Analyzing and Forecasting Overhead Costs in U.S. Naval Shipbuilding

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ABSTRACT

From the perspective of shipbuilding cost analysts, ship design and construction costs can be sorted into three basic categories: direct labor, direct material, and overhead. Of those, overhead is the least understood. In this paper, we define overhead cost and we explain how shipyards report their projections of overhead costs on future U.S. Navy shipbuilding contracts to the government. The relationship of overhead cost to shipbuilding economics and workload is described. We introduce the overhead analysis and forecasting process that is used in the Cost Engineering and Industrial Analysis Group in the Naval Sea Systems Command (NAVSEA). The scope of the discussion includes data sources, standard overhead categories, and the distinction between fixed and variable overhead. How we allocate projected future overhead costs to future ships is described. We conclude with a discussion of issues in overhead cost analysis in the U.S. naval shipbuilding industrial base.

Introduction

For the purpose of cost estimating, the cost to design and build a ship is conventionally sorted into three primary categories: direct labor, direct material, and overhead. Overhead costs are a large part of the total cost of naval shipbuilding. In general, overall cost proportions in naval shipbuilding are about:

Direct labor	24%
Direct material	40%
Overhead	36%

This is in line with Department of Defense contracts overall (GAO, 1995). Direct labor and direct material costs are identified with a single final cost objective (ship or contract). Overhead costs are residual costs that cover everything not treated as direct costs. As the Federal Acquisition Regulations put it, "after direct costs have been determined and charged directly to the contract or other work, indirect costs are those remaining to be allocated to intermediate or two or more final cost objectives" (FAR 31.203(b)). These costs are associated with owning and operating the shipyard and the shipbuilding corporation, plus the non-wage costs of employing a skilled workforce. From the perspective of an individual ship contract, those costs are indirect in nature.

Costs nearly universally recognized as direct costs include raw materials, purchased components, production work hours, design work hours, and subcontracted work. Some costs could be considered direct or indirect at the discretion of management. The choice depends on the value of the cost visibility that would be gained through managing them as direct balanced against the additional effort needed for data collection.

Fixed and variable costs

The distinction between fixed and variable costs is a key concept in overhead cost analysis. Fixed costs "continue unchanged in total within a relevant range despite wide fluctuations in volume or activity." Variable costs "change in

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total in direct proportion to changes in volume or activity" (Polimeni 1994).

Direct labor and direct material costs are variable costs. They rise and fall with production volume. Overhead costs are a mixed bag; some are variable, some are fixed, and some have both fixed and variable components. Many are linked to the size and capacity of the plant, which can only be changed over the long run planning horizon.

Shipyard managers are acutely sensitive to how their operating costs are distributed between the fixed and variable costs. The proportion of fixed to variable overhead reflects the shipyard's capital intensity, level of production technology, and the corporate strategy of the shipyard's owner.

Overhead Costs

Direct costs (direct labor and direct materials) are accrued under work breakdown structure (WBS) cost objects and are charged directly to shipbuilding contracts. Overhead costs, on the other hand, are not charged to WBS cost objects. They are accrued in overhead accounts and allocated to individual ship contracts using direct labor hours as the allocation base.

The overhead costs are influenced by two drivers: shipyard economics (which determines the overhead dollar amount over time) and workload (which is measured in work hours and forms the primary allocation base).

Shipyard Economics

The basis for the analysis of each shipyard's economics is a contractually mandated periodic data submittal called a Forward Pricing Rate Proposal (FPRP). FPRPs are furnished by each of the seven main contractor-owned shipyards engaged in naval new construction: Newport News Shipbuilding, Ingalls Shipbuilding, Electric Boat, Bath Iron Works, NASSCO, Austal USA, and Marinette Marine. The FPRP is one of the bases for negotiating the cost of future naval new construction.

Shipbuilders base their FPRP economic forecasts on a range of information, experience, and judgment. Sources used include:

- The historical record.
- Guidance from employee benefit consulting firms on health care costs, pension costs, etc.
- Collective bargaining with labor unions.
- Expectations of future contract awards from the Navy and other buyers.
- Anticipated legislative changes. Recent examples include the Pension Protection Act and Affordable Care Act.

Each FPRP data set is a package of spreadsheets that shows the yard's forecast of direct labor costs, overhead costs (including general and administrative expenses), and associated workload. The data is presented with cost elements as line items, projected out through a forecast period. Forecast periods are typically about ten years. The cost line items are lower level accounts corresponding to the shipyard's general ledger.

