Since 1988, contractors in the naval nuclear-propulsion industrial base have been realigning their workforces and facilities to match the workload reduction associated with nuclear-powered submarine and surface ship production programs and force structures. During the early 1990s, when the Seawolf submarine program terminated after three submarines, uncertainty about the timing of future orders and anticipated low production rates raised concerns that the remaining producers of naval nuclear components might close down or cease making those components. In 1993, the award of CVN 76 and the initiation of the NSSN program helped to stabilize the industry, albeit at a much smaller scale. Currently, the nuclear industrial base is sized to support submarine and carrier refuelings and production of at least one new attack submarine per year.

In this chapter, we examine the implications for nuclear vendors of producing CVN 77, the last of the Nimitz-class ships. We show that it matters little to the survival of the nuclear industrial base whether CVN 77 is produced or not—a result that obviates the need to assess the effects of various start dates. However, the industrial base for certain carrier nuclear components faces a long production gap, which raises challenging issues that need to be settled if CVX is nuclear. Although that gap is not strictly related to decisions regarding CVN 77 construction, we take the opportunity to discuss this important potential problem here.

This analysis draws on our discussions with and data provided by the nuclear industry, the Naval Nuclear Propulsion Directorate, the Naval Sea Systems Command, and officials of the Office of the Secretary of Defense (OSD). We begin the chapter with an overview of the naval nuclear industrial base, then go on to issues for CVN 77 and CVX.

---

1The Seawolf class was projected to comprise as many as 12 submarines (Selected Acquisition Report, December 1988).
NAVAL NUCLEAR-PROPULSION INDUSTRIAL BASE

Research, development, and manufacture in support of the nuclear Navy are carried out by major corporations under contract to the government and by subcontractors that supply hardware support and technical expertise to the government and the prime contractors. In this section, we discuss the importance and prospects of suppliers who manufacture critical nuclear components, including the

- reactor cores
- control-rod drive mechanisms
- pumps, pipes, and fittings
- instrumentation and control equipment
- valves and auxiliary equipment
- heavy reactor-plant components (reactor vessels, closure heads, core barrels, steam generators, pressurizers).

Table 5.1 lists the manufacturers of these components.

It is essential for the Navy’s nuclear ship programs that the naval nuclear industrial capability survive. Nuclear-system manufacture requires high standards for component manufacturing and quality assurance, specialized facilities for fabrication and testing, and a highly qualified and skilled workforce. Nuclear reactor core manufacture for the Navy is even more specialized and demanding. Naval nuclear reactors are smaller than commercial reactors, use highly enriched fuel, and must operate for decades without being replaced or having major maintenance. They experience frequent power variations, are required to meet quietness and shock criteria, and are designed to operate in proximity to humans. The means of meeting this kind of demand cannot be replaced quickly or cheaply, if it is practical to replace it at all.

The prospects of the naval nuclear industrial base are less than robust, as is starkly illustrated by the dwindling number of critical-component suppliers to the Navy (Table 5.2). All the key suppliers for reactor-plant components are sole-source. With no domestic civilian orders and declining naval orders, the nuclear field is no longer commercially appealing.\(^2\) The large capital investment

Table 5.1

Key Nuclear Suppliers

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<thead>
<tr>
<th>Nuclear Component</th>
<th>Supplier</th>
<th>Location</th>
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<tbody>
<tr>
<td>Nuclear cores</td>
<td>BWX Technologies</td>
<td>Lynchburg, VA</td>
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<td></td>
<td>Naval Nuclear Fuel Div.</td>
<td></td>
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<tr>
<td>Heavy components</td>
<td>BWX Technologies</td>
<td>Barberton, OH</td>
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<tr>
<td></td>
<td>Nuclear Equipment Division</td>
<td></td>
</tr>
<tr>
<td>Control-rod drive mechanisms</td>
<td>Marine Mechanical Corporation</td>
<td>Cleveland, OH</td>
</tr>
<tr>
<td>Pumps, pipe, and fittings</td>
<td>Westinghouse Electro-Mechanical Division</td>
<td>Cheswick, PA</td>
</tr>
<tr>
<td></td>
<td>BW/IP International, Byron Jackson Pump Division</td>
<td>Long Beach, CA</td>
</tr>
<tr>
<td>Instrumentation and control</td>
<td>SPD Technologies</td>
<td>Philadelphia, PA</td>
</tr>
<tr>
<td>equipment</td>
<td>Eaton Pressure Sensors Division</td>
<td>Bethel, CT</td>
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<tr>
<td></td>
<td>Lockheed Martin Tactical Defense Systems (LMTDS)</td>
<td>Archibald, PA</td>
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<tr>
<td></td>
<td>Lockheed Martin Information Systems</td>
<td>Orlando, FL</td>
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<td></td>
<td>Peerless Instrument Corporation Imaging &amp; Sensing Technology Corp.</td>
<td>Elmhurst, NY</td>
</tr>
<tr>
<td></td>
<td>Northrop Grumman Power/Control Systems Division</td>
<td>Baltimore, MD</td>
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<tr>
<td>Valves and auxiliary equipment</td>
<td>Target Rock Corp.</td>
<td>East Farmingdale, NY</td>
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<tr>
<td></td>
<td>Hamil Manufacturing</td>
<td>Trafford, PA</td>
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needed and the low probability of achieving a satisfactory return on investment will probably discourage any new firms from entering the nuclear market.

