Refueling and Complex Overhaul of the USS Nimitz (CVN 68)

Lessons for the Future

John F. Schank, Mark V. Arena, Denis Rushworth,
John Birkler, James Chiesa

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PREFACE

In May 1998, the USS *Nimitz* (CVN 68) entered Newport News Shipbuilding to begin its midlife refueling/complex overhaul (RCOH). In the RCOH, the nuclear reactor was refueled, and significant portions of the ship's structure, systems, and subsystems were repaired or upgraded with transformational technologies enabling the aircraft carrier to adapt to future changes in warfare doctrine and national defense policy. The CVN 68 RCOH was the first for the Nimitz class and only the fourth ever accomplished on a nuclear aircraft carrier (the USS *Enterprise*, CVN 65, has undergone three RCOHs). The Ship Construction, Navy (SCN) funding for the planning and execution of this complex project totaled approximately $2.2 billion. The project took five years of planning and three years of execution to complete.

As a result of numerous changes to the budget and work requirements and a four-month labor-union strike during the overhaul, the scheduled completion of the project slipped by several months and the cost grew over the contracted value. Since there are nine more ships in the class that will receive RCOHs in the future, the Program Executive Officer (PEO) Aircraft Carriers requested that RAND analyze the planning and execution of the CVN 68 RCOH and identify changes in processes and procedures that would lead to better cost and schedule performance for the remaining Nimitz-class RCOHs.

The research had three main objectives:

- To identify and quantify the differences between the initial cost and schedule expectations and the final results of the USS *Nimitz* RCOH.

- To understand the various factors that influenced the cost and schedule differences.
- To identify possible changes to planning and execution procedures that would improve the performance of future Nimitz-class RCOHs.

This report describes the research results of these tasks. Most of the recommendations and process improvements have already been implemented with positive results.

The research documented in this report was carried out within the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the unified commands, and the defense agencies.

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SUMMARY

All Nimitz-class aircraft carriers are scheduled to undergo reactor refueling and complex overhauls (RCOHs) at around 23 years of age. The USS *Nimitz* (CVN 68), the first ship of its class, went through its RCOH between 1998 and 2001 at Newport News Shipbuilding (NNS). The total contract value for the execution of this project was approximately $1.5 billion, some $250 million more than the original contract value. The project was scheduled to last 33 months, but it took several months longer to complete. How much of the cost could properly be interpreted as growth over the budgeted amount? What were the sources of that growth? In what ways did planning and execution management fall short of the ideal? Answers to questions such as these should help in managing future RCOHs, which will have to meet more exacting budgetary limits.

BACKGROUND

A carrier RCOH may be the most challenging engineering and industrial task undertaken anywhere by any organization. Not only must the onboard reactor be refueled, a variety of maintenance and repair actions must also be undertaken, all while the entire ship is being modernized. Modernization includes upgrading the ship's combat system and other warfighting capabilities and upgrading such distributed systems as potable water, electrical power, aircraft refueling, and air conditioning.

At the start of the CVN 68 RCOH, the Navy was aware of additional challenges compounding the difficulty of the task that lay ahead:

- The planning effort was complicated by volatility in the amount budgeted for RCOH execution. It was also hampered by the need for the ship to continue operating, which constrained the degree to which systems could be disassembled and inspected to assess repair needs.
- Emergent defense needs might make it necessary to divert RCOH funds.
- The RCOH management staff was small and would experience turnover during the long course of RCOH planning and execution. Also, the primary organization involved with carrier availabilities, Planning and Engineering for Repairs and Alterations–Carriers (PERA-CV), was dissolved through base realignment and closure (BRAC) actions prior to the start of planning.
- The contractor was accustomed to more-predictable new-construction projects.
- Various organizations with potentially different objectives had a stake in the RCOH process and outcome.

