

The U.S. Navy and the U.S. Maritime Administration (MARAD) together preside over a fleet of some 450 retired naval vessels and merchant ships that grows each month as ship retirements continue. Some of these ships will find their way into the navies of U.S. allies and friendly nations, others will be sold or donated to interested parties, and some will be consumed in live-fire military exercises known as sinking exercises, or SINKEX. Those that remain, about 358 ships, will require some other form of disposal over the next 20 years. Those 358 ships were the focus of our study.

We evaluated four options for how the Navy and MARAD might proceed: long-term storage, domestic recycling (ship dismantlement in U.S. naval or commercial shipyards), overseas recycling, and “reefing”—i.e., the sinking of a ship(s) to create an artificial reef for a marine habitat or as a site for recreational divers. Of these four, only the last three are truly ship-disposal options. Long-term storage, which defers the decision of how to dispose of the ships until some later date, was included to show the consequences of taking no action.

APPROACH

The study’s main thrust was to estimate the costs and offsetting revenues associated with each of the four options, to assess the stability or uncertainty associated with each factor, and to assess the associated risks and impediments. Because the U.S. Navy funds both Navy and MARAD inactive fleet expenses, we estimated total program costs. In some instances, we show the separate Navy and MARAD “shares” of the total costs. All costs are given in constant FY00 undiscounted dollars; total program costs are often also given in discounted net present value dollars.¹

¹A discount rate of 4.1 percent was used, per Office of Management and Budget, Circular A-94, at <http://www.whitehouse.gov/OMB/circulars/a094/a094.html>.

Table S.1 summarizes the costs associated with the long-term storage option and the three disposal options; Figure S.1 shows the costs as a graph. The lower and upper ends of each floating bar in the figure represent the best-case and worst-case values, respectively. This range of values captures the full spectrum of possible outcomes in our cost model. The vertical stroke through each floating bar represents the baseline case, whose value captures the most reasonable expectation of option cost. With ship storage and title holdings as they now stand, the Navy will be responsible for about 45 percent of the cost of each option, with the balance falling to MARAD. Should the Navy transfer title to all eligible auxiliary and amphibious warfare ships to MARAD, the Navy share will fall to about 30 percent, with the balance going to MARAD. This variation is within the range between best and worst case shown.

Long-Term Storage

This option assumes that all 358 ships will be stored for 100 years and will still be in storage at the end of that period. This option is the most expensive of the four in terms of total costs over the 100-year period, amounting to \$4.9 billion in undiscounted FY00 dollars, or \$1.2 billion discounted. In terms of its impact on the near-term annual budget, long-term storage is competitive with the three disposal options, averaging \$50 million per year.

Long-term storage is the course of action with the greatest amount of cost uncertainty. Our concerns about the accuracy of the estimated costs for this option focus on two cost factors:

- **Aging.** This factor represents how a ship's maintenance needs will grow as the ship ages. The cost model baseline uses a uniform aging factor of 0.5 percent per year to reflect the increase in maintenance cost. The expectation is that the older the ship becomes, the more maintenance it will need to stay afloat.
- **Interval between dry dock inspections.** The cost model baseline uses a uniform dry dock interval of 15 years for inspection and repair. If more frequent dry dockings were to become necessary, however—perhaps in response to greater-than-anticipated ship deterioration—costs could increase rapidly.

For our baseline, we used a 0.5 percent aging factor, a 15-year dry dock interval, and constant dry dock costs. The cost estimate for long-term storage in this case is \$4.9 billion in undiscounted FY00 dollars. The best-case scenario involves no escalation in maintenance due to aging, a 20-year dry dock interval, and a constant dry dock cost. Under these conditions, the cost estimate is \$3.8

Table S.1
Estimated Cost of Options

Option	Estimated Cost (millions of US\$)			Baseline Average Annual Budget
	Worst Case	Baseline	Best Case	
Long-term storage				
Discounted	1,750	1,170	960	50 for 100-year program
Undiscounted	7,740	4,920	3,770	
Domestic recycling				
Discounted	2,590	1,370	510	94 for 20-year program
Undiscounted	3,600	1,870	680	
Overseas recycling				
Discounted	140	140	0	34 for 5-year program
Undiscounted	170	170	0	
Reefing				
Discounted	560	370	240	25 for 20-year program
Undiscounted	760	500	320	