LAST-OF-CLASS IMPLICATIONS FOR THE INDUSTRIAL BASE

In 1969, Congress authorized the Navy to procure one complete shipset of reactor-plant heavy-equipment components as a backup to minimize the risk of either delaying construction of nuclear carriers or laying up those carriers,
### Table 5.2

#### History of Naval Nuclear-Component Suppliers

<table>
<thead>
<tr>
<th>Component</th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
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<tbody>
<tr>
<td><strong>Reactor Cores</strong></td>
<td>B&amp;W</td>
<td>B&amp;W</td>
<td>B&amp;W</td>
<td>BWXT</td>
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<tr>
<td>UNC</td>
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<tr>
<td>CE</td>
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<tr>
<td>M&amp;C West.</td>
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<td></td>
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<tr>
<td><strong>Heavy Equipment</strong></td>
<td>B&amp;W</td>
<td>B&amp;W</td>
<td>B&amp;W</td>
<td>BWXT</td>
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<tr>
<td>A-C</td>
<td>AC</td>
<td></td>
<td>B&amp;W</td>
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<tr>
<td>AOS</td>
<td>CW</td>
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<td>CE</td>
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<td>FW West.</td>
<td>CE</td>
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<tr>
<td>Alco</td>
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<tr>
<td><strong>Control Rod Drive</strong></td>
<td>TRW</td>
<td>TRW</td>
<td>TRW</td>
<td>MMCa</td>
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<tr>
<td>Mechanisms</td>
<td>VARD</td>
<td>R/LSi</td>
<td>BFM</td>
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<tr>
<td>M-S</td>
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<tr>
<td><strong>Main Coolant Pumps</strong></td>
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<td>West.</td>
<td>West.</td>
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<tr>
<td>GE</td>
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**NOTE:**
- AC: Allis Chalmers
- Aero: Aerojet
- AOS: A.O. Smith
- B&W: Babcock and Wilcox renamed BWX Technologies (BWXT)
- BFM: Barry, Frank, & Murray
- BWXT: See B&W
- CE: Combustion Engineering
- CW: Curtiss-Wright
- FW: Foster Wheeler

- GE: General Electric
- M&C: Metals and Controls
- M-S: Marvel-Schelber
- PCC: Precision Components Corp.
- R/LSi: Royal Lear Siegler Inc.
- SW: Struthers Wells
- West: Westinghouse

- **a** Successor in same facility to company listed on same line to the left.

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once in service.\(^3\) Because of the long lead times needed for manufacture of these large nuclear-propulsion-plant components, the production backup set has typically been used to construct the next CVN. The components manufactured with the advance procurement (AP) funds for that ship have then replaced the production backup.

This practice will be followed for CVN 77 to the extent that the spare shipset will be used in constructing that ship. However, only a partial replacement spare shipset of reactor-plant components is planned for procurement with CVN 77

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funds. For FY00, the Navy’s budget includes AP funds to procure reactor cores; control-rod drive mechanisms; pumps, pipes, and fittings; instrumentation and control equipment; and valves and auxiliary equipment. Funds are not included to replace the spare long-lead heavy equipment—such as steam generators, reactor vessels, core barrels, closure heads, pressurizers, and some supporting equipment—which leaves the spare shipset incomplete. Therefore, there will be no CVN 77 work for the heavy-equipment vendor, regardless of whether or when CVN 77 is built. This vendor will complete its current CVN work in FY00 and is downsizing to reduce costs as it focuses on meeting the equipment demand for smaller nuclear-submarine components.