The lower level schedule of accounts (the definition of the cost items) and the forecast period are unique to each shipyard, regardless of corporate ownership. A typical, representative FPRP would include approximately 400 lower level overhead accounts, grouped into (typically) about four cost pools, for example:

- New construction
- Design and engineering
- Maintenance and modernization
- Repair

The lower level line items differ among the shipyards. But they can be sorted into common categories. We bucket the yard's lower level accounts into eleven common categories, each identified as fixed, variable, or 50/50 variable and fixed:[1]

1. Fringe benefits (variable; includes paid time off, payroll taxes, employee stock ownership plans, educational assistance, etc.)
2. Health (variable; company portion of employee medical insurance premium)
3. Indirect labor (50/50 variable/fixed; training, support labor, IT, supervision, security, etc.)
4. Pension (fixed; cost of the defined benefit pension plan)
5. Workers compensation (fixed; insurance premiums for work-related medical and wage loss benefits)
6. Corporate office allocations (50/50 variable/fixed; expenses of operating corporate head office)
7. Credits (50/50 variable/fixed; reductions for unallowable costs and for overhead costs not allocable to that facility)
8. Depreciation (fixed; allocation of the cost of tangible assets over their useful life)
9. Facilities (50/50 variable/fixed; utilities, maintenance, certain subcontracted services)
10. Research and development plus bid and proposal (50/50 variable/fixed)
11. Other (50/50 variable/fixed)

[1]The fixed/variable behavior of the eleven overhead categories is not exact; they are not purely fixed, variable, or 50/50. This is a simplifying modeling assumption.