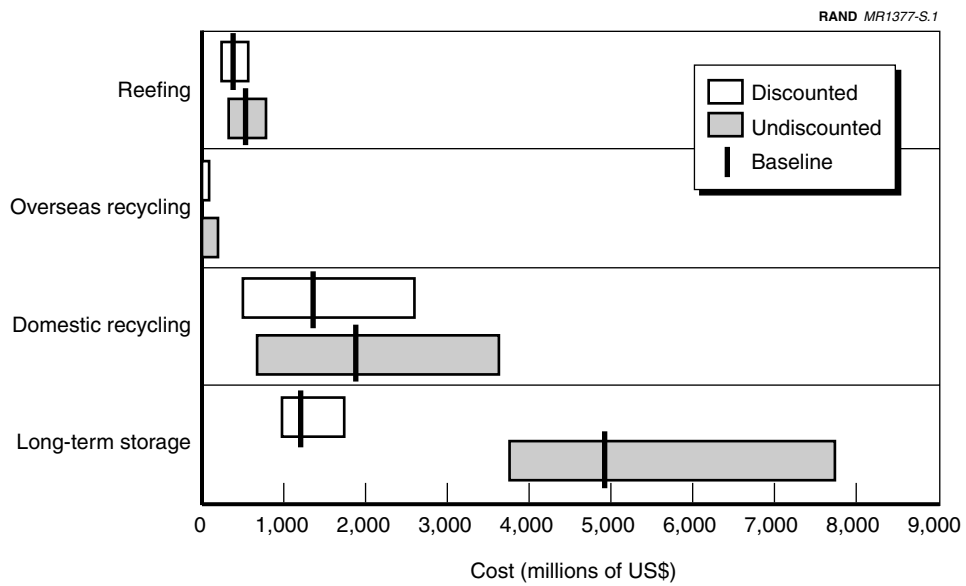


Figure S.1—Estimated Cost of Options

billion in undiscounted FY00 dollars. The worst-case scenario involves a 1 percent cost increase due to aging, a 10-year dry dock interval, and a 25 percent higher dry dock cost. Under these conditions, the cost estimate is \$7.7 billion in undiscounted FY00 dollars.

Long-term storage is not truly an option for the problem of ship disposal. It only defers the problem for another generation. In other words, whether stored for 20, 50, or 100 years, the 358 ships would still have to be dealt with in the end. For this reason, we concluded that long-term storage is not a viable course of action and not a sound policy.

Domestic Recycling

This option proved difficult to estimate accurately because of the labor-cost uncertainties likely to attend ship dismantling in the United States. We used the best data available from Puget Sound Naval Shipyard (PSNS), the Navy's Ship Disposal Program (SDP) contractors, and other sources. The complexity of the dismantling process for the various ship classes is another source of uncertainty. We developed a relationship between light ship weight (LSW) and the dismantling cost based on all the available data. We then used this relationship and other cost factors (such as towing, interim storage, and learning curve efficiencies) to arrive at baseline, best-case, and worst-case cost estimates. The available data on the cost to recycle specific ships at specific ship recyclers vary widely, so we caution against using our estimating approach for any specific ship. Of the variables contributing to the overall cost estimate for this option, the learning curve and the dismantling costs have notable influence while the value of scrap metal has little.

The baseline scenario for this option entails a 95 percent learning curve, the best-fit value for labor costs and ship complexity, and the October 2000 scrap prices. The result is a baseline cost estimate of \$1.9 billion in undiscounted FY00 dollars, or about \$1.4 billion in discounted dollars. The 95 percent learning curve we used is what was experienced by PSNS during its submarine recycling program. This learning curve, which is typical for heavy industry engaged in low-rate repetitive tasks, means that the last ship in a 20-year program will cost about 72 percent of the first. A learning curve beyond 95 percent for heavy industrial work of the kind involved in ship recycling would be difficult to achieve, as evidenced by PSNS experience.

Our best-case scenario for this option entails a 90 percent learning curve, the lower end of the labor cost error band based on the PSNS and SDP data (30 percent less than the baseline rate of \$863 per ton of LSW), the lower end of the ship complexity error band (16 percent less the baseline case), and a 50 percent increase in scrap value. Under these conditions, the estimated best-case cost

for domestic recycling is \$680 million in undiscounted FY00 dollars. Our worst case involves a flat learning curve, the upper end of the PSNS and SDP labor costs (30 percent above the baseline rate), the upper end of the complexity error band (16 percent above the baseline), and a 50 percent decrease in scrap value. Under these conditions, the estimate for domestic recycling is \$3.6 billion in undiscounted FY00 dollars.