As for nuclear components other than the heavy equipment, the cores and the instrumentation and control equipment will be replaced at some point in the carrier’s life, either during reactor refueling or in some other maintenance action (see Table 5.3 for the core procurement schedule). Pumps, pipes, and fittings, as well as valves and auxiliary equipment, are needed for ongoing submarine production. These requirements will sustain the industrial base for the components other than heavy equipment.

In short, CVN 77 does not affect the heavy-equipment sector of the nuclear industrial base. However, if CVX is nuclear, there are reasons to be concerned on

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<th>Table 5.3</th>
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<td>Core Procurement Schedule for New Construction and Refueling</td>
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<table>
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<tr>
<th>Ship Type</th>
<th>Fiscal Year</th>
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<td></td>
<td>98</td>
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<tr>
<td>SSBN&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
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<tr>
<td>CVN&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
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<tr>
<td>NSSN&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1</td>
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</table>

<sup>a</sup>Assumes a force level of 14 Tridents.  
<sup>b</sup>CVN estimates assume ships have lifetime operating tempo similar to that of USS Nimitz.  
<sup>c</sup>CVN 77 new-construction core assumes Advance Procurement funds in FY00.  
<sup>d</sup>Based on one new attack submarine per year, plus refuelings.

<sup>4</sup>Using the backup heavy equipment for construction of CVN 77 without initiating replacement will leave the Navy with no backup to support constructing CVN 77 and operating the fleet. Damage to any of the major components would delay ship construction for years while a replacement component is completed. Cost increases due to construction delays and rushing construction of replacement components could be hundreds of millions of dollars. Similarly, a need to replace this equipment in an operating carrier could result in a ship "immobilized a considerable time until replacement components can be obtained" (Admiral Rickover, congressional testimony before the Committee on Armed Services, United States Senate, Ninetieth Congress, Second Session, March 1968).
behalf of the heavy-equipment manufacturer. These issues are addressed in the following section.

MANUFACTURING HEAVY EQUIPMENT FOR CVX

BWX Technology’s Nuclear Equipment Division (NED) is the sole source for heavy-equipment components. NED is currently using less than 30 percent of its facilities, which occupy 107 acres and have a fabrication area of 1.7 million square feet and office area of 230,000 square feet. As the naval reactors work has drawn down, NED has also shed workers. Figure 5.1 shows the substantial drawdown in employment levels from 1988 to the present, along with planned future employment levels. NED’s forecast of 322 employees by 2001 is based on production of one NSSN per year.

Carrier components account for a substantial part of the workload at NED. The work for 1 Nimitz-class CVN is equivalent to that of 7 submarines; the CVX, if nuclear, is expected to be equivalent to 4–6 submarines (Table 5.4). Current employment levels may increase, depending on the size of a CVX nuclear-reactor plant and its resulting work requirement.

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5This section draws on a December 6, 1996, meeting at BWX Technology’s Nuclear Equipment Division (NED), as well as on many pieces of correspondence and phone discussions among RAND staff, Naval Nuclear Propulsion Directorate staff, and NED personnel.
The production of both submarine and carrier heavy-equipment components may be hampered by the policies used to downsize the workforce at NED. Union rules have forced NED to make termination decisions based on low seniority, resulting in a workforce in which few employees are younger than 45 years old, as Figure 5.2 shows. The current workforce at NED is highly experienced, to the point where there is a virtual absence of junior employees, as shown in Figure 5.3. And, as NED continues to draw down its workforce, the employees at the left edge of the distribution in Figure 5.3 (i.e., the younger employees) will be the ones terminated.

\[\text{Table 5.4} \]

