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THE SHIPBUILDING & FORCE STRUCTURE ANALYSIS TOOL

A USER'S GUIDE

Prepared for the
U.S. Navy

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PREFACE

Periodic defense reviews require analysts to address difficult questions regarding the Navy's ship force structure, resource levels and allocations, and the shipbuilding industrial base. While a range of tools is available to assist analysts in their decisionmaking, the need for improvement exists. In earlier research, RAND identified the types of issues that arise during major defense reviews and described the abilities of the tools currently available to address those issues. RAND also described an overarching analytical architecture that could assist the Office of the Secretary of Defense (OSD), Navy, and other organizations in addressing the difficult naval ship-related questions.

This document describes the effort to implement the integrated architecture as outlined in the earlier work. Also contained in this document are detailed user instructions (see the Appendices) for those interested in exercising the analytical capability of the tool.

The Assessments Division of the Deputy Chief of Naval Operations for Resources, Warfare Requirements, and Assessment (OPNAV/N81) sponsored this portion of the research. The research should be of interest to OSD and Navy policymakers, planners, and analysts concerned with shipbuilding resource requirements and industrial base.

This research was conducted for the U.S. Navy 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.

CONTENTS

Preface	iii
Figures	ix
Tables	xiii
Summary	xv
Acknowledgments	xix
Acronyms	xxi
Chapter One	
INTRODUCTION	1
Background	1
Past Studies: Methods and Their Limitations.....	3
A New Model: Learning from Past Limitations	5
Shipbuilding and Force Structure Analysis Tool	6
Chapter Two	
AN OVERVIEW OF THE ANALYSIS TOOL.....	9
Fundamentals of the Tool's Architecture	9
Key Concepts of the Tool	13
Stored Data and Data Sets	13
Main Inputs	14
Main Outputs	15
Force Transition Model: An Overview.....	17
How the Model Generates a Shipbuilding Plan.....	17
The Industrial Base Model: An Overview	21
The O&S Cost Model: An Overview	22

The Financial Adjustments and Assumptions Model:	
An Overview	22
Constant-Dollar Basis and Net Present Value	23
Assumptions Check	25
Chapter Three	
THE INDUSTRIAL BASE MODEL	27
Shipyards Production Labor	27
The Labor Metric: Full-Time Equivalent	28
Ship Class Labor	29
First-of-a-Class Versus Follow-on Ships	29
Workload, Labor Profiles, and Learning.....	31
The "Project" Concept: When Labor Is Divided Across	
Shipyards	32
Contractor Roles.....	33
Shipyards Labor and Costs	35
New Production, Existing Production, and	
Other Work	35
Effective Versus Required Labor	36
Attrition, Hiring, and Termination Rates	37
Productivity.....	38
Burden Costs	39
The Industrial Base Model in Action	40
Required Labor Calculations	41
Effective Labor Calculations	42
Productivity Calculations	43
Chapter Four	
WORKING WITH THE TOOL	47
Summary	47
Running the Models	49
Limitations of the Tool	49
Data Updates Required	49
Force Transition Model Limitations	51
Industrial Base Model Limitations.....	51
Dealing with Real-World Problems	52
Implications of Changing Ship Life	52
Detecting Industrial Base Problems	54
Extending or Moving Construction Time for a Ship	54
Changing Force Structure.....	55
Conclusion	56

Appendix

A. MICROSOFT ACCESS AND TOOL INSTALLATION	59
B. START-UP AND CREATING A DATA SET	67
C. DATA EDIT AND ENTRY	73
D. RUNNING THE DATA SET—CALCULATIONS	111
E. GENERATING REPORTS.....	119
F. COMPARISON UTILITY.....	133
G. SHIP ROLES, HULL TYPES, AND CLASSES.....	141
References	143

