In determining whether the shipbuilding industry can meet future Navy aircraft-carrier needs and how different carrier-construction schedules might lead to different overall acquisition costs, we must project what we take to be future Navy carrier needs: what must be built by when. It is only within these constraints that we can meaningfully estimate the cost implications of various production schedules. In this chapter, we explore those demands and constraints and, in so doing, identify the critical factors that link construction schedules with force composition. We also determine which new-carrier construction schedules would support force-structure objectives.

**MAJOR FACTORS AFFECTING FORCE COMPOSITION**

Two factors control the size of the carrier force as it evolves over time:

- The age of a ship at which replacement is deemed desirable or is required
- The schedule of constructing replacement ships.

These factors are interrelated. For a fleet size of 12, it is necessary to deliver one carrier every four years if ships are to be retired at 48 years of age. (Below, we consider the reasons behind this nominal life span.) More generally, at steady state,

\[
\text{fleet size} = \frac{\text{retirement age (yr)}}{\text{delivery interval (yr)}} \quad (3.1)
\]

We display this relationship over build intervals of two to six years and for fleet sizes of 10, 12, and 14 ships, in Figure 3.1. To sustain a 12-ship fleet, vessels can be replaced at age 48 if a new ship is delivered every four years. If the average interval between new ships slips to 4.5 years, then either the retirement age of the ships being replaced must increase to 54 years or the fleet size must be decreased to less than 11 ships. Conversely, if the interval between new ships is decreased to 3.5 years, then either the retirement age can be reduced to 42 years or the fleet size can be increased to greater than 12 ships.
Over the long term, this simple 3-variable relationship will dominate the management of fleet composition and the shipbuilding program. And there is good reason for taking the long view: At least a decade is required to budget for, and to construct, a new carrier, and that ship will typically last for nearly half a century of operational service.

Ship-construction decisions covering the next 10 to 20 years cannot be made in isolation from the particulars of current fleet composition. The age distribution of the fleet, at least for the older ships, does not reflect a smooth, stable replacement program. Because of a surge in construction around 1960, three ships are now approaching their 40th year in service. And the demands of national defense and the effects of the national economy on defense budgets have been anything but stable in recent years. Furthermore, different ships have somewhat different capabilities and durabilities, which also influence when ships are retired from the fleet. In the next subsection, we discuss the implications of these factors for the replacement schedule.
Limits on Retirement Age

The range over which retirement age can be reasonably varied is an important question, because, to the extent that there are constraints on retirement age, the only way to achieve a desired fleet size is to sustain a corresponding delivery rate.

In the past, most carriers were retired because they became technologically obsolete. As discussed in Chapter Two, the 1950s and 1960s were marked by a desire for carrier-based operations of aircraft with higher take-off and landing speeds and the benefits of nuclear power. During that period, ships were usually retired after 20 to 25 years (see Figure 2.1). How long a carrier could be made to last was not an issue. Only three carriers were kept for extended periods: Lexington (CV 16, 49 years), Midway (CV 41, 47 years), and Coral Sea (CV 43, 44 years). And of those, Lexington was used for training in its later years and was not considered part of the operational fleet. Thus, until quite recently, the Navy had only limited experience in maintaining a carrier for full operational service for more than about 30 years, which was roughly the service life expected when the ships were designed and built.

Beginning in the 1980s, with a production rate of only three new ships per decade, it became impossible to sustain the desired fleet size without extending the operational life of some ships. To date, as shown in Figure 3.2, seven ships (hull numbers 59 through 65) have been extended to an operational life of about 40 years. Yet, unless ships are constructed faster than one every four years, if a 12-ship fleet is to be sustained, carrier life will have to be extended to 45 years or longer.

