementing an innovative idea in his or her firm's product line when the technology behind the idea originated somewhere else. In such instances, a firm is must decide whether it should attempt to "make" a similar or competing technology in-house, or "buy" the new technology from the leader. For example, even though BD&S had
every technology that is pertinent to its core competencies, but by recognizing what technologies are critical to its interests, and knowing how to access and consolidate them effectively. But it is not sufficient simply to buy core competence technologies from suppliers. As Fine and Whitney point out, firms "learn by trying, not by buying."\(^6\) A company can enlist the help of suppliers in learning new skills and techniques, but to maintain its core competence in the field, a firm has to learn to develop the technology itself.

THE INCREASINGLY RAPID PACE OF CHANGE IN THE MARKETPLACE

To be sure, the process of learning a new technology from a supplier requires less time than developing a totally new one in-house. But in the business world, there are many instances in which this approach simply is not fast enough. Learning is not an immediate process, and a key contract or marketing opportunity might be missed while the company is busily learning new skills and developing the necessary tools it needs to use a novel component or process.

By inserting the technology as soon as possible, the firm also provides the technology with a better foothold in the market than it might have had if the firm waited to introduce it later. Although several companies may put forth dissimilar design concepts in the first generation of a technology, competing firms usually converge on an industry-wide "dominant design" in successive generations of the technology.\(^7\) It is therefore critical for a company to establish its technology—or one on which it is spending a great deal of time and money learning how to make in-house—as part of the dominant design before a rival firm succeeds in establishing a competing technology. Simply put, quickly inserting a technology into the marketplace helps to secure a role for it in the future, thereby protecting the investment the firm has already committed towards learning how to make it in-house.

Quickly inserting a technology in the marketplace is also important to a firm's success in that some industries offer discrete "windows of opportunity" in which companies can sell their products. Defense contractors, for example, vie against one another to win a single development or production contract for a given military program. In a "winner-

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\(^6\) Fine and Whitney, p. 5.

takes-all” market such as this, a company that fails to win a contract may have to wait for quite some time before it has an opportunity to win the next one. Firms in other industries that manufacture expensive products in small numbers and that have a limited customer base—such as manufacturers of space vehicles and launch equipment, for example—may face this same situation. It is therefore imperative that their design concepts and prototypes make use of the best technologies currently available, thereby making their product as attractive and competitive as they can be. For a prime to wait cautiously until its personnel are completely comfortable with the new technology may be the difference between winning and losing a major contract.

A firm can also affect its strategic posture in the marketplace by slowly learning and adopting another company’s technology. A rival firm might take advantage of a company’s hesitation or slow response time to secure a foothold in the market for itself with an altogether different technology. As noted by Gutwald, “[t]he rapid pace of change has become the one constant in today’s fast-paced and brutally competitive environment.” Prahalad and Hamel’s strategy of learning from others is an effective way to protect and develop a company’s core competencies, but only if there is ample time for a company to learn its suppliers’ secrets.

By underlining the rapid pace of change in the business world, Gutwald diagnoses a need for companies to react to quick jolts within the marketplace. But quick changes in the market need not be a totally bad thing against which managers must defend themselves; Chakravarthy suggests that a firm ought to cause such jolts to maintain its competitive lead in an industry. “When a business environment is highly complex and changing rapidly, the resulting turbulence in a firm’s environment makes orderly conduct among its competitors more difficult.” Thus, whether to use it as a strategic tool with which to stay ahead of its competitors or as a defensive maneuver to deal with brutally fast changes in the marketplace, today’s aircraft manufacturer—or any firm that

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8 At the same time, customers like the DOD have to be wary of “the technology push,” which occurs when the contractor and/or the government insists on using state-of-the-art technologies whose costs grossly outweigh their benefits. The DOD should therefore make sure that any new technology used in its equipment is worth the added expense. (Source: Gansler, Jacques. *Affording Defense*. Cambridge, Massachusetts: The MIT Press, 1989, p. 145.)

9 Gutwald, p. 2.


employs quickly evolving technologies, for that matter—needs a mechanism with which it can respond quickly to the introduction of new processes and components.

However, for the reasons outlined earlier, standard make-buy models are sometimes insufficient in such instances. Simply to buy a component from an outside supplier might erode the company's core competence, and to make the technology in-house may hinder its efforts to keep up with its competitors. Today's fast-changing industries require a hybridized solution for procuring new technologies: making and buying.¹²

THE MAKE AND BUY STRATEGY

Making and buying a component or process essentially allows a firm to use the innovativeness of its suppliers to leverage its own core competencies, while maintaining its ability to move nimbly and quickly in the marketplace. Upon realizing the strategic importance of a new technology developed by a supplier, a firm can, as Prahalad and Hamel recommend, learn how to use the technology in its own core competencies. But until it has mastered the new skills and has built the tools and machines necessary to utilize the new technology, the company should also consider buying the components or processes from the supplier. Although not according to any formally laid-out strategy, that is exactly what BD&S did when it outsourced the production of the sinewave spars to Dow-UT while continuing to develop its own in-house RTM effort.

HIGH COSTS OF CONCURRENTLY MAKING AND BUYING

To buy a component or process from a supplier while also developing the capability in-house clearly represents a duplicated effort, and is indeed an expensive proposition. In assessing the appropriateness of the make and buy strategy, a manager must therefore look past the short-term costs of this alternative, and take into account the long-term benefits—improved strategic posture, winning key contracts, etc.—that might arise from making and buying at the same time. In the case of the sinewave spars, for instance, BD&S intends to use the RTM process in successive airplane programs, and the strategic

¹² The notion of making and buying at the same time is not entirely new. Porter mentions this strategy, referring to it as "tapered integration." But he prescribes this approach not as a tactic for using suppliers' innovations, but as a means by which to discipline suppliers. For example, when procuring a particular component, GM and Ford sometimes produce a small fraction of the units in-house to demonstrate to their suppliers that they are not totally dependent on them. In addition to alerting the suppliers to the fact that they are somewhat expendable, this approach also gives GM and Ford a detailed knowledge of the costs of making the component, which is a useful aid in negotiation.
importance of concurrently making and buying outweighed the extra costs incurred by duplicating research and development efforts.

5.1.5 *Quickly Evolving Technology, Leader in Use and Development*

If an aerospace firm is a leader in the use and development of a quickly evolving technology, it is likely that these skills evolved from in-house R&D efforts rooted in one of the firm’s core competencies. Thus, because the technology is clearly relevant to maintaining the firm’s role as a leader in a particular core competence, the firm’s management should retain the component or process in-house so that the company’s own manufacturing team can maintain its lead over those of rival firms. This strategy was demonstrated by BD&S’s decision to keep in-house the design responsibilities for the F-22’s sinewave spars. BD&S prides itself in maintaining world class design capabilities for airplane wings, and it is a leader in designing wing spars. Accordingly, BD&S insisted on keeping in-house the design tasks for the sinewave spars—which were based on several cutting-edge technologies—to ensure that BD&S’s wing team remained the best in the industry.

There may be instances, however, in which a technology is accidentally or serendipitously invented by a company whose core competencies are quite unrelated to the technology. In such instances, a firm may decide to adopt a new core competency if the new skills seem particularly profitable. But if the new technology is not exceptionally profitable, or if the firm considers itself incapable of building a core competence around the technology, it might want to sell or license it to another company that can use it in one of its core competencies.

5.1.6 *Mature Technology, Behind Leader in Use and Development*

As noted earlier, Prahalad and Hamel argue that core competencies should be difficult for prospective competitors to imitate. The knowledge and skills underlying well established technologies are often codified—that is, they are well documented, and are therefore relatively easy for a potential entrant to imitate without the help of the
industry leader. Because the firm is also behind the leaders in the use and development of the technology, these skills represent little if any competitive advantage over other firms, and should almost always be outsourced to suppliers who are more focused on these activities.

