Chapter Three

DATA AND METHODS

Data collection for this report occurred in several stages. The first step involved reviewing literature on new manufacturing methods. The authors reviewed a number of books and articles to develop a framework of lean principles. That in turn drove interview/survey questions, which were sent to manufacturers of aircraft and major subsystems (see Appendix B for questions). Site visits to these companies were made in the summer and fall of 1998, and data were collected on the extent of lean implementation and on cost savings from lean efforts.

In the first stage, an extensive search of publicly available databases was conducted on keywords relating to lean manufacturing. Abstracts of all articles published between 1990 and 1998 were collected. The sheer number (several hundred) of sources made a complete review of all of these articles impossible. Based on the abstracts, articles that offered promise of specifics on performance improvements were collected and assessed. Some offer useful information on lean performance improvements and will be described below. A number of books on lean manufacturing and the Japanese Toyota production model were also collected, including ones published before the term "lean manufacturing" really took hold. Using these books and the articles, a framework of what lean manufacturing involves was developed and is used as a benchmark against which lean implementation was assessed.

After the literature search was completed, a questionnaire was developed to gather details on lean implementation at the participating government organizations and aircraft manufacturers and their

suppliers. This questionnaire was sent to a number of sites in advance of RAND's visits. During the site visits, company representatives gave presentations and offered written documentation detailing the answers to the questions. They also provided tours of their factories where lean projects were in operation or had been planned.

The data provided by the companies during the visits were assessed for two purposes. The first was to determine the extent of lean implementation at the sites. To that end, a number of questions were asked that were not directly cost related. The second purpose was an analysis of the data to determine the actual savings the aircraft manufacturers experienced through the implementation of lean production rather than promised or expected savings from future implementation.

The prime contractors and major subcontractors participating in this study were Boeing–Seattle; Boeing–St. Louis; Boeing–Philadelphia; Boeing–Long Beach; Boeing–Palmdale; Lockheed Martin Aeronautics–Fort Worth; Lockheed Martin Aeronautics–Marietta; Lockheed Martin Aeronautics–Palmdale; Northrop Grumman Integrated Aero Structures–El Segundo; Northrop Grumman Integrated Aero Structures–Dallas; Raytheon Aircraft–Wichita; Bell Helicopter Textron–Fort Worth; and Sikorsky Helicopters–Bridgeport.

Note that not all questions were completely answered at any site. How plants responded to the questionnaire varied considerably, both in level of detail on particular questions and as to what questions were answered at all. In this document, the number of data points underlying each overall average performance improvement is given.

One methodological limitation of the literature review and data collection is that only good news tends to be publicized. Although a great many articles on lean manufacturing were reviewed, not one mentioned significant problems with implementation or instances where productivity went down, even temporarily. Similarly, in their formal presentations, companies only offered cases in which lean implementation went smoothly and offered performance improvements. Private conversations with aircraft industry executives in other settings and outside the formal presentations revealed a more mixed story, however. Quietly, people reported cases where cellular

production had been tried and abandoned, where IPTs faced insurmountable obstacles from powerful functional organizations, and where the operators were not given the training and support they needed. Lean implementation in aerospace has not been an unequivocal success story. One insight is that while the lean production model does offer the potential for performance enhancements, these improvements will be exaggerated if only positive results are reported. Furthermore, the difficulties of effective lean implementation should not be underestimated.

A related problem is that among the many works that lay out best practices that should be adopted for maximum efficiency, far less published evidence details actual improvements backed up by real savings to end-product prices. The metrics most often reported are reduced floor space and cycle times. Specifics of cost reduction are reported infrequently, while the same few companies receive press repeatedly (i.e., Lantech, Freudenberg-NOK, Wiremold). The lack of specifics is not a journalistic flaw, however. Rather, it is a result of the propensity of companies to keep proprietary cost information private, to avoid giving strategic advantage to suppliers, competitors, and customers.

Another issue in data collection relates to the consolidation of the industry during the past few years. An attempt was made to collect some historical information from the plants to put their current position in better context. For example, supplier consolidation initiatives can be quantified by knowing how many suppliers supported the company in the past and how many support it today. However, the considerable restructuring of the industry that took place in the 1990s means that the relevant data may not exist or may be of questionable accuracy. Hence, the development of a deep historical context within which to place recent attempts at lean implementation was not possible.

The companies that participated in this study were at different points on the road to complete implementation of a lean system across their operations. For the purposes of this report, it would be premature to look at cost savings in a mutually exclusive context of whether the company was lean or nonlean. The aerospace plants visited were for the most part taking serious action to improve their operations. Reported cost savings should be considered improvements from ini-

tial lean implementation. This leaves open the possibility that aerospace companies can further improve their performance if they follow the lean concept of continuous improvement.

