TESTIMONY

RAND

Aircraft Carrier Industrial Base

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Preface

This testimony was presented to the Subcommittee on Seapower of the Senate Armed Services Committee on Tuesday, April 22, 1997 in the Russell Senate Office Building in Washington, D.C. The purpose of this hearing was to receive testimony on the Department of the Navy's shipbuilding development and procurement programs as reflected in the Defense Authorization Request for Fiscal Year 1998 and the Future Years Defense Program.

RAND has recently conducted studies on the aircraft carrier industrial base, including an analysis of the costs and production schedule of the next aircraft carrier, the CVN 77. For this study, the Navy asked us to provide an independent, quantitative analysis of the aircraft carrier industrial base, with a focus on CVN 77. We examined how CVN 77 production is constrained by force structure goals, industrial-base considerations, and especially cost implications.

The results presented in this testimony are taken from a study recently concluded within RAND's National Defense Research Institute, a federally funded research and development center sponsored principally by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies. This particular study was sponsored by the Naval Sea Systems Command and was coordinated with the Office of the Director, Acquisition Program Integration, OSD.
Mr. Chairman and members of the subcommittee, thank you for this opportunity to appear before you to discuss the aircraft carrier industrial base. In particular, I’m going to talk to you today about scheduling the production of the next aircraft carrier—CVN 77—how it’s constrained by force structure goals and industrial-base considerations and what the cost implications are. The results I’m going to show you come out of a just-completed study carried out within RAND’s National Defense Research Institute. NDRI, as you may know, is a federally funded research and development center sponsored principally by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies. With the concurrence of OSD, we also do a limited amount of work for the U.S. Navy, mostly on acquisition issues. This particular study was sponsored by the Naval Sea Systems Command and coordinated with the Office of the Director, Acquisition Program Integration, OSD.

This is the latest in a series of industrial-base issues examined by RAND for OSD, the U.S. Air Force, and the Navy. These are listed here [Table 1].

Table 1

| RAND Has Examined a Broad Set of Industrial-Base Issues for OSD, USAF, & USN |
|---------------------------------|---------------------------------|
| Aircraft design base            | Aerospace industry production base |
| Reconstitution production capabilities | Submarine production base |
| Navy technology base            | Expendable-launch-vehicle production base |
| Bombers                         | Aircraft carriers |

The Navy asked us to provide an independent, quantitative analysis of the aircraft carrier industrial base with a focus on CVN 77.

Here is our principal finding: Regardless of when or whether CVN 77 is built, the industrial base will be adequate to support the production of large, nuclear-powered aircraft carriers for the foreseeable future. Of course, if CVN 77 is not built, shipyard capabilities would be reduced in scale. And CVN 77’s start date could result in cost increases or decreases related to industrial-base efficiencies. It could also concurrently decrease or increase risks. But the differences in costs and risks may not be as important as the implications for the carrier force structure.

I’d like to start with force structure issues because in this type of industrial-base analysis, first you decide how many ships you want to sustain in the fleet, and then you see when you have to build in order to replace ships that have to be retired. To elaborate a little, fleet size and the remaining useful life of current carriers determine the dates when new ships are needed. Knowing construction time, this allows us to determine the window of time within which carriers can be started if a
fleet of a certain size is to be sustained. After we talk about force structure constraints, I'll discuss the cost issues—costs both in the shipyards and among the vendors who supply carrier components—as start dates are moved earlier and later. Finally, I'll say something about how production costs might be lowered by taking advantage of innovative technologies and production processes employed by commercial shipbuilders.

Although I recognize that some may think it desirable to change the carrier fleet size and I'll address that in a few minutes, for the time being I'm going to talk about sustaining the current 12-ship force. Though we focus on CVN 77, we can't analyze it in isolation from future construction, because other carriers are being retired and we have to consider the implications of CVN 77's construction schedule for the schedules of future replacement ships. So on this chart [Figure 1], we ask the question, How often do we have to build carriers to maintain a 12-ship carrier fleet? Along the bottom we show the carriers in their planned order of replacement, beginning with CV 64, which is to be replaced by CVN 76, the Ronald Reagan, now under construction. The heights of the thick lines above each ship indicate how old that ship will be if carriers are started—and delivered—at different rates: one every three years, one every four years, and one every five, beginning with CVN 77 in 2008. Naturally, the faster we build carriers, the less time future ships must operate before they are retired. And the further in the future we look, the bigger is this effect. The key constraint on the service life of nuclear carriers is when they are expected to run out of fuel.