FIGURES

S.1.	Summary Tool Architecture	xvi
2.1.	High-Level Architecture	10
2.2.	Model Inputs and Outputs	14
2.3.	Flow Diagram for Force Transition Model.....	18
2.4.	Example Acquisition Plan.....	21
3.1.	First-of-a-Class Versus Follow-on Ship Workloads.....	30
3.2.	Example Labor Profile	32
3.3.	Example Production Plan.....	34
3.4.	Flow Diagram for the Industrial Base Model	41
4.1.	Edit Ship Class Data	53
A.1.	Needed References for VBA.....	63
A.2.	Entering the Solver DLL Key String in VBA Editor	65
B.1.	Warning Screen	68
B.2.	Top-Level Menu	69
B.3.	Manage Data Sets Form	70
B.4.	A Selected Data Set	70
B.5.	Successful Link to a New Data Set	71
C.1.	Data Edit and Entry Menu	73
C.2.	Example of Active Status Bar	75
C.3.	Edit Active Fleet Information Form	76
C.4.	Force Level Requirements	77
C.5.	Ships in Production Data Entry Form	78
C.6.	Example Acquisition Plan.....	80
C.7.	Modify Acquisition Table Format	81
C.8.	Edit New Production Plan	83
C.9.	Edit Other Work List.....	84
C.10.	Edit Ship Class Data Form	86
C.11.	Learning Data Subform	89

C.12.	Material and Equipment Subform	91
C.13.	Operations and Support Costs Subform	93
C.14.	Labor Subform	94
C.15.	Funding Profile Subform	96
C.16.	Edit Hull Types	97
C.17.	Edit Ship Roles	98
C.18.	Shipyards Labor Data	99
C.19.	Shipyards Burden Rates	102
C.20.	Productivity Data	103
C.21.	Other Work Material and Equipment Subform	105
C.22.	Other Work Labor Data Subform	106
C.23.	Edit Labor Profile	107
C.24.	Edit Inflation Index Data	109
C.25.	Data Source Documentation Form	110
D.1.	Calculations Form	111
D.2.	Select Calculation Method	112
D.3.	Missing Production Data Warning	114
D.4.	Funding Assumptions Form	115
D.5.	Invalid Funding Data Warning	117
E.1.	Reports Menu	119
E.2.	Labor Output Form	121
E.3.	Required Labor (FTE) at a Shipyard by Class	122
E.4.	Required Labor (FTE) by Class as a Table	123
E.5.	Required Labor with New Build Table	123
E.6.	Required Versus Effective Labor	124
E.7.	Burden Rates Report	124
E.8.	Funding Output Selection Form	125
E.9.	Detail of Summary Funding by Year Report	126
E.10.	Chart of Summary Spending	126
E.11.	Ship Count Reports	128
E.12.	Table of Hull Types by Year	128
E.13.	Hull Types by Year, XY Plot	129
E.14.	Active Hull Types by Year—Sand Chart	129
E.15.	Table of Ship Requirements	130
E.16.	Data Source Comments Report	131
F.1.	Main Screen	134
F.2.	Labor Differences Pop-Up Window	136
F.3.	Example Absolute Delta Labor Graph with Delta Build Plan	137
F.4.	Funding Differences Menu	138

F.5. Funding Differences Table	138
F.6. Ship Counts Pop-Up Window	139
F.7. Delta Ship Production by Ship Role	140

TABLES

2.1. Sample Deficit Array	19
4.1. Example Force Level Requirement.....	55
G.1. Ship Roles, Hull Types, and Classes.....	142

SUMMARY

Each time a major defense review is undertaken, policymakers must confront a range of complicated issues about the Navy's future force structure, including resource concerns and significant changes in the shipbuilding industrial base. To help answer these concerns, analysts in the Office of the Secretary of Defense (OSD) and the Chief of Naval Operations (CNO) staff turn to the available analytical tools to help provide options to decisionmakers. Although an array of such tools exists, there is a significant need for improvement to ensure that policy and resource decisions are well analyzed and supported.

In earlier research, RAND identified the types of issues that arise during these defense reviews and evaluated the capacity of current analytical models to help address these issues. We found that the most common concerns of defense analysts were cost, schedule, industrial base capacity, shipyard performance, and program management strategies. Further, we found that existing tools lacked an integrated approach that would allow analysts to consider not just individual elements (e.g., manpower and procurement funding requirements) but the interaction and interrelationships among the industrial base components—from attrition rates to ship life extensions, from labor learning curves to overhead costs. We then outlined an overarching analytical architecture that could provide this integrated analysis environment—an environment in which the user is able to understand the implications of force structure choices on resource requirements and the private shipyard industrial base.