To achieve the desired longer life, a Service Life Extension Program (SLEP) was performed for CVs 59, 60, 62, 63, and 64 during the 1980s and early 1990s. SLEPs can add about 15 years to the nominal design life of 30 years. For several reasons, this “limit age” should not be interpreted as a precise number: The wearout mechanisms are not well understood, experience with operating older ships at full operational tempo is very limited, and the level of investment in prior maintenance activities has an effect. As the extended nominal life expectancy of 45 years is approached, it might be necessary to perform additional work if extending the ship life still further is desired. However,

---

1 Coral Sea and Midway were active until they were retired. However, we were told that they were maintenance nightmares.
2 CV 67’s last complex overhaul was more intensive than usual and had some of the characteristics of a SLEP.
3 The ship may continue to wear in ways similar to experience to date, or unexpected wearout modes may be encountered. It may not be possible to arrest some modes, and the ship may have to be retired.
continued extension of retirement age should be regarded as increasingly risky, simply because of the lack of experience with operating carriers (or any other class of ships) in such an age range.

For nuclear-powered ships, another factor places practical limits on ship life. At some point, the reactor core becomes depleted and an expensive refueling
becomes necessary. To date, only Enterprise (CVN 65) has been refueled. Its current fuel supply should permit the ship to operate until late 2013 or early 2014, when it will be 52 years old.

The Nimitz-class carriers’ reactor design is different from that of Enterprise. In the Nimitz plant, each new set of reactor cores is expected to last about 23 years under normal operating tempo. One refueling has been planned for each ship, at midlife, during a shipyard availability that lasts about two-and-a-half years. A second refueling is not judged a wise or practical expenditure of funds, given hull wearout, the tendency of maintenance costs to rise with age, and the need for more and more extensive backfit to bring aging ships up to the technological state of the art of the newer ones. Therefore, the full operational life of a Nimitz-class carrier can be expected to be 48 to 49 years, assuming that appropriate maintenance on the other parts of the ship is performed when needed.

THE PRODUCTION SCHEDULE OVER THE NEXT 25 YEARS

We now have enough information to permit us to examine a variety of possible ship-construction schedules for the next two to three decades so that we can understand more specifically the effects of ship-delivery rate on fleet size and ship-retirement age. First, however, we need to choose a baseline delivery rate. Whereas, in steady state, we would choose a 4-year interval, the somewhat irregular build schedule that has resulted in the current-fleet age distribution may permit a longer near-term interval. We proceed to analyze whether such an interval is feasible.

Figure 3.3 shows what happens to retirement ages of ships now in the fleet under carrier-construction programs having 4- or 5-year start intervals. We can infer from the figure that past variations in the construction schedule will not permit a near-term sequence of delivery intervals exceeding four years. Specifically, waiting five years between ships means that service lives for Eisenhower and Vinson will be necessarily longer than the 49 years at which these vessels are expected to exhaust their nuclear fuel supplies.

We now define a nominal schedule, outlined in Table 3.1 and illustrated in Figure 3.4, in which CVN 77 is delivered in 2008 as originally planned and a

---

4The end-of-fuel date might be postponed by reducing operating tempo, but that reduction cuts effective force size by a fraction of a ship.

5An availability is a period when the ship is scheduled to be in the shipyard for maintenance.
The U.S. Aircraft Carrier Industrial Base