![Figure 1—One Carrier Must Be Built Every Four Years to Sustain a 12-Ship Fleet](image-url)
At that point, they must either be retired or a very expensive refueling overhaul must be performed on a half-century-old vessel.\(^1\) The age at fuel depletion is shown by the dots. And we can see that a build rate of one ship every five years will not sustain a 12-ship fleet once CVN 69 and 70 are ready for retirement. These ships will have to come out of service before their replacements are ready, and the fleet will drop below 12 carriers.

But to understand the implications of this for CVN 77 specifically, we have to look at the specifics of the build schedules. This chart [Figure 2] shows what happens if we start building CVN 77 in 2002, as planned, and then build another carrier every four years thereafter. The bars show the duration of the build period—6.5 years for CVN 77, from early in 2002 to late in 2008, then the first ship of the next class, CVX 78, starts in 2006 and finishes in 2012, and so on at four-year intervals. We also show the ships that each of these new hulls would replace, along with their ages at retirement. So when CVN 77 is done, CV 63 can come out of the force at age 47, and we still have 12 ships in the fleet. If we delay CVN 77 a year, then CV 63 will have to wait to age 48 to retire if we want to maintain a 12-ship fleet. But we can't delay CVN 77 very much longer because then we will be building two carriers almost simultaneously. Leaving aside whether the ship construction budget will allow that, we don't have the shipyard capacity now to permit it.

![Figure 2—End-of-Fuel Date for CVN 65 Constrains CVN 77 Start Date](image)

\(^1\)Most of the carriers shown in Figure 1, nuclear and nonnuclear, will already have been kept in service longer than historical practice. Before 1980, carriers were operated for 20 to 30 years before retirement. The six carriers that have been retired in the 1990s have averaged about 40 years of service.
Newport News Shipbuilding is now the only shipyard that builds large, nuclear-powered aircraft carriers. Unless CVX turns out to be nonnuclear and much smaller than the Nimitz class, facility capacities at Newport News will limit construction of new carriers to a maximum of about one every two-and-a-half years. We can’t slip the construction start date on CVX 78 very much at all, because the next ship to be replaced, CVN 65, is projected to run out of fuel around 2014, as shown by the dot. So the first CVX has to be completed prior to 2014 if the force size is to stay at 12. And as you follow the sequence of bars upward, you can see again the hard constraints on the build schedule that are imposed by end-of-fuel dates on subsequent carriers. The point of this chart is not to set a build schedule for the next quarter century but to show that force structure considerations constrain the start date for CVN 77 and subsequent ships, and it’s not just a matter of one carrier getting a little older if CVN 77 is delayed; it’s our ability to sustain a force structure of 12.

If a decision is made to reduce fleet size, one way is to skip CVN 77 and just retire CV 63 without a replacement. The result of that would be a rather long gap in carrier construction, which would increase the costs of construction and risks of achieving the performance desired of the follow-on ship. I’ll talk about that a little more later. The other way to allow the force size to decrease is to build CVN 77 and either retire more than one ship, say CV 63 and CVN 65, or inactivate a Nimitz-class ship prior to a refueling complex overhaul. That would result in a more modern fleet, one with more capability and possibly less expensive to maintain, and would permit more flexibility in scheduling future production starts.

[continued]
Figure 3—Buildup Is Very Slow
(One New Carrier Delivered Every Three Years)

What if, on the other hand, because of some change in the global threat situation it was decided that 12 carriers are not enough? Then we'd have to start building ships faster than one every four years because, as we've seen, that barely keeps us at 12. But because of the necessity of retiring ships when they get up to around 50 years of age or when they run out of fuel, we don't get a fleet size increase right away. This chart [Figure 3] shows what happens when we speed up construction to one ship every third year and delay retirement of present ships as long as practical. If we start the next ship in 2000 and build one every three years, the fleet size hits 13 in 2006 when that first ship comes on line, but it doesn't remain there. We don't get to a sustained 13-ship fleet until 2013 and we don't achieve a 14-ship force structure until 2016. So expanding the fleet is something that can be done only slowly within the present industrial capacity, even if the near-term ship construction budget is increased substantially.