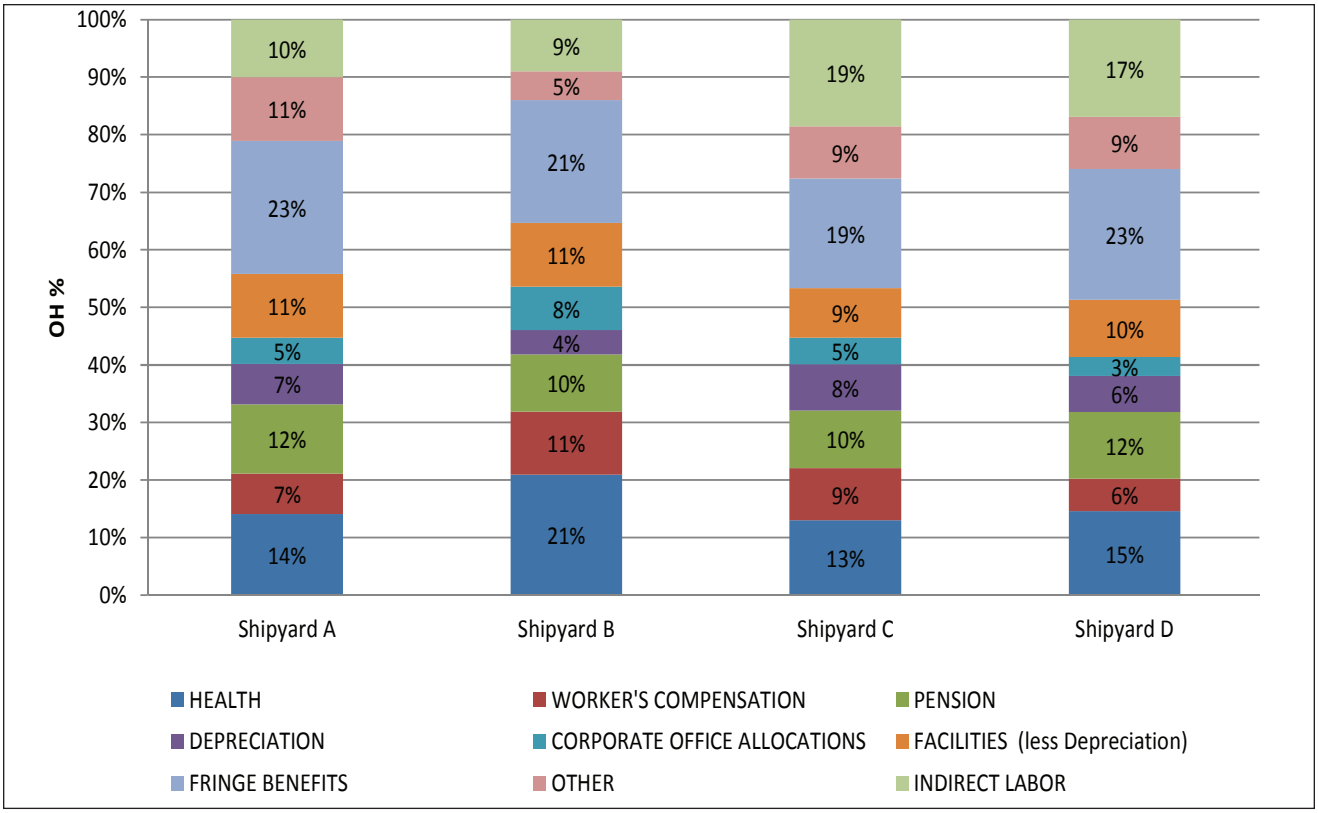

FIGURE 1. Comparison of shipyard overhead cost proportions.

We review the economics in the shipyard-submitted FPRPs, using the eleven overhead categories (dollars by year), plus the direct labor rate ($/hr). For each of the categories, and for the direct labor rate, the shipyard's projections are studied based on benchmarking analyses (across shipyards and other industries) and other information such as:

- Each shipbuilding facility's historic escalation of individual labor and overhead cost elements.
- Wage and benefit economics negotiated in recent labor agreements by non-shipbuilding defense and industrial labor unions.
- Comparisons of FPR economic escalation data among contract U.S. naval shipbuilders.
- Benchmarking wage and benefit rate and rate escalation, with broad indices by category published by the Bureau of Labor Statistics.
- NAVSEA's independently forecasted workload, phasing and schedules.

Figure 1 illustrates representative overhead category proportions among shipyards (data is notional, not actual). Figure 2 uses similar information; it focuses on one shipyard and highlights its relative position in each category, relative to the range of the other shipyards. This is an additional measure of relative performance.

Based on benchmarking and analysis, we create forecasts for the direct labor rate (by year) and the eleven overhead categories (dollars by year). These are the "adjusted FPRPs." Adjusted FPRPs are produced for each shipyard.

Having completed the benchmarking and analysis, the eleven standard overhead categories are further condensed into two overhead pools: fixed and variable. The fixed overhead pool is kept in dollars by year. The variable overhead pool dollars by year are expressed as a rate ($/hr) using the shipyard's forecast of workload as the allocation base. The result is:

- Direct labor rate ($/hr) by year
- Variable overhead rate ($/hr) by year
- Fixed overhead dollars by year

These rates define the shipyard's economics, for the purpose of calculating rates to be used in NAVSEA ship cost estimates.

Shipyard Workload

Based on scheduled shipbuilding activities, projected direct labor hours, anticipated schedules, and expected