**CVN and NSSN Heavy-Equipment Components, for Comparison**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CVN Nimitz Class</th>
<th>NSSN</th>
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<tbody>
<tr>
<td>Fabrication man-hours</td>
<td>1.1M</td>
<td>0.15M</td>
</tr>
<tr>
<td>Number of components</td>
<td>16 large</td>
<td>6 small</td>
</tr>
<tr>
<td>Approximate weight</td>
<td>2,000 tons</td>
<td>200 tons</td>
</tr>
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\[\text{Figure 5.2—Age of Hourly Workforce, BWX Technology, Nuclear Equipment Division, as of November 14, 1996} \]

\[\text{SOURCE: BWX Technology, Nuclear Equipment Division, Barberton, Ohio: briefing to RAND, December 6, 1997.} \]

\[\text{6A few employees in their thirties or early forties have the technical skills required for operating modern computer-aided design and manufacturing (CAD/CAM) equipment.} \]
The naval nuclear community is aware of this situation and is working with NED to facilitate its transition to the next generation of workers. The major issues are how many new personnel should be hired and trained, and when that hiring and training should occur.

At NED, the CVX nuclear-versus-conventional-propulsion decision extends beyond workforce considerations to equipment and facility decisions. The current carrier work will be completed by FY00. Even now, some fabrication and welding equipment is no longer needed for the remaining carrier work. NED must now make decisions on the disposition of that equipment and also of facilities dedicated to carrier-component construction. NED must either mothball equipment and facilities and commit to some continuing overhead costs or sell them off.

The Navy's planned schedule for new heavy-equipment design, development, and construction assumes that a nuclear-propulsion decision is made in FY00 and ship authorization in FY06 (see Figure 5.4). NED recommends the
schedule shown in Figure 5.5, which provides for start of heavy-equipment fabrication in FY00. The firm estimates its recommended schedule will cut $40 to $60 million from the workforce and facility retrenching and the subsequent rebuilding that would occur over the 4-year hiatus assumed in the notional schedule. NED states that making the propulsion decision on CVX by FY99 will allow it to make more-efficient decisions on equipment, facilities, and personnel and thus to realize the $40–$60-million savings.

The point about rushing the schedule is worth elaborating. For the Nimitz class, six to seven years has been the average manufacturing time for components such as reactor vessels, pressurizers, steam generators, closure heads, and core barrels. That period is longer than the interval between contract award and shipyard need. Thus, for CVX, fabrication of heavy-equipment components would need to begin in advance—well in advance—of hull construction, even if all production processes are up and running.

Suppose that CVX 78 has the same shipyard construction schedule as CVN 76 and that its heavy nuclear-system equipment takes the same time to manufacture as that of the Nimitz class. Fabrication of some components would then have to start five to seven years in advance of the shipyard’s work (see Figure 5.6), or 14 years in advance of the ship’s delivery. Granted, CVX 78’s nuclear equipment is expected to require less work to build than CVN 76’s. However, CVN 76 is the ninth ship of a class, and some inefficiencies must be allowed for first-of-a-kind components, including uncertainties in lead time for both design and fabrication. In addition, the CVN 76 schedule takes advantage of an experienced, continuously employed workforce; the use of new hires for nuclear CVX components might slow the schedule even more.

**CONCLUSIONS**

The production start date and schedule for CVN 77 have little effect on nuclear vendors. In fact, it matters little to the viability of the nuclear vendors whether CVN 77 is produced at all. Manufacturers of light equipment and reactor cores will survive for the foreseeable future with the work associated with NSSN construction and with submarine and carrier refuelings. And, because an already-
### Figure 5.4—Schedule for CVX (Nuclear) Heavy-Equipment Components (FY06 CVX 78 Shipyard Start)

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### Figure 5.5—BWX Technology’s Recommended Schedule for Heavy-Equipment Components and Current Schedule (FY06 CVX 78 Shipyard Start)

- Current schedule
- NED schedule
- Common to both

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constructed spare set of heavy equipment will be used on CVN 77, there will be no CVN 77 work for the sole remaining manufacturer of heavy equipment. This manufacturer—the Nuclear Equipment Division of BWX Technology—must survive only on NSSN construction.

Although CVN 77 is not critical to the survival of naval nuclear vendors, the timing of the propulsion decision for CVX does have major implications for NED, because the remaining carrier work will come to an end in FY00. If the Navy adheres to its current plan of beginning heavy-equipment fabrication for CVX in 2004 (if CVX is nuclear), NED will mothball or sell construction equipment and replace workers only as needed for NSSN work. If a decision to make CVX nuclear-powered is made by FY00, fabrication could begin earlier, which would avoid the costs of retrenching and reconstituting its production capability. NED estimates this would save $40 to $60 million.