Despite the difficulties, many aspects of the RCOH were successful. The overhaul significantly improved the ship's material condition. The Navy and the contractor did an excellent job of managing the funds and time available during the last year of the overhaul. The shipyard, ship's force, and subcontractors accomplished more than a million man-hours of unplanned work authorized by the government only eight months before delivery. The Navy and the contractor improved methods of sharing financial data and communicating to support just-in-time decisionmaking. In addition, both the Navy and the contractor learned from the CVN 68 experience and made substantial improvements in planning and execution for the CVN 69 and CVN 70 RCOHs. These improvements on the CVN 69 RCOH include the following:

- Reduction of the work-package development and advance-planning phase from five years to four years by stabilizing budgets, developing reusable planning products, and building an experienced workforce to accomplish these tasks.
- Use of integrated product and process development, which allowed significantly more type commander (TYCOM) involve-

ment in the development of the work package and more contractor involvement in job-scope planning.

- Prestaging of critical equipment such as propellers and generator rotors, which reduced cost and schedule uncertainties associated with the open-and-inspect strategies used on CVN 68.
- Better job-scope development, which allowed entry into the CVN 69 execution contract with only 14 "Class F" estimates (in which the cost of the job can be estimated only to within +/–40 percent due to limited understanding of the job scope), as compared with more than 90 on CVN 68.
- Tighter management of the emergent and supplemental-growth pool, based on weekly metrics.
- Improved efficiency of the contractor workforce resulting from improved cost-accounting procedures and weekly reviews of expenditures with cost-account managers.

Specific examples of improvements new to the CVN 70 RCOH planning process include the following:

- A new emphasis on strategic planning, which strikes right at the heart of workload forecasting, perhaps the biggest cost driver in the shipbuilding industry. By looking at long-range workforce, facilities, and schedule requirements for aircraft carriers, surface ships, and submarines, the Navy is making early modifications to overhaul schedules, preventing unexpected business-base changes, which drive up overhead costs.
- A new contracting strategy based on the development of discrete annual planning packages that allow the contractor to complete specific tasks during each of the advance-planning years. This is reducing the cost of ship checks and drawing development and will provide a better understanding of the cost of work prior to the start of an RCOH.
- A new modernization strategy, which installs approved ship alterations (rather than engineering-change proposals, as in the new-construction vernacular). This strategy will improve configuration control and logistics supportability and will reduce life-cycle costs by creating more reusable planning products.

- A new work-assignment strategy that maximizes the use of customer-contracted teams whose familiarity with certain new technologies will provide higher-quality work at a reduced cost.

The problem-oriented emphasis in this report stems from our objective, which was to find ways to improve planning and execution processes. It should not be interpreted to imply that more was wrong with the RCOH than was right with it.

COST GROWTH

We restricted our investigation of cost growth to the NNS execution contract (ignoring planning costs, government-furnished equipment (GFE), etc.). Even with this restriction, identifying the amount of cost growth over budget is not as straightforward as it might seem, because there is no irrefutable view as to what should be counted in the base and what in the increment.

At the outset of RCOH execution, the Navy and NNS agreed to a price of $1.22 billion for a well-defined basic work package. That total covered 16.2 million labor hours. The expectation by the summer of 2000 was that the total labor input would ultimately reach 20.9 million hours, a labor-hour growth of 29 percent.

The base negotiated settlement, however, did not include allowances for emergent and supplemental (E&S) costs and for small-value changes (SVCs). These allowances could reasonably have been included in the base, particularly considering that some difficult-to-cost tasks were deliberately put in the E&S pool at the outset and that NNS would incur no profit penalty by using up the allowances. With the allowances, the negotiated settlement covered 19.4 million labor hours, suggesting a growth of 7.7 percent. Furthermore, about one-fifth of that could be attributed to inefficiencies associated with a union-labor strike in mid-1999. Since our purpose is to enlighten future planning, it seems inappropriate to include strike-related growth, as strikes at NNS are infrequent. A labor-hour growth estimate closer to 6 percent would thus be justified.

This modest 6 percent labor-hour growth translated into a substantial cost growth, 17 percent, because the labor rate also grew slightly and the overhead rate came in 10 percentage points above what had

been expected. The compounded effect was a total labor cost growth of 12 percent; the remainder (of the 17 percent) was the result of an almost one-third increase in material costs. (The material cost increase was due to the addition of work items to the package and to an underestimate of subcontract costs, which are included in the material budget.)

