In addition to the shipyard itself, the industrial base for aircraft carrier construction includes a large complex of firms providing the thousands of individual carrier components that the shipyard does not fabricate itself. These components range from such standard items as fasteners, to somewhat specialized items such as pipes and valves, to such highly specialized items as catapults and arresting gear. They include those bought by and supplied directly to the shipyard (contractor-furnished equipment [CFE]) and those bought and supplied to the shipyard by the government (government-furnished equipment [GFE]). In this chapter, we focus on CFE suppliers.¹

We sought answers to three questions about the industrial base that would be called on to supply nonnuclear components for CVN 77 and subsequent carriers:

- Will qualified suppliers be available and willing to support construction of the next aircraft carrier?
- When will commitments for long-lead items be needed in order to meet the postulated delivery date of 2008 for CVN 77?
- What are the cost consequences of various dates when orders are placed with major CFE vendors for the next carrier (CVN 77)?

Some broad characteristics of the vendor base impinge on our approach to answering these questions. First, over 2,000 firms are supplying CFE for CVN 76, which is now under construction; these firms account for about $800 million worth of products. It is obviously not practicable to examine each of these firms

¹A large portion of the GFE consists of electronic equipment (radars, communications equipment, etc.), which, while adapted in design for carriers, is based on a broad set of products having other military and commercial uses. Furthermore, GFE that is modified or updated to meet evolving mission needs is, at times, backfitted to some or all operating carriers; CFE, on the other hand, is seldom replaced. Thus, typical suppliers of GFE have a much broader and more continuous market for their products than do typical suppliers of CFE.
in the detail devoted to the shipyard itself and to the firm supplying the heavy nuclear equipment. Fortunately, half the total CFE business (in dollars) is provided by about two dozen firms, and 40 percent is provided by ten firms (see Figure 6.1).

Second, an overarching problem for most of the suppliers, especially those providing items that are unique to carriers, is the intermittence of carrier work. The usual interval between carrier starts is four or five years, and there will apparently be six years between the starts of CVN 76 and CVN 77. It takes some suppliers two years or less to satisfy the demand from a carrier, so they must have other lines of work. In fact, the several suppliers of high-cost items produce a variety of goods and services; the products made for aircraft carriers generally represent a narrow, specialized niche in their product base. Since each firm’s product base (and its management approach) evolves, so does its ability to deliver items for carrier construction. Because of the evolving diversity of CFE suppliers, our research questions can be meaningfully answered only for the aggregate of firms; furthermore, the answers may change as time passes.

Figure 6.1—Total Dollar Value of Contractor-Furnished Equipment in Relation to Number of Suppliers
In this analysis, we have made no effort to examine any firm in sufficient detail to permit postulating a specific course of action to ensure an efficient supply of that firm’s products. Instead, we have tried to understand the range of factors and situations affecting the majority of firms supplying products for aircraft carrier production. In answering the questions posed above, we offer an aggregate assessment of that industrial base and some broad strategies the Navy and the shipyard might follow to minimize problems in obtaining the necessary products in the future.

**AVAILABILITY OF QUALIFIED SUPPLIERS**

CFE must often be designed especially for carrier use; therefore, there is an advantage to obtaining equipment from an experienced supplier. But, as we pointed out above, many firms supplying CFE cannot survive on carrier orders alone, because carrier construction is intermittent. There is thus always the risk that a qualified supplier will come to regard its carrier work as expendable—particularly as the defense industry continues to downsize and consolidate. Firms are acquired by new owners who may regard carrier-specific product lines as less important than the old ones did. These new owners may then be less inclined to allocate the necessary production resources to satisfying an order for carrier equipment.

To understand better the degree to which a continuous vendor base may be threatened, we discussed the matter with officials of Newport News Shipbuilding and with several firms making critical products for the current class of aircraft carriers. Although hardly an exhaustive survey, its results were so uniform as to persuasively support a conclusion: Barring some unforeseen set of circumstances, we do not anticipate major problems in obtaining commitments from present suppliers to furnish their products for the next aircraft carrier (CVN 77), assuming it is started within the 2000–2002 time frame. If the next carrier is delayed further, our confidence in the availability of present, proven suppliers begins to decrease, if only because of uncertainties regarding the overall industrial environment and the situations of specific firms that far in the future.

**SCHEDULING PROCUREMENT OF LONG-LEAD ITEMS**

Many aspects of our industrial-base analysis are driven by timing and scheduling factors. One of the most important of these is the timing of orders for long-lead items, items that require a long time for the supplier to produce and particularly those that must be installed early in the construction of a carrier. Orders for such items are usually placed one or two years before work begins in
earnest on carrier construction. Here, we examine the timing of such orders and how that timing affects the overall carrier-construction schedule.

It is useful to review the time intervals required for construction of recent carriers. In Figure 6.2, we show the overall build period for the Nimitz-class carriers, divided into four sequential intervals:

1. Contract award date to start of fabrication (SF) of hardware in the shipyard.
2. Fabrication start to keel laying. (Beginning with CVN 71, the construction process changed to one in which major modules are assembled in an area beside the dry dock, then placed in the dock and assembled into the ship proper. For CVN 71 and later, “keel laying” is equivalent to placing the first pre-assembled module into the dry dock.)
3. Keel to launch, where launch denotes moving the ship from the dry dock to a nearby pier for further fitting out.
4. Launch to delivery of the completed carrier, ready for commissioning and shakedown operations.