BCAG’s recent move towards outsourcing its forging designs for landing gears is one example of this strategy. Several firms, including Wyman-Gordon, are equally capable of designing forgings, so this activity is of minimal strategic importance to BCAG throughout the development of its landing gears. Moreover, because it does not have actual forging experience, BCAG’s in-house forging design team is not as skilled as Wyman-Gordon’s in several regards. It is therefore appropriate for BCAG to outsource the design of the forgings to an outside specialist like Wyman-Gordon.

5.1.7 Mature Technology, Leader in Use and Development

As noted earlier, Prahalad and Hamel argue that core competencies should be difficult for prospective competitors to imitate. In most instances, it is therefore unwise for a company to organize any of its core competencies around several functions that are already technologically mature. A firm’s niche in the marketplace arises from the skills and products that it can provide faster, cheaper, or of a higher quality than competitors or prospective competitors. To base a company’s core competencies on well-established technologies therefore jeopardizes its distinctiveness in the market, and it is usually prudent to outsource these components or functions.

There are, however, instances in which it is important for a firm to be familiar with certain technologies no matter how mature they are. As noted by Fine and Whitney, one of the most important assets a manager can have when judging a make-buy situation is a working knowledge of the processes and techniques behind the part or process being considered. It is especially important that a manager understand technologies that are directly important to the firm’s core competencies. To that end, a firm should consider retaining well-established technologies in-house if they are deemed to be critically important to the company’s core competencies.
BD&S’s decision to retain in-house a small fraction of the tooling production is one example of this strategy. Indeed, BD&S’s managers readily acknowledged that its primary tooling supplier, UCAR, was very capable of providing high quality tools on time, and for a competitive price. Nonetheless, BD&S’s tooling managers retained a small fraction of the production responsibilities in-house. Because such a small fraction—approximately one third—was retained in-house, it is doubtful that this decision was driven solely by the up-front costs. Rather, it indicates that BD&S’s tooling engineers recognized the value of the knowledge that could be obtained by making a small fraction of the tools internally. As Fine and Whitney suggest, and as reflected in BD&S’s actions, firms learn skills by trying to make something in-house, not by buying components from suppliers.\footnote{Fine and Whitney, p. 5.}

Figure 5.2 summarizes the make-buy decisions arising from the case studies presented in Chapters 3 and 4 by mapping ex post the outsourcing judgments of the respective companies onto the Technology Maturity/Firm’s Competitiveness framework.

### 5.1.8 The Framework

The make-buy decisions surrounding the components studied in Chapters 3 and 4 are summarized in Figure 5.3. It is worth noting that this study yielded no data for two of the eight sections in the framework (denoted with an asterisk “*”). The first such section describes a situation in which a company is a leader in the use and development of a quickly evolving technology, but the technology is not related to any of the firm’s core competencies. However, even though there was no such scenario in either case study, an appropriate course of action for this situation may be distilled from other scenarios and some deductive reasoning. If a firm has a leading role in the development of a new technology, it stands to reason that it ought to develop the technology into a core competence, or off-load it altogether. Left unfocused and without a role in firm’s strategic positioning in the marketplace, such a capability represents an additional expense that may yield few benefits.
The second section in the framework without any supporting case study data reflects the situation that arises when a firm is not a leader in the application of a mature technology, and yet the firm holds on to the technology as part of its core competence.

Figure 5.2: Mapping Make-Buy Decisions From Case Studies Onto the Technology Maturity/Competitiveness Framework
However, by virtue of the fact that the company is behind the industry leader with respect to one of its alleged “core competence” technologies, it is doubtful that the firm actually has such a core competence, \textit{per se}, at all. Thus, a company that finds itself in this section with respect to a particular technology ought to improve its competitiveness in that technology, or give up on the core competence altogether.

\textbf{THE ROLE OF THIS MAKE-BUY FRAMEWORK AMONG OTHER MODELS}

As mentioned in Chapter 2, there are many factors surrounding almost any make-buy decision. A firm’s core competencies, transaction costs, and labor situation are only a few of the concerns that a manager must balance when deciding among his or her company’s outsourcing options. To be sure, there are instances in which some factors play a larger role than others, but very infrequently is an outsourcing judgment based exclusively on a single criterion. Even though the proposed framework does not exhaustively address all the possible criteria that enter into make-buy decisions, it attempts to illuminate key factors that are important in the context of the aerospace industry that have been overlooked or underemphasized in make-buy models thus far. Simply put, this framework should be considered in conjunction with, and not instead of, other make-buy models that approach the problem from other points of view.

\section{5.2 \textit{CHAPTER SUMMARY}}

Based on the observations discussed in Chapters 3 and 4, this chapter proposed a framework that explains \textit{ex post} how managers in the U.S. aerospace industry decide to make or buy a particular component or process. The proposed framework can also be used by managers in the future to help them think through the strategic implications of outsourcing decisions. The make-buy framework reflects two criteria that play key roles in the industry’s outsourcing judgments, but that have been underemphasized or overlooked altogether in make-buy models to date: the technological maturity of the component or process, and the competitiveness of a firm with respect to the particular technology. Finally, this chapter described a make and buy strategy that large companies should consider for securing or maintaining a leading role in their respective core competencies.
The next chapter will examine some of the principal policy concerns surrounding the U.S. aerospace industry's make-buy decisions.

Figure 5.3: Summary Framework of Make-Buy Decisions in the U.S. Aircraft Industry

"**" Denotes that no data for these scenarios was available in case studies.
CHAPTER 6: POLICY IMPLICATIONS OF MAKE-BUY DECISIONS

This chapter addresses two principal ways in which the aerospace industry’s make-buy decisions may be affected by or may eventually lead to changes in the policies of the U.S. government. First, the “globalization” or “internationalization” of the industry—including, for instance, the increasing tendency towards buying components from suppliers outside of the U.S.—has transformed this sector of the economy from a predominantly American concern to one of world-wide proportions. Second, the emerging lean manufacturing model that is re-shaping how make-buy decisions are made is also changing the structure of the industry’s inter-firm relationships. Whereas primes and suppliers used to deal with one another in a more or less “arm’s length” fashion, they are now actively working towards a system of inter-firm cooperation. These closer relationships may, however, conflict with current antitrust laws in the U.S.

But this chapter does not arrive at conclusive policy recommendations for government and industry; rather, it is intended merely to highlight several of the salient issues underlying these policy areas.

6.1 THE “GLOBALIZATION” OF THE INDUSTRY

Because the aerospace sector is a driver of many product and process technologies, aerospace manufacturers are a welcome addition to almost any country’s economy. Accordingly, many countries are now actively working towards developing a domestic
aerospace industry of their own, and international strategic alliances—especially with Japanese suppliers—have become a familiar feature of the American aerospace industry. But over time, this trend may have negative impacts on the industry as a whole.

6.1.1 Erosion of America’s Leading Role in the Industry

As noted in Chapter 3, foreign governments are fostering commercial aerospace ventures within their own countries by coaxing U.S.-based primes to procure components from their domestic suppliers. For example, some foreign governments allow their nations’ airlines to buy aircraft only if they contain some domestically produced components, while others offer primes in the U.S. handsome incentives such as cost sharing agreements to make the prospect of overseas production attractive. Such arrangements between a company and a government to place some degree of benefit in the purchasing country are known as “offsets,” and they are becoming commonplace in the commercial aerospace industry.