Labor hours and overhead rates increased for many reasons, but we cannot confidently infer the specific causes, or contributions, to the increased costs. We can, however, identify multiple problems in RCOH planning and execution management that could have contributed not only to higher costs but also to schedule slippage. These difficulties were most apparent in the nonnuclear repair and modernization tasks.

PROBLEMS IN PLANNING AND EXECUTION

Planning for the nonnuclear aspects of the CVN 68 RCOH was characterized by problems of several types. First, not all parties with a stake in the outcome had sufficient input. The stakeholders included the Aircraft Carrier Program Office (specifically, PMS 312); the TYCOM (the commander of the aviation forces in the Pacific Fleet in this case); the Naval Sea Systems Command (NAVSEA) Supervisor of Shipbuilding, Conversion, and Repair (SUPSHIP) at the NNS site; and NNS itself.

Because PERA-CV, the field agency of PEO Aircraft Carriers most knowledgeable about carrier availabilities, had been dissolved, PMS 312 assumed responsibility from the outset for developing the nonnuclear repair portion of the work package and retained substantial authority during execution. This was problematic because that office's focus has not traditionally been on waterfront issues. The TYCOM is the ship's "owner" and has the biggest stake in seeing that it emerges from the RCOH able to accomplish its missions. The TYCOM was involved throughout the CVA 68 RCOH planning and execution process, but most heavily in the early planning stages, when TYCOM personnel provided information on the material condition of the ship and on the types of repairs they believed would be needed. However, as planning progressed, the TYCOM's role diminished and, in that office's opinion, it was given little authority in the continuing development of the work package.

SUPSHIP NN Code 1800, the organization where some of the PERA-CV analysts were ultimately assigned, did not become involved in planning until two years into the process. It eventually did play a key role in developing the work package that was included with the request for proposal (RFP) for RCOH execution. NNS did not participate as much as it possibly could have during development of the nonnuclear work package, despite having built all of the Navy's nuclear-powered aircraft carriers and having accomplished a number of carrier availabilities, including RCOHs for CVN 65.

NNS did provide initial estimates of the costs of the tasks contained in the work package. No Navy office, however, had adequate staff to bring the Navy's 50 years of experience in constructing and maintaining large-deck carriers to bear in a timely manner to provide independent cost estimates that could serve as a check on NNS's numbers.

The relationship between planning and budgeting was problematic. While planning was under way, the top-line budget number for the RCOH was moving up or down—mostly down—in response to both perceived RCOH needs and unrelated demands for funds elsewhere in the Department of Defense (DoD). The planning process could not react quickly enough to this budget volatility. As a result, the development of the work package was not directly tied to the available budget.

It did not help that NNS responded to the RFP with a proposal having a cost greater than that suggested by the initial estimates it had provided to the Navy. Navy and NNS negotiators thus faced the challenge of shaping the work package to fit the available budget. The challenge was all the more difficult because Navy stakeholders had not reached an internal consensus regarding the goals of the RCOH. The early planning goal of a ship equivalent in capability to a new one had been rejected as unrealistic but had not been replaced with a new consensus. Not coincidentally, no priorities had been established for deciding which tasks to drop should costs turn out higher (or the budget lower) than expected. The result was uncoordinated triage and ad hoc workarounds, such as the decision to pay for predictable tasks (e.g., the painting of tanks) with funds intended for unpredictable work. That decision virtually guaranteed that money

for unpredictable work would be tight, approvals would be delayed, and overruns would occur.

During execution, any change to tasks in the basic work package, any SVCs, and any work to be paid out of E&S funds had to be the subject of a field modification requisition (FMR) from SUPSHIP NN. Budgetary problems aside, the complex nature of an RCOH results in many requests for change in the basic work package's task list as execution progresses. However, because work on the CVN 68 RCOH that could have been predicted had been placed in the E&S pool, many more FMRs for additions to the approved task list were made than would have been expected. Another factor driving up the FMR count was the lack of a clear understanding of the material condition of the ship. The numerous FMRs overwhelmed personnel at SUPSHIP NN, whose staff for managing the RCOH was no larger than that for overseeing an availability an order of magnitude smaller.