So where does this all leave us? Even with the current schedule, carriers are not being retired until fairly advanced ages. CVN 65 would be 52 years old when the first CVX replaces it if CVN 77 starts on time and the first CVX starts four years later. Because of the necessity of replacing CVN 65 at that point as it runs out of fuel, the CVX start date cannot be postponed. So if CVN 77's start date is postponed, that will result in starting those two carriers within three years of each other. This is all with 12 ships. Of course, as we've seen, reducing the fleet size allows more flexibility. But if it becomes necessary to expand the force, we're not now in a position to achieve that anytime soon.

With these scheduling constraints in mind, let's now turn to the industrial-base implications of varying CVN 77's start date. As I've said, in the event of a production gap, we will not lose critical skills to the extent we will be unable to
reconstitute them. However, it will be more challenging to build an aircraft carrier after an extended gap, and it will probably cost more and take longer. Let’s now turn to quantifying the cost implications. We’ll begin with costs in the shipyard and then look at the situation with the component vendors.

We constructed a mathematical model that takes into account all the current and projected work at Newport News Shipbuilding. The model considers a wide variety of factors (Table 2) and estimates least-cost workforce profiles as work ebbs and flows. What constitutes the least cost varies as CVN 77’s start date is varied against a fixed background of other work. Here (Figure 4), we show the best that can be done for CVN 77 start dates ranging from 1999 to 2008. We take the cost of building CVN 77 when it’s started in each of those years and subtract the cost of starting it as planned in 2002. So that planned date represents the zero cost differential, and a positive number indicates a higher cost than starting in 2002 and a negative number indicates savings. We see that as the start date is delayed, it costs more—$300 million more for a delay of just one year. If you start earlier than 2002, you save money—about a quarter of a billion dollars for a start in 2000.

Notice that I’m talking in very round numbers. Our methods permit estimates of a precision adequate for planning purposes only. While we believe we have the trends and the magnitudes roughly right, these are not budget-quality numbers.

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2 This work reflects current Navy construction and maintenance programs scheduled for Newport News. It does not include potential future programs, e.g., CVX, Arsenal Ship, SC21.
Figure 4—Starting CVN 77 Later Costs More, Earlier Costs Less

[continued]
Why do we get these results? While the numbers on the previous chart represent all costs to the shipbuilder, labor dominates. This chart [Figure 5] shows the anticipated labor level in person-years at Newport News over the period we’re concerned with and beyond. As you can see from the lower, continuous portion of the graph, without CVN 77 total person-years would drop by about half over the next six years and would keep dropping before starting to recover in 2006. The bulk of the labor demand for CVN 77, represented by the small, free-floating peak, occurs a little after the valley in the labor demand curve. As the CVN 77 demand is moved to the right, it begins to pile onto even higher labor demand, leaving the valley even emptier and requiring greater swings in the size of the workforce. And those swings cost money in terms of rehiring, training, and other workforce inefficiencies. But if CVN 77 is started earlier, the peak labor demand for CVN 77 falls more neatly into the valley and the yard’s total workforce requirements approach efficient leveling.

![Manloading](chart.png)

**Figure 5—Why Do the Cost Results Turn Out as They Do?**
So far, we've been talking about a six-and-a-half-year build period for CVN 77. What happens if we stretch that out some? Here [Figure 6] we repeat the curve from two charts back—the one that peaks out around $400 million—and add lines representing build periods a year longer and two years longer. As you can see, stretching the schedule reduces costs because it allows management more flexibility in scheduling tasks and mitigates the penalties associated with large changes in the workforce. In fact, for the eight-and-a-half-year case, delay beyond 2002 costs very little—but then the CVN 77 isn't available when it's needed. Let's look at starts that result in delivery in 2008. If we start a year earlier than 2002 and take a year longer than the six-and-a-half years we've been assuming, we save about a quarter billion dollars. If we start two years earlier and take two years longer, we save about 400 million.