Offsets are also becoming a day-to-day business reality for defense aerospace primes in the U.S. With the demise of the Cold War, and with so much pressure to reduce the government’s budget deficits, the DOD’s total spending for defense procurement has declined nearly 72 percent since 1989.1 Because so few new weapon systems are being bought by the government, the sustainability of the nation’s defense aerospace industry is in jeopardy:

In these conditions, it is not possible to maintain the same defense base. However, in some areas, such as combat aircraft, foreign sales have increased to make up a part of the difference, thereby enabling the industry to maintain some sustainability... In these conditions, foreign sales play a crucial role in maintaining the U.S. defense industrial base.2

Thus, foreign countries are representing an increasingly significant portion of U.S. defense aerospace contractors’ sales. But by relying more and more on foreign sales for survival, U.S. primes are feeling increasingly pressured to engage in offset agreements. Much like the situation faced by the U.S.’s commercial aircraft industry, foreign

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2 Trice, p. 4.
governments are beginning to use the allure of large sales to encourage defense primes to offset components or systems to suppliers within the purchasing country. The DOD has been reasonably accepting of this new reality within the defense aerospace industry. By letting U.S.-based contractors sell their aircraft to other countries, the DOD has in effect ensured that America’s defense aerospace industry—and therefore the nation’s capacity to defend itself—remains strong even though the U.S. government cannot properly support it.

But these strategies clearly result in a shift of aerospace manufacturing activities away from the U.S., and have raised questions about the direction, or even absence, of U.S. industrial policy. Aircraft development has long been “cherished within the U.S. as one of the industries in which America dominates global competition,” and the nation’s “leadership in aircraft manufacturing and aviation has been a major component of [the U.S.’s] economic strength and national security.”

Perhaps more important than the amount or value of components handed off to foreign suppliers, however, is the strategic importance of those components and the technologies underlying them. Because of outsourcing agreements with U.S.-based aircraft manufacturers, “Japanese industry has attained world-class capabilities in manufacturing aircraft components such as fuselage panels, thick and complex composite structures, long shafts for aircraft engines, and primary actuation... In addition, the manufacturing excellence achieved by [Japanese] companies such as Toray in carbon fiber and Sharp in flat panel displays has allowed Japanese industry to establish dominant positions in several critical areas of the aircraft supply chain.” It has been widely believed for years in the U.S. that even though Japan and countries like it might be able to manufacture aerospace parts and develop technologies that are pertinent to the production of aircraft, they are unable to move into the ranks of global leaders in the industry. Simply put, it was widely assumed that these countries would continue to play a secondary role in the production of aircraft.

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5 High-Stakes Aviation, p. 2.

6 High-Stakes Aviation, p. 2.
However, by controlling key technologies that aerospace primes in the U.S. rely on, Japan is beginning to erode the U.S.'s leading role in the industry, and may soon be able to assume the role of co-leader. And although to a lesser degree, China has also started to become a significant threat to the U.S.'s primary role in the industry:

They [China] started with Russian technology. Then, they did co-production for McDonnell Douglas. Next they started doing minor pieces for Boeing. Now they are doing rear fuselage and tail pieces for Boeing. And they have entered into a memorandum of agreement with the Europeans and other Asian nations to build a 100-seat aircraft—an aircraft for which 43 percent of the market is in North America. This process of competency building could have happened without offsets, but not as quickly.7

**EFFECT OF LEAN SYSTEM ON TECHNOLOGY TRANSFER TO FOREIGN SUPPLIERS**

The problems associated with foreign offsets may be exacerbated by the adoption of the lean manufacturing model by U.S. aerospace producers. In an effort to achieve many of the benefits of the lean system, American aircraft manufacturers and their suppliers are sharing more information than they used to, including knowledge that only ten years ago would have been considered proprietary.8 Following the example of Japanese auto manufacturers, suppliers and primes in the U.S. are learning the value of close information sharing and inter-firm trust.9 By working closely instead of at "arm's length," companies are better able to solve design problems, and can combine their experiences and ideas to come up with better and more cost-effective ways to manufacture components or systems.

However, armed with a more thorough knowledge of a prime’s design or process secrets, foreign suppliers may then be able to develop rival components or processes of their own, thereby challenging the prime’s role as a leader in that particular area. Therefore, by electing to outsource the design and/or production of components to foreign suppliers in a lean manufacturing environment, aircraft manufacturers in the U.S. may be

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7 Barber, Randy. *Policy Issues in Aerospace Offsets*, p. 11.

8 It is important to emphasize the fact that such exchanges of information travel in both directions. Just as suppliers in a lean manufacturing environment are expected to provide critical design and process information to their customer companies, suppliers in the aerospace industry are also being provided more information by their customers (source: Bozdogan, Kirkor. LAI overview of Supplier Relations Focus Group research results: Defense Science Board Task Force on Vertical Integration and Supplier Decisions, Washington, D.C., 30 October 1996).

laying bare the very secrets and skills that gave them their strategic advantage over firms in other countries.

6.1.2 Effects of Offsets on the U.S.'s Defensive Posture

U.S.-based defense aerospace contractors do not intentionally try to sell arms to unfriendly nations, and the U.S. government would never knowingly approve such a transaction. And as described in Chapter 4, the DOD has in place many regulations that prevent defense contractors from vending most advanced military technologies to foreign countries. These restrictions are not motivated by economics, but by military strategy. By refusing to sell its most advanced weapons to other nations, the U.S. government aspires to ensure that American troops never come under attack from weapons made in the United States.

But despite a contractor's best efforts to ensure that weapon systems will not fall into the hands of an enemy, offsets can make it difficult for U.S.-based companies to guarantee that their products and components do not eventually wind up in the hands of America's adversaries. "For example, technology transferred to Brazil through an offset program ended up improving the targeting capability of Iraqi Scud missiles."10 Thus, by using offsets as a means to win foreign contracts, American defense contractors may inadvertently cause defense technologies to be delivered to enemies of the U.S. government. The transfer of such technologies to unfriendly—or potentially unfriendly—nations may in turn result in the unnecessary deaths of U.S. troops, and a weakening of the country's overall defensive posture.

6.1.3 Minimizing the Negative Effects of Offsets

Good or bad, offsets are playing an increasingly important role in the make-buy decisions of America's aerospace contractors. But inasmuch as the industry is of principal importance to the economic and military well-being of the nation, should the government not have some say in the industry's offset decisions? Towards controlling

the amount of offset agreements in the commercial aircraft industry, the U.S. government negotiated:

a trade agreement on large commercial aircraft in the 1979 Tokyo Round [of GATT negotiations] that banned government-mandated offsets in commercial sales. However, only 24 developed countries have signed on to that agreement, and it still does not cover most of the developing countries. Nor does it cover non-GATT members, such as China and Russia.\(^{11}\)

Despite the shortcomings of this approach in the short-term, however, the U.S. government sees the GATT agreement as a medium through which it can successfully defend the interests of its commercial aerospace manufacturers. Accordingly, it is a policy of the U.S. government to require all new GATT entrants to sign on to the aircraft agreement.

But no such mechanism is in place to protect the U.S.’s defense aerospace sector. Ironically, this lack of protection arose because the DOD insisted that goods and services pertaining to national security or to the military be excluded from GATT\(^ {12}\)—the same treaty that is now used by U.S. trade representatives to defend the commercial aircraft sector against the threat of unwanted offsets.

### 6.2 Antitrust Implications of Lean Manufacturing

#### 6.2.1 What are Antitrust Laws?\(^ {13}\)

The American economy is largely predicated on the notion of the free market system. U.S. policy makers have long revered the marketplace’s “invisible hand” as the principal mechanism for the optimal allocation of resources, and have believed in its ability to maximize the country’s overall welfare. But the free market system is not infallible or

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without limitations; most economists contend that there are instances of market failure that require government intervention.

MONOPOLIES AND OLIGOPOLIES

One such instance of "market failure" that the U.S. Department of Justice (DOJ) is particularly concerned with is increased market concentration, including the emergence of monopolies and oligopolies. A market is monopolized when a unique product or commodity is produced and distributed—and therefore controlled—by a single firm. This situation is often regarded as a market failure because many monopolists find it possible and profitable to restrict output and charge prices that are significantly higher than would be the case if the given industry were organized competitively.