As the RCOH neared completion, additional funding became available to compensate for strike costs and to support growth in E&S work. A large number of changes, previously shelved for lack of funds, were approved. This influx of work caused NNS problems in managing its workforce, not only on the RCOH but also for other projects in the shipyard. Overtime was needed to maintain schedules, and some inefficiency resulted.

Navy management of the RCOH was hampered by a lack of timely, accurate, and useful data from NNS on the progress of the repairs and the estimated costs at completion. Progress-related data were received at least three months late and were often displayed in a manner that was confusing and unhelpful for Navy project managers. Furthermore, a change in the data-collection and management system within NNS resulted in some needed data being unavailable or inaccurate.

The complexities of RCOH management were exacerbated by the fact that NNS's labor force was not the only one working on the ship. A large Navy crew was assigned to the carrier throughout the RCOH and was responsible for carrying out part of the work package. Coordination between the two labor forces was complicated by their use of different task identification systems and was the responsibility of only two persons on the waterfront. Coordination failures, as well

as the inexperience of the ship's force at some tasks, resulted in rework by both NNS and the ship's force.

AREAS FOR IMPROVEMENT

In addition to the improvements to planning and execution that have already been made for the CVN 69 and 70 RCOHs, we suggest that the following three sets of actions be taken.

Improve the Planning Process

Effective planning is critical to the success of an RCOH. It is important to involve knowledgeable people and organizations early. These organizations include, at least, SUPSHIP NN Code 1800 (especially the personnel from the PERA-CV organization), the TYCOM, and NNS.

NNS is the organization that will execute a major portion of the total work package for future RCOHs, and it is the one that has practical experience with large-carrier availabilities. Thus, its expertise and knowledge should be used not only in the development of the nuclear repair package, as is now the case, but also in identifying specific tasks that should be in the nonnuclear repair package.

The above organizations should work together to develop a list of tasks for possible inclusion in the work package of each RCOH. This list should be general in nature and should cover all *potential* tasks. Such a list could form the basis for determining what should be included in the work package for each RCOH. The list could be refined with each successive RCOH.

Each task should have a priority established. The highest priority would be given to tasks that *must* be accomplished during the RCOH. The lowest would indicate tasks that could be done if budget were available but that could also be deferred without degrading the ship's safety or operating capability. Costs should be developed for each task to permit priority-driven revision of the task list should budgets turn out to be lower than expected.

Finally, the planning for each task should include some understanding of the task's relationship with others on the list. Performing one

task may require that another task also be accomplished. Or, if one task, such as replacing a major component, is not included, another task, such as repairing that component, may be required.

The participation of the organizations involved in planning should not stop with the development of the work package. Navy organizations, such as the TYCOM and SUPSHIP NN, should prioritize tasks in the work package and advise on the actions to take during budget negotiation and contracting if budgets turn out to be constrained or if tasks must be removed from the package.

Improve Data and Estimating Capabilities

Useful data and effective forecasting capabilities are essential for successfully planning and executing an RCOH. During planning, to formulate a work package, it is necessary to have historical availability data on the Nimitz class and on the specific carrier scheduled for RCOH. A database of task labor and material costs agreed upon by the Navy and NNS would also help in prioritization, as described above.

During RCOH execution, timely, useful, and accurate data are needed to evaluate the current cost and schedule status of the RCOH. These data should have sufficient detail that all elements of a specific task are easily identifiable from an overall integrated plan that covers numerous tasks. Forecasting methods are needed to project the cost at, and the timing of, completion. PMS 312 must also establish processes and criteria for informed decisionmaking during RCOH execution, when inspections result in FMRs for increases in work and costs.

In general, NNS should freely share with the Navy those data required for effective planning and execution. For example, the Navy should be able to see the basis for the man-hour estimates to accomplish a specific task. The Navy must, of course, understand the business-sensitive nature of the data. It must protect against any possible misuse, especially if any of the data are pertinent to projects for which NNS must compete with other contractors, and some data should remain private.

In an open-book data environment, the Navy would have access to the same data that are used to formulate the quarterly cost performance reports (CPRs). That would allow the Navy to monitor the cost and schedule as events transpire and would permit timelier decisionmaking.