Since we are concerned with the order, delivery, and integration of major components requiring long lead times and that are assembled into modules, we want to examine the overall ship-construction time from keel laying to delivery of the ship. This interval for the Nimitz-class carriers to date is shown in Figure 6.3. For the last six ships, the construction method has been the same and

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Figure 6.2—Recent Ship-Construction Times (Award to Delivery)

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$^a$SF = Start of fabrication of hardware.
the time from first module (keel) to final delivery has been remarkably constant: about five years, plus or minus a few months. While that interval could be compressed somewhat, shipyard officials believe that about five years from keel to delivery (equivalent to about eight years from contract award) is close to optimal, and that compression would increase costs and risk. We therefore adopt a period of five years as the nominal duration for the keel-to-delivery interval.

Major items such as the main propulsion-drive turbines and speed-reduction gears, which require 24 to 30 months to assemble, must be installed relatively early in the shipbuilding process. In general, 24 to 30 months is a good estimate for items that require special manufacturing processes and that are ordered only at extended intervals, so that the supplier cannot sustain a continuous manufacturing activity. If such items are to be delivered to the shipyard at or near the start of the 5-year keel-to-delivery interval, then orders for those major items must be placed seven to eight years before scheduled ship delivery. Such timing corresponds well to the overall ship-construction times (contract award

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2 Times for specific items in any given plant may vary outside this range, depending on the timing of other work in the vendor’s plant.
to delivery) shown in Figure 6.2 and is therefore an important element in establishing the practical delivery date for an aircraft carrier. Thus, if the Navy wants CVN 77 delivered in 2008, orders for some of the major ship components should be placed by 2000.

**COST CONSEQUENCES OF VENDOR ORDER DATES**

Most of the vendors supplying high-cost components to CVN 76 will complete their work in 1997 or 1998. Any gap between that time and component orders for CVN 77 will cause some loss in the readiness of the vendor to fill the next order. Certain factors lead to a “restart cost,” which must be added to the price of the next shipset of products from each vendor. Among those factors are normal turnover in staff, which leads to a loss of workers having recent experience in manufacturing processes; tooling, which gets shunted aside to make room for other work; and second- and third-tier vendors, which suffer some attrition. In general, the restart-cost penalty tends to increase most rapidly in the first year or two after completion of the prior order; then the rate of increase diminishes as the restart cost approaches the cost required after an extended gap in production.

An understanding of the restart-cost penalty for vendor-supplied components and materials should be of help in planning the overall schedule and in budgeting funds for the next aircraft carrier. Some limited but useful information on this topic can be gleaned from estimates provided by a few of the major vendors during discussions with Newport News Shipbuilding during the summer and fall of 1996.

Vendors representing about 45 percent of the total value of components and supplies for CVN 76 production provided estimates of the price for the next shipset of products, according to when the order was placed, with order times ranging from 1998 to 2002.

The aggregate results are shown by the solid line in Figure 6.4, which we consider a lower-bound estimate of total vendor restart costs because it does not include many vendors producing the remaining 55 percent of total CFE value.

Conducting a similarly detailed survey of the many vendors in that remaining 55 percent was impractical. To get some estimate of the likely restart costs for those other vendors, we first observed that about one-fourth of the large vendors surveyed indicated no change in price as a function of order date (within the range of dates examined). It seems plausible that a somewhat larger fraction of the remaining vendors might be supplying standard products and that their price quotes would not be very sensitive to order date. Therefore, we as-
assumed that one-half of the remaining vendors would experience restart costs proportional to those of the high-cost products, leading to the estimates shown by the dashed line in Figure 6.4.3 We believe the dashed line represents a rough upper bound of the range of such estimates for all vendor-supplied products needed for CVN 77 construction. We further assumed that both the lower- and upper-bound estimates will be essentially invariant for orders placed after 2002. While any given vendor’s situation can change quickly, we believe the aggregate results indicate with some reliability the cost changes to be expected with later placement of orders for major CVN 77 components and material.

CONCLUSIONS

We answer the three questions we posed at the beginning of this chapter as follows:

3The increment represented by the dashed line is one-half the value of the points on the solid line. We realize this assumes a 50/50 missing/surveyed split instead of 55/45. It further assumes that, for the half of the missing vendors with proportional costs, those costs are proportional to the costs from all the surveyed vendors (instead of, e.g., the three-quarters with nonzero changes). However, the imprecision is consistent with the very rough nature of the one-half estimate.
• Qualified suppliers should be willing and able to support construction of the next aircraft carrier if construction is started within the 2000–2002 time frame.

• To meet the postulated CVN 77 delivery date of 2008, the Navy will need to commit funding to some long-lead items by 2000.

• Compared with costs expected for a CVN 77 start in 2002, CFE costs can be reduced by $20 to $30 million if ordered by 2000 and by $70 to $110 million if ordered by 1998. (Here, the lower ends of the ranges are derived from the lower-bound estimates shown in Figure 6.4 and the upper ends are derived from the upper-bound estimates.)