An oligopoly is similar to a monopoly, but differs in that the product or commodity is controlled by a small group of firms rather than by a single firm. Indeed, a small handful of firms selling a unique product may conduct themselves in a competitive manner, and there are many examples of oligopolies in the U.S.—nation-wide long distance telephone carriers, for one—in which there is no breakdown in the market mechanism. Nonetheless, the domination of large or strategically important industries by a small group of firms is often scrutinized by the DOJ because a few companies can coordinate their actions to extract monopoly-like rents from the marketplace. Recent consolidations in the aerospace industry have led policy makers to be increasingly concerned about the possible emergence of greater market concentration and reduced competition in the future.

THE SHERMAN AND CLAYTON ACTS

To address the acute public resentment of monopolies and anticompetitive behavior by private businesses, Congress enacted the Sherman Act in 1890 and the Clayton Act in 1914. The intent of these acts was to render illegal any activities that restrain trade, result in an undue amount of monopoly power in a particular market, or lend themselves to excessively collusive behavior among firms. Various legislation has been passed since the adoption of the Sherman and Clayton Acts to close loopholes and to address specific problems in the marketplace, but such statutes are for the most part based on these acts.
6.2.2 Reconciling U.S. Antitrust Policies With Lean Relationships

TRADITIONAL INTER-FIRM RELATIONSHIPS IN MASS PRODUCTION SYSTEM

The types of supplier relationships traditionally espoused by North American and European manufacturers were "arm's length" in nature. Primes frequently pressured subcontractors to provide components for less money, and paid little heed to the long-term financial health or production and quality control methods of the firms downstream in their supply chains. Precise design specifications were handed down to subcontractors in a "build-to-print" fashion, and primes rarely solicited input from suppliers about how to improve a component's design or how to streamline a manufacturing process. But despite any inefficiencies the traditional approach to supplier relations might have brought about, this type of relationship was looked upon with favor by antitrust authorities like the DOJ. Companies that were uncooperative with one another were clearly not capable of colluding, and therefore had little opportunity to participate in any kind of anticompetitive behavior.

INTER-FIRM RELATIONSHIPS IN LEAN MANUFACTURING SYSTEMS

Lean manufacturers, on the other hand, foster closer and more cooperative ties with their suppliers. For the lean approach to work, a supplier must share with the prime a substantial part of its proprietary information about costs and production techniques—information that most classical mass producers would never have divulged to another company.\textsuperscript{14} To this end, suppliers and primes that have adopted the lean model often co-locate their employees in an effort to familiarize each company with the capabilities and management techniques of one another.\textsuperscript{15} And unlike traditional mass producers, lean manufacturers have established long-term alliances with their suppliers, routinely investing in suppliers and teaching them how to improve their operations. The closeness of inter-firm relationships within a lean supplier network may therefore invite closer scrutiny by the DOJ for possible anticompetitive behavior.

\textsuperscript{14} Womack, et al., p. 149.

\textsuperscript{15} The co-location of personnel by BCAG, Menasco and Wyman-Gordon (discussed in Chapter 3) is just one example of how lean supplier relationships are taking root in the U.S. aerospace industry.
That the lean manufacturing system may appear to be somewhat incongruent with the ideals embodied in the Sherman and Clayton Acts is understandable. The lean paradigm was first developed in Japan under very different political and economic circumstances than those faced by the authors of America’s antitrust laws. Not only did Japan’s government not object to this high degree of cooperation among firms throughout the development of the lean system, it promoted it.

Today Japan does indeed have laws that ostensibly prevent firms from conducting themselves in an anticompetitive fashion. However, Japanese antitrust enforcement agencies tend not to do much to punish flagrant violators of the nation’s antitrust regulations. U.S. trade authorities have repeatedly tried over many years to persuade the Japanese government to enforce these laws, and Japan has responded by increasing penalties for violators twenty-fold. Nonetheless, Japan’s antitrust statutes—or the antitrust statutes of most countries, for that matter—are not nearly as rigidly enforced and do not weigh as heavily on the minds of business people as those in the U.S. But even though the DOJ may be sterner than analogous agencies in other countries in enforcing antitrust laws, it does demonstrate some flexibility in applying the Sherman and Clayton Acts.

"Horizontal" vs. "Vertical" Agreements

Production or marketing agreements among companies that are “horizontal” in relation to one another, e.g. between two manufacturers of computer chips, are more suspect in the eyes of DOJ officials than agreements between firms that are “vertical,” e.g. a manufacturer of computer chips and a manufacturer of finished computers. The sharpest competition in a market occurs among horizontal competitors, and the anticompetitive potential of an agreement between two or more of these firms is therefore greatest. Moreover, the legitimate business justification for such agreements is often weakest. There are few instances in which horizontal competitors need to coordinate their efforts in any way.

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16 Appendix B offers a summary of the historical origins of the lean system’s unique prime-supplier relationships in Japan.
17 Schaeffer, et al., p. 697.
18 Schaeffer, et al., p. 697.
On the other hand, parties at different points in the production chain must have agreements with one another, e.g. computer manufacturers must have agreements with chip manufacturers, but horizontal agreements seldom serve any legitimate business purpose. Thus, aerospace companies will encounter less resistance from the DOJ when buying components and processes from vertically-situated companies rather than horizontal ones.

**COLLABORATIVE EFFORTS RESULTING IN INNOVATIVE PRODUCTS**

There are instances, too, in which collusive behavior by two or more firms brings to the marketplace a new product or a more efficient process that, if the collusion was disallowed by the DOJ, might have otherwise remained undiscovered or undeveloped. If permitted to work cooperatively, firms can combine their resources and talents to achieve a synergy that none of the firms could have achieved independently. In cases such as these, antitrust authorities weigh the negative effects of the firms’ cooperative behavior against the positive benefits that might be achieved if the firms are allowed to work together. For example, the DOJ frequently lets horizontally competing companies form joint ventures in the hopes that the new venture will be able to come up with new and innovative products or processes from which the market will benefit in a way that more than offsets any adverse anticompetitive side-effects the deal may have.

Some joint ventures involving horizontal competitors in the aerospace industry have been approved in the past. For example, in 1983:

> ... five companies—United Technologies, Rolls Royce, Japanese Aero Engines, MTU, and Fiat—entered into a joint venture to develop, produce and sell a gas turbine aircraft engine... The term of the venture was to be 30 years. The joint venture was to be owned 30 percent by United Technologies and 30 percent by Rolls Royce, with the balance being owned by the other three [joint venture partners]. Rolls Royce’s air-compression technology was to be used in one section of the engine, and United Technologies’ combustion and turbine technology was to be used in the other main section.19

The DOJ did not challenge the creation of the joint venture for three reasons. First, although United Technologies and Rolls Royce were horizontal competitors in their industry, the joint venture was expected to develop and produce a new engine that none

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of the joint venture partners currently produced. Second, it was unlikely that any of the partners would have incurred the substantial costs and risks of developing the new engine independently. Third, only one engine comparable to the one proposed by the partners was available on the market, and it was also produced by a joint venture. In this way, the DOJ was effectively increasing the degree of market competition by allowing a second consortium to enter the market.

UNEVEN ENFORCEMENT OF ANTITRUST LAWS IN DIFFERENT INDUSTRIES

Over the years, antitrust authorities in the U.S. have tended to exhibit different degrees of concern for anticompetitive behavior in different industries. The DOJ has been noticeably more relaxed about anticompetitive issues stemming from proposed mergers involving aerospace firms than for comparable mergers in other sectors of the economy. For example, when Boeing announced in 1995 its intention to merge with McDonnell Douglas, Boeing's share of the commercial airplane market already equaled that of Standard Oil's share of the kerosene market when the DOJ divided it into smaller firms.