Improve the Relationship Between the Navy and NNS

During the CVN 68 RCOH, the relationship between the Navy and NNS was strained. Many in the Navy expressed mistrust of NNS, believing the contractor at times withheld information that would have been useful for RCOH planning and execution. This problem must be resolved for subsequent RCOHs. The Navy and NNS must have more confidence in each other and must work more closely together during both planning and execution. They must commit to a long-term relationship with mutually agreed-upon objectives and effective communication strategies that lead to openness and trust.

The path to a better relationship is not one we can map out here. The two organizations might consider assigning employees to each other's offices for periods of time. This is a technique often used by U.S. military services in their interactions with the militaries of other nations. However it is established, a solid, professional relationship between the Navy and NNS is needed to successfully plan and execute the remaining RCOHs for the Nimitz-class ships.

SPECIFIC RECOMMENDATIONS

In light of our study findings, we recommend that the Navy take the following specific actions:

- Develop flexible, effective contract-negotiating processes. The current process is too rigid, subject to manipulation, and likely to result in lose-lose rather than win-win outcomes.
- Establish RCOH goals that are clear enough to form a baseline repair package that is consistent with the budget and that is well supported by (and communicated to) all carrier stakeholders.
- Collaborate with NNS to improve Navy-contractor communications, broadly considered. In particular, establish metrics to en-

able senior managers to make accurate, timely assessments of RCOH progress.

- Reduce the rotation rates of Navy program-office and shipyard managers to improve continuity and RCOH experience.
- Improve the efficiency of contract-change management, i.e., the ability of the shipyard and the Navy to identify, fund, and contract new work. To achieve this goal, NNS may have to assume more risk in the execution of RCOHs.

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ACRONYMS AND ABBREVIATIONS

ACO	administrative contract officer
AIRLANT	Naval Aviation, Atlantic Fleet
AIRPAC	Naval Aviation, Pacific Fleet
ALRE	aircraft launch and recovery equipment
APO	assistant project officer
ATR	above-threshold reprogramming
AWP	availability work package
BRAC	base realignment and closure
C4I	command, control, communications, computers, and intelligence
CAPS	Carrier-Availability Planning System
CARPOP	carrier reactor-plant overhaul package
CAST	carrier-availability support team
CDRL	contract data requirements list
CHT	collection, holding, and transfer
CLA	carriers, littorals, and auxiliaries
CLIN	contract line-item number
CNO	Chief of Naval Operations
COFC	cost of facilities capital
COH	complex overhaul
COMNAVAIRLANT	Commander, Naval Air Forces Atlantic

COMNAVAIRPAC	Commander, Naval Air Forces Pacific
CPI	cost performance index
CPIF	cost plus incentive fee
CPR	cost performance report
CSMP	current ship's maintenance plan
CVN	carrier vessel, nuclear
DoD	Department of Defense
E&S	emergent and supplemental
EAC	estimate at completion
EVMS	Earned-Value Management System
FMR	field modification requisition
FY	fiscal year
GFE	government-furnished equipment
GOCO	government-owned, contractor-operated
ICAN	integrated communications and advanced network
IMP	Incremental Maintenance Program
INSURV	Board of Inspection and Survey
IR	inspection report
JCN	job control number
LOE	level of effort
MMP	modernization ship-design management plan
MPN	Military Personnel, Navy
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NNPP	Naval Nuclear Propulsion Program
NNS	Newport News Shipbuilding
NRRO	Naval Reactors Representative's Office
O&MN	Operations and Maintenance, Navy
OPN	Other Procurement, Navy

PCO	procuring contract officer
PEO	Program Executive Officer
PERA-CV	Planning and Engineering for Repairs and Alterations–Carriers
PMP	*Program Management Plan*
PSA	post-shakedown availability
RCOH	refueling/complex overhaul
RFP	request for proposal
RPPY	Reactor-Plant Planning Yard
SCA	ship cost adjustment
SCN	Ship Construction, Navy
SDM	ship design manager
SLEP	service-life extension program
SPAWAR	Space and Naval Warfare Command
SRA	selected restricted availability
STA	special transfer authority
SUPSHIP NN	Supervisor of Shipbuilding, Conversion, and Repair, Newport News
SVC	small-value change
SWLIN	ship work line-item number
TAR	technical analysis and report
TYCOM	type commander