![Cost Differences From Baseline](image)

**Figure 6**—Longer Build Times Decrease Costs
So we can save some money by getting the shipyard work started earlier. We can also save some money by getting the vendors started earlier, for the same reasons. This chart (Table 3) shows the savings achievable from both these sources. These numbers are all savings relative to starting both CVN 77 and the procurement of contractor-furnished equipment for that ship in 2002. The zero in the lower right corner represents that base case. Then, as we’ve seen, if we start the ship a year earlier, we save $260 million; two years earlier, we save $390 million. But these numbers assume CFE procurement begins the same year the ship does. If, for any one of those CVN start dates—2000, 2001, or 2002—we start CFE procurement ahead of time, we save more money, as you can see by looking up the columns. The additional savings amounts to 10 or 20 million dollars if CFE procurement is begun a year ahead of the planned 2002 start date for CVN 77, 30 to 50 million if it’s two years ahead, more if you begin several years ahead of a 2002 ship start date.

Table 3

Earlier Procurement of Contractor-Furnished Equipment
Yields Some Additional Savings

<table>
<thead>
<tr>
<th>CFE Procurement Start</th>
<th>Savings relative to baseline ($M) for CVN 77 start in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>1998</td>
<td>440</td>
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<tr>
<td>1999</td>
<td>410</td>
</tr>
<tr>
<td>2000</td>
<td>390</td>
</tr>
<tr>
<td>2001</td>
<td>*</td>
</tr>
<tr>
<td>2002</td>
<td>*</td>
</tr>
</tbody>
</table>

*CFE procurement cannot begin after shipyard start

Let’s summarize, then, what we’ve learned about CVN 77 costs so far. First, they rise if shipyard construction is delayed beyond 2002. The ship will cost $300 million more if it’s delayed only a year. Second, substantial savings can be realized by starting ahead of 2002. Ship construction costs can be lowered by some $250 million to $400 million, and, if contractor-furnished equipment is procured early, another 50 to 80 million dollars can be saved. We should caution, however, that we arrive at these estimates by moving CVN 77 labor and costs around against a fixed background of other demands. Of course, those demands will also be moved around as Newport News and its vendors search for ways to minimize costs across all projects. We don’t take account of any adverse effects from those actions on projects at other shipyards—higher costs, longer schedules, and so on.

We’ve already considered briefly the cost effects on vendors of procuring their products before work begins in the shipyard. Now let’s look a little more closely at the vendor base, starting with the vendors of nuclear equipment and then moving on
to the nonnuclear sector. Here, a principal question is, if CVN 77 is delayed or even canceled, will these vendors stay viable so that very large reconstitution costs and risks can be avoided?

In the case of the nuclear vendors, the disappearance of the commercial nuclear-power market together with a reduction in Navy orders has certainly led to a drastic downsizing of the industry. Generally speaking, for each of the various types of nuclear equipment, only one firm remains in existence to produce it. And most of these firms have, over the last ten years, reduced their workforces and retired facilities. But that portion of the industry that manufactures light equipment and reactor cores remains viable at its present scale with expected demands unrelated to carrier construction. Those demands include constructing components and core sets for one new attack submarine a year plus refueling submarines and carriers as needed. The same holds, really, for Babcock & Wilcox, the sole manufacturer of nuclear-related heavy equipment. Some years ago, an extra ship set of heavy-equipment components was manufactured as back-up for the Nimitz class, and the construction of each carrier entailed the incorporation of the previous ship's back-up and the construction of a new back-up set. So CVN 77 will use an already built heavy-equipment set, and as 77 is the last ship of its class, no new back-up set will be built. (Heavy-equipment components are acquired only for new ships and are not replaced during overhauls.) Thus, when or even whether CVN 77 is built will not affect Babcock & Wilcox in the near term. They are downsizing to meet the anticipated future demand of one submarine ship set per year and expect to remain viable at that level.

The same basically holds true for nonnuclear vendors. No major product lines are in serious jeopardy. But some firms are having trouble sustaining a workforce adequate to supply carrier components in the current long gap between CVN 76 and 77. The longer that gap lasts, the more it will cost to reconstitute these capabilities. So we believe that orders for major long-lead-time items for CVN 77 should be placed no later than 2000, and possibly as early as 1998. As we saw earlier, this will result in some modest savings through leveling out the vendor workforce. It will also ensure that work in the shipyard does not have to wait on vendor-supplied equipment.