Figure 3.3—Build Intervals for Sustaining a 12-Ship Fleet

Table 3.1
Nominal Ship-Replacement Plan

<table>
<thead>
<tr>
<th>Ship Replaced</th>
<th>Name</th>
<th>Year Delivered</th>
<th>Nominal End of Lifea</th>
<th>Replaced By</th>
<th>Year Replaced</th>
<th>Age When Replaced (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV 64</td>
<td>Constellation</td>
<td>1961</td>
<td>2006</td>
<td>CVN 76</td>
<td>2002</td>
<td>41</td>
</tr>
<tr>
<td>CV 63</td>
<td>Kitty Hawk</td>
<td>1961</td>
<td>2006</td>
<td>CVN 77</td>
<td>2008</td>
<td>47</td>
</tr>
<tr>
<td>CVN 65</td>
<td>Enterprise</td>
<td>1961</td>
<td>2014</td>
<td>CVX 78</td>
<td>2013</td>
<td>52</td>
</tr>
<tr>
<td>CV 67</td>
<td>John F. Kennedy</td>
<td>1968</td>
<td>2013</td>
<td>CVX 79</td>
<td>2017</td>
<td>49</td>
</tr>
<tr>
<td>CVN 68</td>
<td>Nimitz</td>
<td>1975</td>
<td>2024</td>
<td>CVX 80</td>
<td>2021</td>
<td>46</td>
</tr>
<tr>
<td>CVN 69</td>
<td>Eisenhower</td>
<td>1977</td>
<td>2026</td>
<td>CVX 81</td>
<td>2025</td>
<td>48</td>
</tr>
</tbody>
</table>

aThe nominal end of life is defined as 45 years after delivery for conventional ships and as the end of core life for nuclear ships.

force size of 12 operational ships is sustained. For most ships, we assume the 6.5-year construction period currently planned for CVNs 76 and 77, but we allow an extra year for the two succeeding ships, which will be the first two ships of the CVX class. (The 6.5-year build period for CVN 77 may be somewhat optimistic, given that elements of the industrial base will have to rebuild capacity after the 6-year gap following CVN 76.)

The Navy plans to replace CV 64 with CVN 76, which is scheduled for delivery in 2002. The Navy has not announced plans for retirement of other ships, so we assume that those ships will be retired in order of hull number as new ships are
delivered. With respect to CV 63 and CVN 65, that order is consistent with the consensus of Navy officials that maximum force capability will be achieved by keeping Enterprise in the fleet until it can be replaced by the first CVX design.6

---

6As mentioned in Chapter Two, after CVN 77, the DoD plans to procure a new aircraft-carrier design, provisionally called the CVX. The design for this ship should be finalized by 2004; CVX 78 is planned to replace Enterprise in 2013. Funding for construction of the ship is now planned for FY06.
The plan also assumes delivery of replacement ships on a relatively smooth schedule of one every four years as shown above. The postulated delivery dates for CVN 77 and CVX 78 are as early as those ships are likely to be available.

Two aspects of this nominal plan deserve emphasis. First, it is already too late to achieve a ship-replacement schedule that does not require operating some conventionally powered ships beyond their already-extended 45-year planned service lives. The risks and costs of such operation are unknown, but prudence suggests that they not be treated as trivial. Second, the most critical milestone in the early future is replacement of Enterprise. If the present nuclear cores follow the expected depletion rate and are expended in about 2014, then it will be essentially impossible to extend that ship another few years. Even assuming an abbreviated refueling/complex overhaul (RCOH) is performed, the refueling and associated maintenance overhaul would be costly and, even more important, could require a year or more to perform. Thus, it is especially important that delivery of CVN 77 and the first CVX be achieved close to the present schedule.

The constraints imposed by the end-of-fuel dates for the nuclear carriers are indicated in Figure 3.4. A slip in the CVX 78 delivery date will force the fleet size to drop below 12 when Enterprise runs out of fuel. If NNS builds CVX, the CVN 77 start date cannot be slipped more than a year or so. Otherwise, near-simultaneous construction demands from the two ships will severely strain, and may exceed, the capacity of the nation’s nuclear-carrier construction facilities.

Once Enterprise is replaced, there is a little flexibility in the schedule. Note, however, that the assumed delivery dates for CVXs 81 and 82 are within a year or so of the end-of-fuel dates for the ships they are replacing. Thus, CVX 79 and CVX 80 cannot be much delayed, for the same reason CVN 77 cannot be.

**Effects of Skipping CVN 77**

Some people have suggested that because CVN 77 is the last of a class and because a new design is being planned, it might be desirable to skip construction of CVN 77 and move more quickly to the new CVX design. We have shown that the schedule for replacing some of the older carriers is already tight. Under what conditions might it be practical to skip CVN 77?