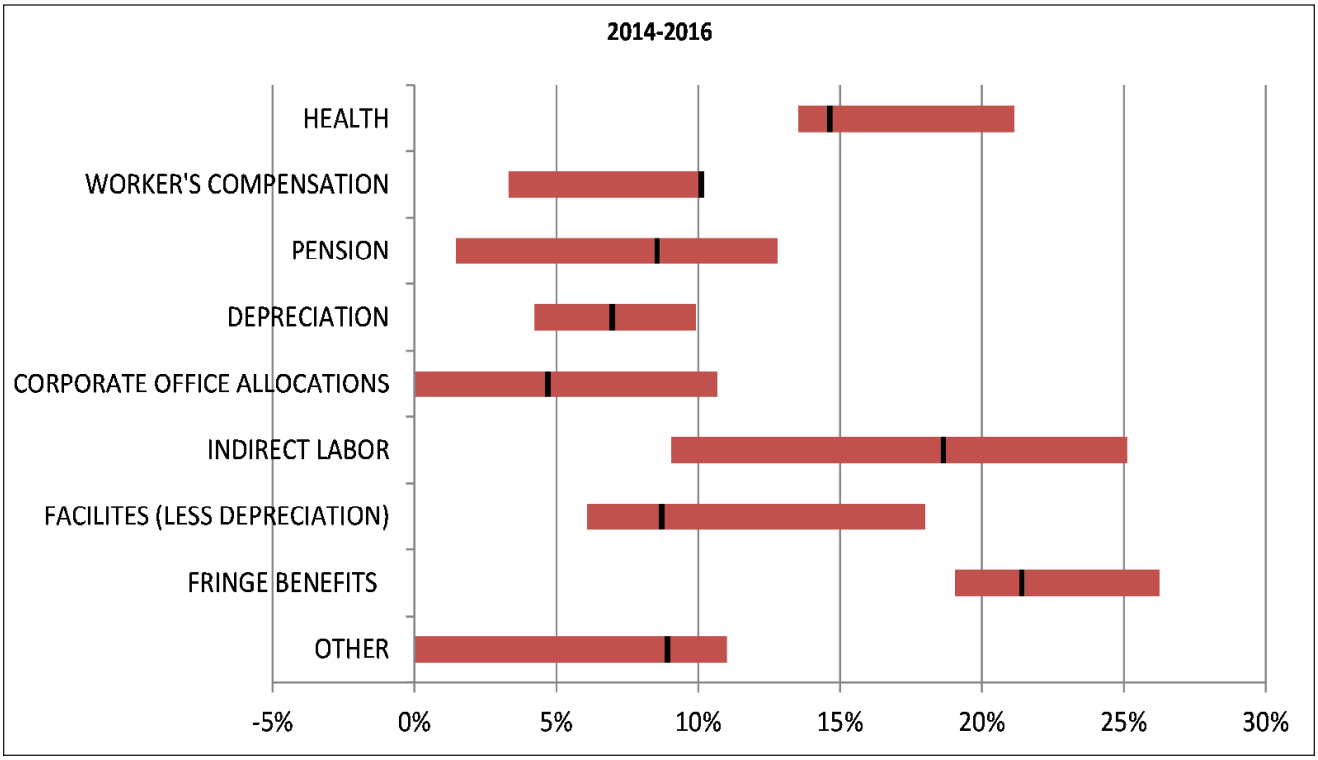

FIGURE 2. Relative position of one shipyard's overhead cost proportions.

construction phasing (e.g., bell curve, left skew, right skew…) an aggregation of forecasted workload (hours) is generated for each yard. This includes ship acquisition programs for naval, other public sector, and commercial ship work (including design and construction), repairs, overhauls, and availabilities. The workload in direct labor hours is the allocation base over which the fixed portion of overhead is spread. Each ship in the yard absorbs its share of the fixed costs.

Labor & Overhead Rates Calculation

Our independently developed forward view of the shipyard's economics is used to produce direct labor and overhead rates based on the government's forecast of future workload in each shipyard. The direct labor and overhead rates are calculated in two ways: 1) yard-wide rates by year and 2) composite rates for each ship over the entire period of execution. An overview of the process is described below.

1. The ship cost estimators provide direct labor hours, and start and end dates, for each ship (or other specifically identified effort at the shipyard).
2. The hours are phased over the construction period. This is done for each ship forecasted in the yard, as shown in Figures 3 and 4. The profiles used in this phasing are developed specifically for each program. They are periodically re-examined, refined, and updated.
3. Yard-wide workload by year is calculated as the summation of workload for individual programs for that year (Figure 5).
4. The yard-wide variable overhead costs ($) for each year are calculated as a product of yard-wide workload (hours) and the variable overhead rate ($/hr) described earlier in the Shipyard Economics section.
5. The yard-wide total overhead costs ($) by year are calculated as a summation of the variable overhead dollars from the previous step and the fixed overhead dollars by year (from the Shipyard Economics section).
6. The yard-wide overhead rate ($/hr) by year is calculated as a division of total overhead costs ($) by year and total workload by year (hours). The yard-wide overhead rate as a percentage of direct labor is calculated as a ratio of the overhead rate ($/hr) to the direct labor rate ($/hr) (from the Shipyard Economics section).
7. For each ship, a composite direct labor rate ($/hr) and overhead rate ($/hr), are calculated by weighing yearly yard-wide direct labor rates and overhead rates by the phasing of the workload for that ship.

8. The direct labor cost ($) for the ship is calculated as a summation of the product of the yard-wide direct labor rate ($/hr) by year and the workload by year for that ship. Similarly, the overhead costs ($) for the ship are calculated as a summation of the product of the yard-wide overhead rates ($/hr) and the workload by year for that ship.

NAVSEA has developed a macro-based Excel tool to facilitate the rates calculations, it is known as RIBET (Rates and Industrial Base Evaluation Tool). It has been used in every NAVSEA cost estimate since October 2012.

Discussion

Shipbuilding overhead rates and trends in overhead rates are examined in detail by NAVSEA engineering, contracts, the Program Executive Offices, and in the Pentagon. This is necessary because the overhead is such a large component of cost.

With the naval shipbuilding budget under continual scrutiny, a perennial question is, how can overhead costs be reduced? Many overhead costs cannot be addressed through the types of industrial engineering studies or lean process improvement initiatives that are used to reduce direct labor hours.