Finally, we were asked by the Navy to determine if there were any innovative technologies or production processes that were not being applied in Navy-funded ship construction but which might save money if applied to CVN 77. We were also asked what was a reasonable amount to invest in those technologies. Because little ship construction is under way in the United States that is not being funded by the Navy, we investigated what some foreign shipbuilders—both government and commercial—are doing, in the United Kingdom, France, and Finland. We were especially interested in commercial shipyards because of the cost-competitive nature of the commercial environment.

We did not find any technological advances that individually would result in large cost savings if implemented by U.S. shipbuilders. But foreign shipbuilders are taking advantage of a wide range of existing technologies and production processes that have not been implemented in shipbuilding funded by the U.S. Navy. We
believe overseas shipbuilders are saving substantial amounts of money, and this is particularly true of those constructing large cruise ships, which are the closest equivalent to a carrier in habitability terms. These savings accrue through large-scale outsourcing, especially for ship parts that can be supplied and installed as modules, and by close coordination with contractors for just-in-time delivery, among other things. Some of the approaches taken save money not just during construction, but also over the life of the ship, by reducing the need for maintenance or the number of personnel required on board. Tanks and voids on these ships, for example, are being designed so they are only painted once—during construction.

![Graph showing Nimitz-Class Availability Costs, FY2009–FY2056](image)

**Figure 7—Nimitz-Class Availability Costs, FY2009–FY2056**

If the Navy invests now in R&D supporting the incorporation of some of these innovative technologies and production processes, the result might be savings later in maintenance and personnel costs. We now turn to the question of what is a reasonable amount for the Navy to invest in R&D to avoid two specific types of future costs: costs associated with major maintenance activities scheduled to occur as the ship periodically becomes available in the shipyard and costs associated with the ship's-company enlisted crew. To begin answering that, we show in these graphs (Figures 7 and 8) the annual scheduled-availability and enlisted-crew costs anticipated for Nimitz-class aircraft carriers (in FY98 dollars). CVN 77 will be the last ship of that class. So the graphs go out to the projected retirement date of that ship. We start them in 2009 because we assume that the incorporation of new technologies or processes, either on CVN 77 or by retrofit on other ships, could not yield availability or personnel savings before then. In these graphs, we assume that
future costs will be similar to the historical costs of Nimitz-class ships. Our data show that as these ships age, availability costs increase. Thus, we believe our estimates are conservative. Also, Figure 7 does not allow for maintenance activities performed outside those availability periods or availability costs that are higher than planned because of unanticipated repairs or maintenance needed. The availability costs we do count amount to half a billion dollars or so each year through most of this period, except for years that include a carrier refueling, when the cost approaches $3 billion. The enlisted-crew costs begin around $800 million a year and step down as the Nimitz-class ships are retired. When we add all these up from 2009 to the retirement of CVN 77, the total cost of the scheduled availabilities for the fleet will be $38 billion, and the enlisted-crew costs add up to $27 billion. Some of those costs are for CVN 77 and some are for the rest of the class. Whatever portion of CVN 77 costs we might expect to save, we would save only some percentage of that portion for the rest of the class, where improvements would have to be economically retrofittable if they are to be made. So if we take the CVN 77 costs and 10 percent of the costs for the rest of the class and discount to present value according to the OMB-approved rate, we get something on the order of $10 billion. Assuming that the cost-saving advances can realize a 10 percent reduction in availability and crew costs, then total savings could amount to roughly $1 billion. It might then be reasonable to devote a few hundred million dollars to the R&D required to achieve those savings.

After analyzing force structure, shipyard and vendor costs, and the potential of innovative technologies and production processes, we make these recommendations: First, begin some ship fabrication before 2002. The potential for savings there is
quite substantial—well in excess of a hundred million dollars. Second, contract for vendor-supplied equipment in advance of the shipyard start. That should permit additional savings in the tens of millions of dollars. Third, invest about $300 million in R&D on production process and application-engineering improvements that could reduce the costs of carrier construction, O&M, and manning. We need to make R&D investments now to reduce the future availability and crew cost streams that will otherwise be incurred. Given the potential for savings in those areas, R&D is likely to provide generous returns in eventual cost reductions while contributing to greater operational efficiency and quality of life for those aboard Nimitz-class carriers. (We did not estimate the potential savings to CVX, which could be considerable.) In fact, it would be a good idea to establish a stable annual R&D funding level for carriers, given the costs involved in building and operating these ships.