If a fleet size of 12 ships is to be maintained, then CVN 65 must be replaced not later than about 2014. Assuming that the first CVX (now CVX 77) replaces CV 63, then CVX 78—now the second ship of its class—must still be finished by 2014. We assume that construction of the first and second CVX ships will require 7.5 years, and we allow a 3-year interval between starts; the result is a start date for the first CVX of about 2004 (and replacement of CV 63 at 51 years
of age in 2012). Whether such an accelerated start for the CVX design is practicable cannot yet be assessed, because the basic design parameters have not yet been defined.

**Changing Force Size**

We have observed that needs and budgets change, and that a force size of 12 might not be right for the long-term future. Thus, we need to explore ways to change the force size—particularly to increase it, which is the more demanding alternative.

Retirement ages are already high under the nominal plan, so force size can be increased only by delivering new ships at shorter intervals. But the long build periods, the need to retire aging ships, and the likely incremental nature of any buildup program limit the rate at which the fleet can be increased. For example, consider the outcome of a near-term attempt to increase force size by two ships, to 14. First, we make the optimistic assumption that the starts of both CVN 77 and CVX 78 are moved ahead two years, to 2000 and 2004, respectively, and that subsequent ships are started every three years thereafter. Second, we assume that existing ships would be retained in the force as long as possible, up to the full 49 years for the nuclear-powered ships. We also assume that only one yard, NNS, is building carriers.

These assumptions yield the time profile of force size in Figure 3.5, which indicates that a fleet size of 14 cannot be sustained until around 2016, even when the plan described above—an aggressive one by current standards—is implemented. That schedule could be accelerated a bit if the delivery rate increases to a frequency even higher than one ship every three years. However, because it typically takes seven to eight years to construct the first ships of a new class, further acceleration would not yield much reduction in the time required to achieve a 14-ship fleet.

Perhaps, instead of sustaining or increasing the carrier fleet, the impetus in the near future will be to reduce it (see Chapter Two for related issues). Whereas force size can be increased only by changing the delivery rate, there are several ways to decrease it. All of them amount to cutting back the delivery rate (e.g., by delaying or canceling the construction of new ships), or retiring ships early, or both.7

---

7Neither the options we present here for illustrative purposes nor the order in which we present them should be taken to suggest a preference for any one option. Determining which method is best would require a thorough cost analysis of the various options; such an analysis was not an objective of this research.
Figure 3.5—Time Required to Increase Fleet Size

For example, suppose a decision is made to reduce the force size to 11 carriers early in the next decade. One option would be to remove CV 63 from the force without replacing it—that is, to skip the construction of CVN 77. Or, it might be preferable to build both CVN 77 and CVX 78, but to allow some slip in the nominal schedule outlined above while still retiring CV 63 and CVN 65 on schedule. Another option would be to build both CVN 77 and CVX 78 on schedule, but to retire CV 63 and CVN 65 somewhat earlier than planned, thus avoiding some operating costs and possibly some maintenance costs on those ships. Each of these options would cause the force size to fall to 11 ships. However, if subsequent construction is sustained at a rate of about one ship every four years, the force could eventually be rebuilt to 12 ships in the future.

CONCLUSION

If force size is to be sustained at 12 ships, two new carriers (beyond CVN 76) must be delivered by 2014. At 52 or 53 years of age, two currently operating ships would then be much older than any fully operational ship has been to date, and one of them—Enterprise—will run out of nuclear fuel. Allowing a nominal seven to eight years for construction would mean that the second of those two replacement carriers must be started around 2006. Limitations on ship-construction budgets and carrier-construction facilities make start intervals of less than three years problematic.
Thus, shipyard work on the first of those carriers—CVN 77—must for all practical purposes begin by 2003. The planned start date of 2002 would be consistent with the 4-year construction interval that will sustain a 12-ship fleet when ships retire after 48 years of service—the life expectancy now planned for the Nimitz class.