There is a tendency to view overhead costs as somehow contributing less value than direct costs. There is a perception that overhead is not "lean." When overhead costs are increasing in the short run due to decreased workload, this may be the case. If that were to continue in the long run, then a strategic re-scaling of the enterprise, to reduce fixed overhead, may be in order. Generally, though, as a member of the U.K. Ministry of Defence Procurement Executive once remarked:

> "It is quite wrong to regard direct costs as somehow more useful and essential than indirect costs… the popular analogy between 'teeth' and 'tail' is misleading. Direct cost may represent the teeth but indirect costs comprise not just the tail but the blood supply and central nervous system as well" (Pugh, 1986:129).

Across the seven shipyards, and among the eleven overhead categories, the largest costs are related to employee health and welfare. About half or more of the overhead costs are generated by paid holidays, vacation time, sick leave, health insurance, retirement benefits, and pensions. While these are subject to specific negotiations in the near term, long term reduction can come either through controlling the growth in costs such as health care (which might be beyond a shipyard's control) or by reducing the employee benefit (which will have adverse impact on the standard of living of the workforce), so such measures may not be a long term solution.

As pointed out by GAO (1995), defense contractors have engaged in cost reduction initiatives involving reducing the frequency of janitorial services or outsourcing of cafeteria operations. However, those typically result in only marginal

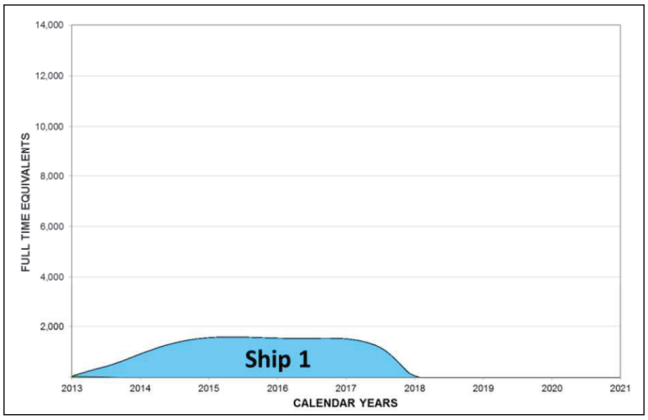

FIGURE 3. Workload for Ship 1 in Shipyard ABC.

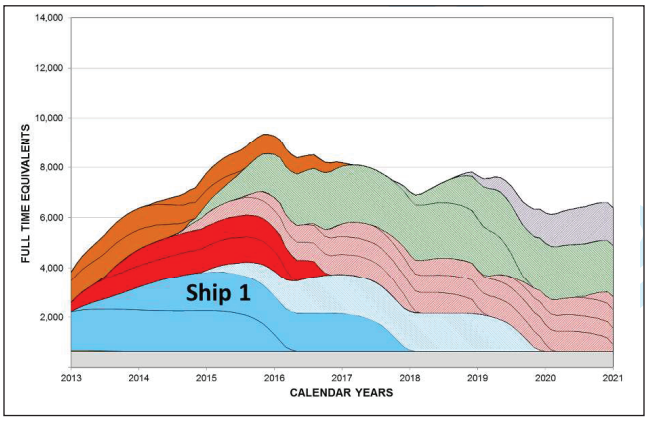

FIGURE 4. Complete workload for the yard.

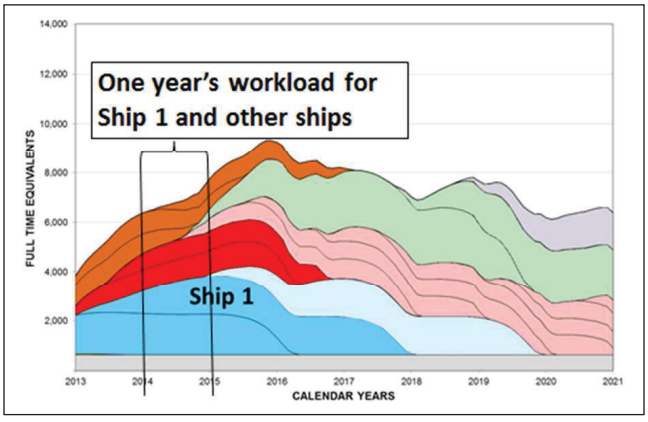

FIGURE 5. Ship 1's proportion of total work in the yard, in an example year.

savings. Furthermore, outsourcing work to sub-contractors will move costs from the prime contractor's overhead to the direct material category.