Womack et al. (1990) contend that one and only one lean manufacturing system exists. Indeed, certain basic precepts underlie its structure, including a consistent focus on improvement throughout the enterprise. However, lean manufacturing can be conducted in a number of ways on the factory floor. There may or may not be one best way. We saw a number of different approaches, tools, techniques, and so forth. It should be noted that adoption of all specific lean best practices is not required for lean implementation and also that two competing lean best practices may enhance performance in different ways. Cost trade-offs must also be analyzed, even when lean implementation is involved. The important point is to determine and focus on the initiatives that have the highest net impact on the *total* weapon system cost, not just those with the largest localized activity percentage reductions.

REPORTING RESULTS: ACCOUNTING FOR SAVINGS FROM LEAN PROCESSES IN DEFENSE MANUFACTURING

If lean manufacturing is thoroughly implemented and proponents of the lean system have accurately represented its potential, savings should show up in the bottom-line price that the government pays for aircraft. Lean manufacturing offers the commercial-world "target pricing" model as a method of setting prices. The model suggests that companies determine the competitive price they would like to charge for their product and work backward through the value stream to determine cost targets for various components of the final product. Careful attention is paid to in-house costs to minimize the prime manufacturer's portion of the cost. Primes use the mechanism of close relationships with their subcontractors and suppliers to help them reduce their prices to the prime contractor and still make their profits.

On large weapons systems, the government normally uses a different method of determining how much it will pay for what it buys, the

cost-plus method.[1] Here, all the different costs to produce the aircraft are estimated, and a percentage for profit is added on top. The total price is then negotiated with the prime but is still based primarily on projected costs. Successive lot prices are normally based on the actual costs incurred in producing previous lots, plus profit. This traditionally has provided a powerful disincentive for manufacturers to reduce their cost structure because a percentage profit on a reduced cost structure will yield smaller profits. (It is not the purpose of this report to discuss the causes and consequences of cost-based contracting, however.) The cost-based method depends on contractors accurately collecting and reporting their costs. To ensure the collection of data in a consistent and comparable manner across programs, the government has created the CCDR system, which requires contractors to report specifics on different components of cost.

The CCDR System

Government regulations require the collection of specific components of cost for an aircraft development or a particular lot or block of aircraft production. The CCDR system was developed in the early 1970s. The government's goals in the development of this system were threefold:

> The main thrust of CCDR is to assist all DOD Components in (1) preparing cost estimates for major system acquisitions reviewed by the Defense Systems Acquisition Review Council (DSARC) at each program decision milestone, (2) developing independent Government cost estimates in support of cost and price analyses and contract negotiations, and (3) tracking contractor's negotiated cost. (OASD, 1999.)

One of the strengths of CCDR is its attempt at standardizing categories of cost so that data can be collected systematically and the costs of different programs can be compared on a more detailed level. Cost data reporting elements include engineering, tooling,

[1]There is more room for negotiation and a focus on containing costs during the development stage of a program, where trade-offs between cost and performance can be made (a process known as Cost as an Independent Variable, or CAIV).

quality control, manufacturing, purchased equipment, material overhead, other costs, general overhead, and subcontract costs. The CCDR manual has specific instructions and many subcategories for classifying costs in reports to the government. In the interest of brevity and to address the impact of lean at a higher level, we have used six broad categories from the CCDR instructions to provide a general portrayal of lean impacts. These six categories are engineering, tooling, quality control, manufacturing, materials and purchased parts, and overhead and general and administrative (G&A) costs, which are treated as one category.

Each of these CCDR categories is treated in a separate chapter. These chapters feature descriptions of the type of effort contained in the category and how lean manufacturing implementation could affect those efforts. Each chapter also provides some specifics of the lean initiatives of different defense aircraft manufacturers and what savings were reported. An additional chapter on lean lessons for managing the workforce is included because worker involvement is critical to the lean system. (However, labor costs are actually captured in the other CCDR categories.)

The defense industry thus presents an additional challenge for lean implementation. If not focused and managed properly, functional data collection can impede the lean approach that explicitly links the overall goal of cost reduction in all of the different functions of the firm. Specific lean initiatives often cross these functional boundaries as well and could result in additional costs incurred in one functional area that reduce the costs in other areas by an even greater amount. Nonetheless, if lean is truly implemented, total weapons system costs should reflect these savings.