Of course, the vigor with which antitrust laws are enforced varies significantly according to the political climate of the day, and one might explain the different outcomes by pointing out that the rulings occurred at different times. But antitrust statutes are often applied differently to similar cases that are being investigated at the same time. In 1996, the DOJ approved the merger between Boeing and McDonnell Douglas—a move that amalgamated the first and third largest commercial airplane manufacturers in the world at the time—but "hound[ed] Microsoft, haul[ed] country doctors into court as antitrust miscreants, and agonized about the proposed merger of Staples and Office Depot."²⁰

ABSENCE OF COLLUSIVE BEHAVIOR IN DEFENSE INDUSTRY

However, even though the DOJ may appear to be less concerned with respect to anticompetitive behavior in the aerospace sector, it seems to be even less concerned yet with these issues in the defense side of the industry. The defense community has recently been going through a flurry of mergers and acquisitions, and several segments of the industry are now consolidated into a select few firms that each hold a significant

share of the market. Yet the DOJ has allowed these mergers to happen. Among the reasons why the government is not nearly as sensitive about antitrust violations in the defense sector are the following:

⇒ the monopsonist buyer—that is, the government—can play firms against one another
⇒ if no other firms are available, the government itself may enter the market
⇒ public visibility—especially of costs—is high
⇒ “custom designed” products like military hardware are not substitutable; therefore, there is no market to “share”
⇒ demand is unpredictable; therefore, it is hard to divide up the market

**Occurrence of “Bottlenecks” in DOD Supply Network**

Before allowing a defense contractor to buy out or merge with one of its suppliers, the DOD and Federal Trade Commission (FTC) first scrutinize the deal to make sure that after the merger, the new owner does not prevent a competitor from having a continued supply of critical elements that were previously produced by the supplier. For example:

In the merger between Lockheed and Martin Marietta, the FTC was concerned about Lockheed’s vertical integration into the manufacture and sale of both military aircraft and LANTIRN, a navigation and targeting system supplied by Martin Marietta that is a critical component of certain military aircraft. After the merger, Lockheed would be in a position to modify and upgrade LANTIRN in ways that could discriminate against its aircraft competitors, thereby raising the costs or reducing the performance of those competitors’ aircraft. The FTC therefore ordered Lockheed not to make changes to LANTIRN that discriminate against other aircraft firms unless necessary to meet foreign competition, to compete with other night vision products, or as approved by the Secretary of Defense.

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Precedent for Lean Supplier Relationships in U.S.

Antitrust authorities in the U.S. have already encountered lean-style supplier relationships, and were not terribly bothered by them. In the 1980s, the DOJ approved a deal in which GM and Toyota combined their resources in a joint venture called New United Motor Manufacturing Inc. (NUMMI). In the deal, GM offered the use of a defunct assembly plant in California, and Toyota volunteered a management team to run the operation. GM’s objective in the joint venture was to learn about the lean production system from the company that developed it: Toyota. To that end, NUMMI’s managers were expressly instructed not to make any compromises to the lean production model—including how the company dealt with its suppliers.24 Since that time, all three of the major American auto producers—GM, Ford, and Chrysler—have emulated Toyota’s management style, and have initiated various permutations of the Japanese-style supplier relationships, all with at least the tacit approval of the DOJ.

6.3 Chapter Summary

This chapter examined two principal ways in which the aerospace industry’s make-buy decisions are affected by current policies of the U.S. government. One, the “globalization” of the industry may be putting into jeopardy America’s leading role in the design and production of large-scale aircraft. Because of the key role the aerospace industry plays in the country’s economy, this challenge to the U.S.’s dominance in the market may in turn affect the overall competitiveness of the nation’s industrial base.

Two, the emerging lean manufacturing model that is re-shaping the structure of the industry’s inter-firm relationships may conflict with existing antitrust legislation in the U.S. However, because such relationships are “vertical” in nature, and often result in innovative products that might not have been developed otherwise, these supplier relationships may not be prone to excessive scrutiny by the DOJ. Moreover, historically, antitrust officials in the U.S. appear to have exhibited less concern about the aircraft industry than other industries.

24 Womack, et al., p. 83.
The next chapter will summarize the previously described framework which explains how outsourcing decisions are made in the U.S. aircraft industry. As well, the chapter will tie together the principal lessons learned throughout the thesis, and offer ideas for future research on the topic of make-buy decisions.
CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

At the outset of this thesis, four principal objectives were put forth. One, the thesis was intended to offer insight into the circumstances and criteria underlying make-buy decisions in the U.S. aircraft industry. Two, it was to propose a framework that explains *ex post* how managers in America’s aerospace sector decide to make or buy a particular component or process, and that offers suggestions for future outsourcing decisions in the industry. Three, it was intended to recommend a strategy that large companies in the industry should consider for securing and maintaining a leading role in their respective core competencies. Four, it was to address the principal ways in which the aircraft industry’s make-buy decisions may be affected by the policies of the U.S. government, and how these decisions may, in turn, affect U.S. policies. The purpose of this chapter is to summarize the main lessons learned in pursuit of these objectives, and to answer explicitly the questions asked in Chapter 1. As well, this chapter will recommend directions for future research in the area of make-buy decisions.

7.1 CRITERIA BEHIND THE INDUSTRY’S MAKE-BUY DECISIONS

As discussed in Chapter 2, there are typically a host of factors and considerations behind every make-buy judgment. However, throughout the case studies presented, several factors weighed more heavily than others in the managers’ outsourcing decisions. In no particular order, these factors are:
7.1.1 Existence/Absence of Formal Make-Buy Policies

Both of the primes examined in this investigation have recently instituted formal make-buyn policies that focus on their core competencies, and that delineate explicitly how and according to what criteria such judgments should be made by their managers.¹

Their suppliers, however, do not appear to have similar, formally-structured policies. Outsourcing judgments for lower-tier suppliers are largely decided according to the specific circumstances surrounding the development and production of a particular component or process. This tradition of ad hoc outsourcing decisions by suppliers is largely a result of the fact that it is the primes themselves, and not their suppliers, that are held accountable for meeting the U.S. government’s incredibly rigorous standards. To ensure that their airplanes comply with the stringent requirements regulating both commercial and defense aircraft manufacturers, the case studies reveal that primes in both the commercial and defense sectors routinely tell their suppliers exactly what materials they ought to use, and from where they ought to procure them. Simply put, there are many instances in which a supplier’s make-buy “decisions” are not really decisions at all; rather, they are handed down as edicts by the primes. This, however, is merely an observation of past and current practices, and should not be construed as the “correct” or “lean” way of doing business.

¹ As noted earlier, BCAG and BD&S do indeed belong to the same parent company. Nevertheless, Boeing’s two Groups are managed independently, and make-buy policies are formulated at the Group level.
7.1.2 Who Is Responsible for Making Make-Buy Decisions?

The primes in both case studies have a formally defined make-buy team or organization that is responsible for formulating and enforcing a Group-wide outsourcing strategy. These top-level organizations do, however, regularly solicit input from several managers throughout their respective Groups, thereby ensuring that outsourcing decisions are not insensitive to significant case-specific circumstances. All of the supplier firms investigated relegate important make-buy decisions to an *ad hoc* team of representatives from several departments within the company.