One possible future scenario would involve investment in labor-saving production technologies, to reduce direct labor hours. That would make the remaining hours more productive, so that they create more value, and would be compensated accordingly. However, while this will reduce the variable overhead cost that is driven by direct labor hours, it will increase fixed overhead dollars (higher depreciation) and it will decrease the allocation base. So, the proportion of overhead cost might actually increase.

Overhead costs could also rise in future, if (for example) wages and salaries (direct labor) were traded off in a labor union negotiation, in favor of higher fringe benefits (overhead).

The overhead cost analysis and forecasting method described in this paper requires detailed, proprietary information on the shipyard's internal cost structure. When that level of information is not available, overhead cost forecasts have been built using regression analysis methods to extrapolate historical data into the future. However, such regression findings need to be treated with caution. Defense industries (including shipbuilding) are volatile in terms of both overhead cost drivers (economics and workload), so the predictive value of past history is limited. When detailed projections of the lower level drivers (future economics and workload) are available, that information provides superior insight. Cash (2001), and Defense Acquisition University (CLB 029) provide further elaboration of this point.

Issues arise due to the tendency to compare the overhead rates as a percentage of direct labor costs or as a $/hour rate without considering the effects of changes in workload. The overhead rate expressed in these terms can be lower with higher workload at a yard, however, the total outlay could be higher due to increased variable direct and overhead costs. This effect is most pronounced while comparing projected vs. actual overhead rates. While running regression analysis, the impact of workload on the overhead rates must be taken into account to avoid inaccurate cost estimates.

Overhead costs are roughly a third or more of the total cost of naval shipbuilding. Although quite large in isolation, they appear roughly in line with benchmarks from other industries. For example, "one estimate indicates that overhead costs at the prime contractors are 35 percent of the recurring flyaway costs of the total value stream of costs of the aircraft" (Joint Strike Fighter estimate, cited in Cook and Graser, 2001:104).

Conclusion

Overhead is one of the three components of Navy shipbuilding cost. It is less visible than the other two components (direct labor and material). Because overhead cost is influenced in different directions by a variety of variables, the underlying reasons for changes in overhead costs and rates are not always immediately apparent. How or even whether it would be advantageous to decrease overhead cost is occasionally unclear; in some cases an increase in overhead cost could be linked to a decrease in total ship cost.

The overhead analysis, benchmarking, and adjustment techniques developed by NAVSEA has yielded a number of benefits to the Navy. Shipbuilder FPRP forecast bias and negotiation positioning have been lowered based on NAVSEA rate projections; this has restrained cost estimate growth and reduced variances with actual rates. The RIBET tool provides analysts with a robust platform for creating workload forecasts and rate projections, with faster turn-around times, better configuration control, and improved process control. The result of those improvements is that estimators, program managers, and contract negotiators have better information available for evaluating alternatives and making more effective budgetary and programmatic decisions.

Recommendations for future research. Since 2010, NAVSEA has made considerable progress in overhead cost analysis and forecasting of naval ship new construction. Additional work is needed, though, due to the high impact of this subject on the Navy and Defense Department budgets.

A new developmental project was started in late 2015, in concert with our colleagues in the office of the Deputy Assistant Secretary of the Navy (Cost and Economics)/Naval Center for Cost Analysis. This cross-organizational effort is developing further refinements in the Navy's overhead cost projections, with a focus on cost escalation. It will lead to more informed positions as contract negotiations on future naval ship acquisition programs begin.

Looking forward, our strategic R&D agenda for additional overhead cost analysis includes consideration of whether real options methods could add insight (Koenig 2009, Page 2012). We also propose an investigation of direct costing as a potential alternative to the absorption costing method that is currently used and presented in this paper (Chandra and Paperman 1976).

Closing Thoughts

This paper is the only documentation in the open literature that describes how overhead rates are projected by NAVSEA's Cost Engineering and Industrial Analysis Group. These rates

are embedded in the U.S. Navy ship acquisition program Component Cost Positions, in the cost estimates submitted by NAVSEA for use in the annual Report to Congress on the Long Range Shipbuilding Plan, and in exploratory analyses of alternative future ship and force structure concepts.

Our objective in writing this paper was to inform the engineering community as to the top-level drivers of ship design and production cost. Insight into ship production overhead cost will be important for naval architects, force structure planners, and industrial strategists as they conceive and realize the ships, the fleet, and the industrial base of the future.

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