Overseas Recycling

Virtually all present-day recycling of merchant ships and warships is done overseas in four Asian countries: India, Pakistan, Bangladesh, and the People's Republic of China. Turkey is the only European country that has a notable ship recycling industry. At one time, overseas recycling was a major means of disposal for Navy and MARAD ships.

The basic business model for overseas ship recycling is as follows: The ship owner or broker delivers a ship to the recycling site and in return receives payment based on the ship's LSW, the prevailing cost for recycling labor and materials, and the anticipated revenues for scrap metal and reusable equipment. Most merchant ships sail under their own power to the recycling site, but all or nearly all of the 358 ships in the Navy and MARAD inventory are or will be inactive and thus must be towed. For all 358 ships, the towing cost will exceed the ship's value in the overseas recycling markets, although some combination of markets and judicious choice of towing arrangements may produce a small amount of revenue for the U.S. government. The cost for overseas recycling of all 358 vessels assuming suboptimum choices for towing arrangements and including the cost of storing the ship during the notional five-year duration of such a program would be no higher than \$170 million in undiscounted dollars. Such a program may cost nothing if towing costs can be optimized. However, overseas recycling activities have been subject to great uncertainty because of short-term economic pressures and long-term environmental and safety pressures. Established industries in India and Turkey appear to be in decline because of these pressures. Moreover, U.S. regulations regarding the export of polychlorinated biphenyls (PCBs) will have to be amended before the United States can resume exporting ships containing residues of this pollutant.

Discussions under way within three United Nations (UN) organizations—the International Maritime Organization (IMO), the UN Environmental Program, and the Basel Convention on the Transboundary Movement of Hazardous Wastes—may lead to a new regulatory regimen for the ship recycling industry that could radically alter the nature of the international maritime industry. Because of all these uncertainties, we recommend that the Navy and MARAD not pursue the overseas recycling option despite its attractive cost.

Reefing

Reefing is a very promising ship disposal option. There is a history of success in using sunken ships to build reefs that benefit marine life, commercial and sport fishing, and recreational diving. Reefing is also one of the least expensive disposal options. The baseline case cost estimate for a 20-year program to dispose of the current inventory of 358 ships through reefing, including towing and interim storage, is \$500 million in undiscounted FY00 dollars. Offsetting government tax revenues can be expected from the business activity associated with the new reefs. Calculations using optimistic estimates show that the accumulated tax revenues will equal the cost of the program by its twelfth year.

Compared to the overall cost of the domestic recycling option, that of the reefing option is less sensitive to variations in learning curve and ship preparation costs. This is because the costs of towing and interim storage, which are fixed costs, make up a greater fraction of the total cost in reefing than they do in domestic recycling. To estimate the cost of the reefing option, we analyzed the cost data available from previous reefing projects and obtained estimates from Navy shipyards and commercial groups. The data lie on a remarkably uniform trend line, which allowed us to do a high-confidence evaluation of program cost versus ship complexity.

The baseline for the reefing option assumes a 95 percent learning curve and the best fit values for the labor costs and complexity factors. The cost estimate in this case is \$500 million in undiscounted FY00 dollars. The best-case cost scenario entails a 90 percent learning curve, the lower end of the labor cost error band (± 30 percent), and the lower end of the complexity error band (± 16 percent). The result is \$320 million in undiscounted FY00 dollars. The worst case entails a flat learning curve and the upper end of both the labor cost and the complexity error bands. For this case the estimate is \$760 million in undiscounted FY00 dollars.

The biggest unknown associated with reefing is the standard to be used for preparing ships for reefing. Most reefing projects thus far have employed local, U.S. Coast Guard, or Canadian standards in cleaning and preparing ships for sinking. A sound long-term reefing program requires new national standards for ship cleaning and a coordinated Navy-MARAD interagency program.

RECOMMENDATIONS

To reduce the current risk of ship sinking or other notable environmental damage, the Navy and MARAD should exploit the experience gained in the Navy's ongoing Ship Disposal Program and the recently initiated MARAD program to dispose of poor-condition ships in the inventory. At the same time, both agen-

cies should initiate coordinated discussions with the Environmental Protection Agency (EPA) and other coastal regulatory authorities to develop standards for reefing that will make it a viable, long-term option for disposing of as many of the 358 ships as possible. The goal should be to dispose of the current inactive fleet by 2020 or earlier, since that time frame will have only a modest impact on the Navy and MARAD budgets and is well within the capabilities of the available industrial base. The Navy and MARAD should not opt for overseas recycling; such a program would involve many impediments and difficulties. Neither should they opt for long-term storage. This option entails high and uncertain costs and only defers, rather than solves, the problem of disposing of the 358 ships.