7.1.3 Differences in Make-Buy Decisions Between the Defense and Commercial Sectors

The most significant difference between BD&S and BCAG's make-buy policies is that foreign offsets play a key role in BCAG's outsourcing decisions, while BD&S's managers pay relatively little attention to the prospect of international sales at the outset of a program. This disparity in strategies is due to DOD-issued specifications that "explicitly say that all critical components and materials need to come from sources under the jurisdiction of the U.S. government."²

Several years after a new aircraft has been introduced into the DOD's arsenal, however, defense contractors are allowed to sell it to foreign governments that are deemed by Congress to be "friendly." But as noted in Chapter 3, the amount of capital invested throughout the design and development of any new aircraft program is enormous by almost any measure. And because of the DOD's insistence on American-made components in the first production phases of a program, this massive front-end investment must be initially made within the U.S. Upon setting up a production line, this capital—which includes such things as large specialized equipment, and extensive employee training—is often difficult to move to another country. Thus, because they cannot engage in offset agreements in the early stages of a new aircraft program, defense primes experience more difficulties than their counterparts in the commercial sector in using offsets as a means by which to secure foreign sales.

² Coe, Steven. 5 May 1997.
7.1.4 The Industry's Diversions from the Classical Lean Model

In the spirit of close relationships between customer firms and their suppliers, primes that espouse the classical lean manufacturing system\(^3\) often know relatively little about many of the parts and systems in their products.\(^4\) For example, a Japanese auto maker frequently "creates basic design information such as cost/performance requirements, exterior shapes and interface details based on the total vehicle planning and layout, while parts suppliers do [the] detail engineering."\(^5\) Moreover, the detailed engineering drawings for these kinds of components, commonly referred to as "black box parts," are often owned by the supplier.

The lean manufacturing system emerging within the U.S. aerospace industry is notably different in this regard, though. Managers in both the defense and commercial aircraft sectors typically seem to prefer not to extend this same degree of faith to their suppliers. Because many of the components and systems in an airplane are "mission critical," aerospace manufacturers are extremely sensitive to the quality of materials and components used in their airplanes. Thus, because the primes are held responsible by the U.S. government for any failures in their airplanes, they generally do not buy components in a "black box" fashion. For example, even though Wyman-Gordon attends to much of the detailed engineering behind the forgings for the 777's main landing gear, BCAG maintains an in-house forging design team, and retains the rights to all of the work that Wyman-Gordon's design engineers do for BCAG programs.

It is important to note, too, that this "hands-on," almost paternalistic, approach to program management is not merely a product of outdated corporate culture; rather, it is a logistical necessity brought about by stringent FAA and DOD requirements. The notion of "black box parts" will therefore continue to be an impossibility within the U.S. aerospace industry unless significant changes are made to federal aviation regulations and military procurement specifications.

\(^3\) The "classical lean manufacturers" are the Japanese auto manufacturers, who are widely credited with developing the lean paradigm.

\(^4\) Womack, et al., p. 147.

7.1.5 Implications of the Industry’s “Globalization”

The “globalization” of the industry may be putting into jeopardy America’s leading role in the design and production of large-scale aircraft. Because of the key role the aerospace industry plays in the country’s economy, this challenge to the U.S.’s dominance in the market may in turn affect the overall competitiveness of the nation’s industrial base. This situation begs a difficult question: Should the U.S. government intervene, and restrict the right of U.S.-based aircraft manufacturers to engage in offset agreements? And if so, how should the government go about this?

7.1.6 Congruence of Emerging Lean Inter-Firm Model with U.S. Antitrust Laws

The emerging lean manufacturing model that is re-shaping the structure of the aircraft industry’s inter-firm relationships does not seem to conflict with existing antitrust legislation in the U.S. Because inter-firm relationships in the industry are usually “vertical” in nature, are highly visible to government trade authorities, and often result in innovative products that might not have been developed otherwise, these supplier relationships are typically not prone to excessive scrutiny by the DOJ.

7.2 The Proposed Make-Buy Framework

Among the factors mentioned in the above list of make-buy criteria, two were found to play key roles in the aircraft industry’s outsourcing decisions: the technological maturity of the component or process, and the competitiveness of the firm with respect to the particular technology. However, despite their prominence in the aerospace sector’s outsourcing judgments, these factors are not reflected or are underemphasized in current make-buy models. The proposed framework, a two-by-two matrix, therefore divides the field of potential make-buy situations according to these two criteria.

Drawing on data from the case studies, the framework rationalizes ex post how managers in the U.S. aerospace sector decide to make or buy a component or process.
As well, the framework can serve as a guide that managers in the industry can use *ex ante* when formulating a make-buy strategy for their companies.⁶

### 7.3 The Make And Buy Strategy

As noted by Gutwald, "[t]he rapid pace of change has become the one constant in today's fast-paced and brutally competitive environment."⁷ The successful manufacturing firms of the future will therefore be those that know how best to adapt quickly in the marketplace. To that end, large incumbent firms should consider concurrently making and buying components or processes as a means to secure or maintain a leading role in their core competencies.

Despite a company's best efforts to develop or implement a new technology, an outside supplier—or potential supplier—can sometimes do it first. In such instances, a firm may be able to use the innovativeness of its suppliers to leverage its own core competencies.

Upon realizing the strategic importance of a new technology developed by a supplier, a firm can learn how to incorporate the technology into its own core competencies. However, in today’s business environment, there are many instances in which this approach is simply not fast enough. Learning is not an immediate process, and a key contract or marketing opportunity might be missed while the company is busily learning new skills and developing the tools it needs to use a novel component or process. Thus, until it has mastered the new skills and has built the tools and machines necessary to utilize the new technology, the company should also consider buying the components or processes from the supplier.

⁶ Of course, when developing *ex ante* guidelines for outsourcing decisions by observing *ex post* decisions, one must guard against the "*post hoc* fallacy," which assumes that decisions made in the past were optimal, and past strategies should therefore be used again in the future. However, the model is not intended to replace common sense or sound judgment; rather, it is intended to distill the experience and wisdom of existing strategies, and to serve as a means to illuminate the salient issues underlying make-buy decisions in the U.S. aircraft industry.

⁷ Gutwald, p. 2.
7.4 RECOMMENDATIONS FOR FUTURE RESEARCH

7.4.1 The Need for More and Different Case Studies

Despite their pronounced and deliberate disjointedness, BCAG and BD&S, the two primes studied in this thesis, belong to the same parent company: Boeing. It is therefore quite possible that their make-buy policies and practices have similar overtones simply because they are controlled at the highest levels by the same management structure. As the popular maxim goes, "the acorn does not fall far from the tree."

All of the suppliers named in this study make components for several companies, and the suppliers’ managers attest to the fact that other primes—like Lockheed Martin, for example—are quite different from Boeing in many regards. Thus, future research in the industry’s make-buy decisions would benefit from a study of other aircraft primes’ outsourcing policies.

But in defense of the data in this investigation, any study of the U.S. aircraft industry’s make-buy decisions would be sorely lacking if it did not thoroughly investigate Boeing and its outsourcing policies. The sum of Boeing’s commercial and defense groups represents a large proportion of the overall U.S. aerospace industry, and make-buy decisions made within Boeing are therefore telling indicators of the industry as a whole.

7.4.2 Investigation Into How Make-Buy Decisions are Decomposed

Throughout the development and manufacturing of something as large and complex as an airplane, thousands of decisions—some explicit, others implicit—are made with respect to how the aircraft’s structure is decomposed, and how the various design and production activities are decoupled. For example, when decomposing the design and production responsibilities for the F-22’s wing spars, BD&S decided that designing a working RTM process and designing the part-specific tooling necessary for producing the spars were distinct activities, and a separate make-buy decision was made for each. But why was such a distinction made? Inasmuch as the part-specific tools play a
critical role in the RTM process, why was the responsibility for the tooling not automatically lumped into the decision to outsource the RTM process?

The analysis in this investigation exactly mirrors the way in which the activities were decomposed by the primes. For instance, this study regarded BCAG’s decision to outsource the production of its landing gears as a discrete judgment because that was how BCAG’s managers perceived the situation.

Future research in this area might therefore scrutinize the way in which make-buy decisions are decomposed. Are there instances in which a single make-buy decision should be broken down into a handful of smaller ones? And under what circumstances would it be prudent to fuse several small outsourcing judgments into one decision, thereby relegating all of those activities to a single party? This thesis set out to offer insight into how make-buy decisions are resolved, but it did little to reveal how the questions behind such decisions are defined.
APPENDIX A: THE F-22 WING STRUCTURE

Figure A.1: The F-22 Wing Structure

1 Courtesy of Glenn Lussier, Dow-UT's F-22 Program Manager.
APPENDIX B: THE HISTORY OF SUBCONTRACTING IN JAPAN

With a drastically different operational framework, corporate culture, and organizational structure, lean production is fundamentally different from the mass production methods historically espoused in North America. The highly cooperative relationships among the members of a lean supply network are a drastic departure from what most managers in the U.S. are accustomed to. But why did Japanese supplier relations evolve so differently from those of U.S. firms? This appendix looks at the historical origins of lean supplier relationships in Japan.

B.1 THE EMERGENCE OF DUALISM

The genesis of Japan’s system of inter-firm cooperation is nested in the country’s history of labor relations. At the turn of the 20th century, Japanese wages were more or less the same throughout any given sector of the economy, and each worker possessed a fairly broad repertoire of skills that was of equal value to many companies. As shown in Table B.1, this homogeneity in the labor market created a situation in which workers were more or less a commodity, frequently moving from one employer to another.

The outbreak of World War I dramatically altered this, however. The sheer size of the expansion in the manufacturing sector during the wartime economic boom brought about

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1 Nishiguchi, Toshihiro. Strategic Industrial Sourcing: The Japanese Advantage. New York: Oxford University Press, 1994. This entire section (unless otherwise noted) is from Chapter 2 of this book.

2 Pomponi, Control of Manufacturing Processes with MRP II, p. 22.
some profound changes in Japan’s manufacturing sector. In particular, Japanese companies discovered that it was more efficient to finely differentiate labor. Instead of having a single shipbuilder perform all of the tasks of ironing, drilling, riveting, and welding, a company would hire an iron worker, a driller, a riveter, and a welder.

This concept, however, was by no means unique to Japan. At the same time in the U.S., Henry Ford was perfecting his system of mass production, which was also largely based on giving workers very specialized tasks. Ford intentionally designed his system so that workers needed a negligible amount of training to do their jobs.\(^3\) Whether or not this was the most efficient method for manufacturing automobiles was never the primary issue when he formulated this strategy; rather, it was a product of Ford’s infamous distrust for everyone but himself.\(^4\) By breaking down the assemblers’ jobs into trivial tasks that required virtually no training, Ford created an environment in which “the workers on the line were as replaceable as the parts on the car.”\(^5\) Modeling their operations after Ford’s, many American managers carried on this philosophy for years. And while employee relations and training might not seem to have much of a direct effect on how manufacturing supply networks are organized, Ford’s widely adopted outlook on the matter eventually caused American managers to organize their supplier networks very differently from those of their Japanese competitors.

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**Table B.1: Length of Service of Skilled Workers\(^6\)**

<table>
<thead>
<tr>
<th>No. of Years</th>
<th>Metalworkers [%]</th>
<th>Printing Workers [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 0.5</td>
<td>12.9</td>
<td>23.8</td>
</tr>
<tr>
<td>0.5-1</td>
<td>39.6</td>
<td>18.3</td>
</tr>
<tr>
<td>1-2</td>
<td>6.6</td>
<td>18.8</td>
</tr>
<tr>
<td>2-3</td>
<td>17.8</td>
<td>11.8</td>
</tr>
<tr>
<td>3-5</td>
<td>11.4</td>
<td>11.4</td>
</tr>
<tr>
<td>5 or more</td>
<td>11.7</td>
<td>15.9</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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\(^3\) Womack, et al., p. 31.

\(^4\) Womack, et al., p. 33.

\(^5\) Womack, et al., p. 32.

\(^6\) Nishiguchi, p. 20.
As in Ford’s system, Japanese managers did indeed break down manufacturing processes into smaller, more specific jobs. What was especially different, however, was that their system required its workers to learn many skills that were often set according to specifications established by their particular company. It was therefore necessary to thoroughly train new employees according to the firm-specific requirements of their jobs. But training employees was and is an expensive proposition. This reality brought about a philosophy in the Japanese manufacturing sector that is championed by many companies all over the world today: An effective employee is not a consumable resource, but an asset. And like any other asset a firm might invest in, a highly trained employee is something that a company wants to hold on to.

Accordingly, several large Japanese manufacturers came up with two very effective ways to keep their employees from jumping from one company to the next. One, they instituted a linkage between an employee’s length of service and their rate of pay—the longer a worker had been with the company, the more money he earned. Two, the firms introduced a retirement pension scheme in which the amount of retirement pay awarded to an employee was proportional to their length of service. These employment policies were indeed successful in dramatically increasing the workers’ commitment to their respective companies.

But not everyone in Japan worked for a major manufacturer. And like Henry Ford, many Japanese managers did not subscribe to the practice of rewarding the loyalty of their workers. A large portion of the labor market was consequently caught in jobs that were much less stable and didn’t pay nearly as well as those that had graduated pay schemes. The labor market quickly separated into two disparate groups: well paid, permanent workers; and lower income laborers who tended to move from company to company. The difference in wages between the two groups was widened even further by the economic downturn during the decade after World War I. Whereas the earnings for permanent workers in large manufacturing firms remained almost unchanged during the downturn, the rate of pay for workers in other companies declined significantly under the burden of a large surplus of labor. With the splitting of the workforce into two segments with such glaring differences in wages, the emergence of what is now known as the dualist system was complete. It was in this new socioeconomic context that the strategic use of workers in the peripheral sector came to make economic sense.
A permanent job inside a large manufacturing firm was indeed secure, but the business world outside the factory was in a constant state of flux. Then as now, demand for manufactured goods went up and down quite regularly. This presented an interesting dilemma for Japanese manufacturers: How could a company with a constant number of employees adjust itself to fit an ever-changing environment? The rigidity of the long-term employment strategy in Japan necessitated new policies that could account for the variability that is inherent in the business world. To respond to fluctuations in demand, Japanese manufacturers started to use temporary workers for those jobs that required fewer firm-specific skills. But unlike their more permanent counterparts, a temporary worker’s wages did not increase over time, and a company was not obligated to pay him a pension upon his retirement. These working conditions were obviously much less attractive than those of the permanent employees, but the slumping labor market made it very difficult to find a job in the 1920s, so many workers were willing to accept these terms. Temporary workers soon came to constitute an essential part of the work force in the large manufacturing sector of the Japanese economy during the 1920s.7

B.2 The Dawn of the Supplier Firm

This period of metamorphosis in Japan’s manufacturing sector was not isolated to its labor relations, however. Shortly after the dramatic evolution of the nation’s workforce, technological developments took place that dramatically changed the landscape of Japanese industry. New generations of machine tools emerged that were more affordable than before, allowing smaller companies to own and operate equipment that formerly would have only been available to large firms. The development of national transportation and communication systems largely removed the geographical barriers that once got in the way of inter-firm commerce. And “[t]he standardization of manufacturing processes... promoted the division of labor among varied manufacturing units, giving rise to jobs like simple machining and drilling that could be easily and cheaply done by subcontractors.”8 Together, these factors created an environment that was much more conducive to starting a small business than the conditions at the turn of

7 Nishiguchi, p. 28.
8 Nishiguchi, p. 34.
the century. And sure enough, manufacturing firms consisting of only a handful of employees started springing up all over Japan.

As these companies were established, the segment of the working population that was either expelled from or unable to get into the highly coveted jobs with large manufacturers drifted into employment in the small firms. Table B.2 highlights the dramatic increase—from 20.8% to 30.1% within 10 years—in the number of workers in heavy manufacturing industries who worked for companies with between 5 and 29 people.

But while it may have been easier than ever to start a small manufacturing business in Japan in the late 1930s, it was still very difficult to make a decent profit. Small and extremely vulnerable, the subcontracting firms endured several years of abuse at the hands of the larger prime contractors. There was no sense of loyalty between suppliers and assemblers. Before the outbreak of World War II, it was common practice for prime contractors to discard their subcontractors during a recession.9 When the War started, however, the subcontractors’ situation took a turn for the better.

Table B.2: Number of Male Workers per Factory in Private Heavy Manufacturing Industries, 1920 and 193010

<table>
<thead>
<tr>
<th>No. of Workers per Factory</th>
<th>1920</th>
<th>1930</th>
<th>1920 Percentage</th>
<th>1930 Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 or more</td>
<td>122,700</td>
<td>80,000</td>
<td>50.2%</td>
<td>34.0%</td>
</tr>
<tr>
<td>100-499</td>
<td>40,400</td>
<td>46,100</td>
<td>16.5%</td>
<td>19.6%</td>
</tr>
<tr>
<td>50-99</td>
<td>18,000</td>
<td>19,600</td>
<td>7.4%</td>
<td>8.3%</td>
</tr>
<tr>
<td>30-49</td>
<td>12,400</td>
<td>18,700</td>
<td>5.1%</td>
<td>7.9%</td>
</tr>
<tr>
<td>5-29</td>
<td>50,800</td>
<td>70,900</td>
<td>20.8%</td>
<td>30.1%</td>
</tr>
<tr>
<td>Total</td>
<td>244,300</td>
<td>235,300</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

To meet the burgeoning demand for munitions throughout the Manchurian Incident and the Sino-Japanese war, the Japanese government decided that it would be more efficient

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10 Nishiguchi, p. 30.
to organize subcontractors into networks that served a single contractor. It was believed that these channeled groups, called keiretsu, would be better able to coordinate their operations than if they continued to operate in a disjointed, "anarchic" manner. The government tried to create an environment that fostered mutual friendship, or shinboku, rather than hierarchical control relationships. This type of arrangement was quite acceptable to the prime contractors. By assigning subcontractors to keiretsu, each supplier could better focus its efforts on the needs of one assembler firm, and would therefore be better able to devote itself more completely towards developing its technological expertise in the methods and standards of that particular prime contractor. And by buying contract-specific equipment that catered to the needs of one prime contractor—which can be very expensive, thereby requiring a high degree of commitment on the part of a smaller supplier—subcontractor firms could serve their primes more efficiently by tailoring their capital investments to the specific requirements of a single assembler.

Before the government initiative, such an investment would have been perceived by many subcontractors as an unacceptable risk. Because Japanese prime contractors of the pre-war era had a well-established history of discarding their supplier companies, it didn’t make sense for suppliers to commit to a large capital investment on any one contract, no matter how much it improved their quality or cost-effectiveness.

However good its foresight and intentions, though, the government’s wartime experiment failed. The manufacturing keiretsu arrangement fell apart shortly after Japan’s surrender, and things quickly devolved back to a state of laissez-faire. But the more cooperative approach to manufacturing made a big impression on the psyche of Japan’s business leaders—an impression that would shape their thinking for many years to come.

B.3 THE RE-EMERGENCE OF SUBCONTRACTING IN THE POST-WAR ERA

Japan’s economic recovery after the war suffered at the hands of Joseph Dodge, General MacArthur’s financial advisor in the Pacific. By completely cutting off Japan from much

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11 It is important to note that while the government was encouraging this kind of behavior throughout Japan’s manufacturing community, Toyota started organizing its suppliers in this manner almost one year before the announcement of the government’s policy.
needed reconstruction loans, Dodge sent the country’s economy into what seemed to be an irreversible tailspin. But just as war got the Japanese into this unenviable situation, war would get them out. The Korean War caused the demand for Japanese goods to skyrocket, and the economy experienced an immediate rejuvenation. In addition to large quantities of munitions, United Nations forces turned to Japanese manufacturers for motorized vehicles. And while the Korean War boom only lasted a year, it sparked a recovery that turned around the entire automotive industry.

As shown in Figure B.1, demand for automobiles made by Toyota and Nissan, Japan’s largest vehicle manufacturers, grew only slightly between 1950 and 1955. This modest increase was easily met by the major assemblers through the use of overtime work and temporary laborers. By 1960, however, the demand for Japanese motor vehicles had grown by leaps and bounds, and auto producers simply couldn’t keep up. To expand their production capacity at such an aggressive pace, Toyota and Nissan drew on the lessons they had learned during the war—they started to rely heavily on the manufacturing capacity of their subcontractors.

![Graph showing vehicle production by Toyota and Nissan, 1950-1960.]

**Figure B.1: Vehicle Production by Toyota & Nissan, 1950-1960**

But the supplier base in the manufacturing sector was ill-prepared to take on these new challenges from the automotive companies. Due to their smaller size, subcontractors had little capital, and they couldn’t do much to expand their capacity on their own. Moreover, they were plagued by a wide array of quality problems that were very costly.

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12 Based on figures presented in Nishiguchi, pp. 63-64.
to the auto assemblers. Toyota quickly realized that to use subcontractors as a means to expand its overall production capacity, it was going to have to improve its supplier base. To that end, Toyota “encouraged its suppliers to modernize their facilities and provided them with technical assistance and, if necessary, helped them financially.”

By 1958, the company had begun to openly share its employees with its subcontractors. In this way, Japanese manufacturers—led by Toyota—reconstructed the subcontracting keiretsu that collapsed after the war. Other companies picked up on the idea, and the institutionalization of cooperation and mutual trust between prime contractors and their suppliers went on to become a source of great competitive advantage for Japanese companies for many years.

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13 Nishiguchi, p. 64.
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BD&S Group directive #AD-DBS-003, issued 16 June 1995 by J. Schmit, Senior Vice President of Operations.

BD&S internal memorandum draft, issued 3 March 1997 by J. W. Evatt, Executive Vice President.


experimented with the RTM process for many years, it took an innovative approach from Dow-UT’s development team for BD&S to use the technology in critical wing components.

FOCUS ON FIRM’S CORE COMPETENCIES

In deciding whether to make or buy in this instance, a manager ought to consider first his firm’s core competencies. If the new technology is not within the domain of the company’s core competencies, the design and/or production responsibilities ought to be relegated to whoever is the best at doing the job—which means outsourcing the task to a supplier. This strategy keeps the firm’s assets and activities focused on its core competencies.

There will, however, be instances in which a new or quickly evolving technology developed by a company is strategically vital to maintaining another firm’s core competencies. For instance, it is not unthinkable that a firm other than 3M might stumble across a better way to deposit adhesives on thin films. One approach for a company trailing behind the industry leader in the development or application of such a critical technology is for the firm to develop its own version of the technology in-house, or to double its in-house research efforts to create a rival process or product which makes use of different technologies. But such research can be a years-long undertaking, and may not necessarily yield any commercially viable results whatsoever. This strategy could therefore lead to lost market opportunities, or could even result in another firm taking over the company’s core competence for itself.

ABSORPTION OF CORE COMPETENCE TECHNOLOGIES FROM OUTSIDE FIRMS

A company does not, however, always have to develop its core competence technologies in-house. As noted by Prahalad and Hamel, it is possible for a firm to learn specific skills and procedures from outside suppliers while holding onto—and even strengthening—its core competencies. After all, a core competence is not engendered by simply mixing together a handful of random technologies; rather, it is brought about by a company’s ability to weave together several skills and areas of expertise. A firm that prides itself in maintaining a core competence can continue to do so not by inventing

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5 Prahalad and Hamel, p. 80. Of course, suppliers might be somewhat protective of their trade secrets, and may not be willing to share all the details of a proprietary technology with another firm.

Robert K. Perrons