This document describes the result of efforts to implement this integrated architecture, the Shipbuilding and Force Structure Analysis

Tool. The purpose of the tool is to assist the OSD, Navy, and other organizations in addressing the difficult naval ship-related questions. The general architecture of the tool is shown in Figure S.1.

The tool consists of four linked models. The first model, the Force Transition Model, determines when new ships are acquired and when existing ships retire, based either on a given acquisition plan or on a desired force structure. The outputs from the force transition model serve as important inputs to the next two models: the Industrial Base Model and the Operating and Support (O&S) Cost Model. The Industrial Base Model calculates workforce demands and labor costs based on the acquisition plan. The O&S Cost Model determines the operating and support costs for ships in the fleet. The last model, Financial Adjustments and Assumptions Model, allocates the various funding streams to the appropriate budget categories, adjusts the base year of the costs to a fixed year, and applies a discount rate for discounted cash flow analysis. This model also determines whether the inputs used by the other models violate basic assumptions or whether data are incomplete, thus producing misleading results.

This document serves as a basic introduction to the tool. It describes the general architecture and outlines some basic concepts that may

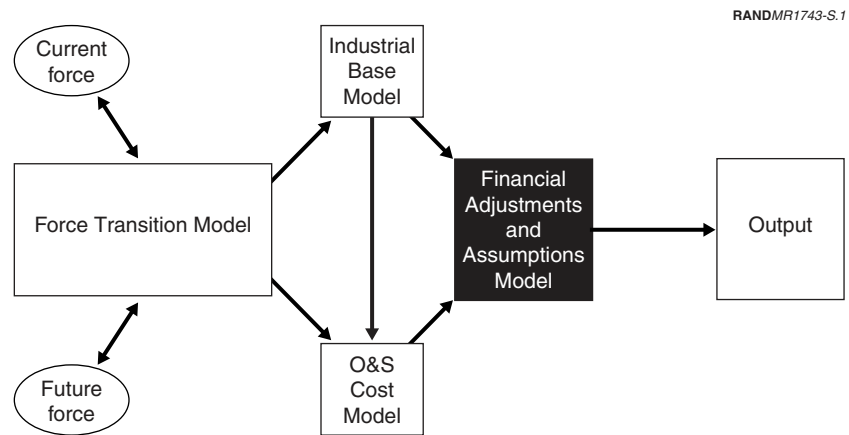


Figure S.1—Summary Tool Architecture

be necessary to understand before using the tool. The tool's primary user is meant to be an analyst seeking to determine the industrial base and resource implications of a desired force structure choice. We intend this document to provide users with the tool's basic navigational capacities, guiding them through the user interface, providing background concepts and a description of methodology, offering data field definitions, and pointing out the tool's central features. We also provide more detailed discussions of two of the tool's primary models—the Force Transition Model and the Industrial Base Model. Finally, we consider the tool's current limitations as well as common issues the user will confront. The appendices serve as a user's guide and data dictionary for analysts interested in using the tool.

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ACRONYMS

AP	advanced procurement
CFE	contractor-furnished equipment
DCMA	Defense Contract Management Agency
DLL	Dynamic Link Library
DoD	Department of Defense
FTE	full-time equivalent
FY	fiscal year
G&A	general and administrative
GFE	government-furnished equipment
LP	linear programming
M&E	material and equipment
MOD	UK Ministry of Defence
MPN	Military Personnel, Navy (budget category)
MS	Microsoft
NAVCOMP	Navy Comptroller's office
NAVSEA	Naval Sea Systems Command
NNS	Newport News Shipbuilding

NVR	Naval Vessels Registry
NPV	net present value
OMB	Office of Management and Budget
O&M	operation and maintenance
OMN	Operations and Maintenance, Navy (budget category)
OPNAV	Office of the Chief of Naval Operations
O&S	operating and support
OSCAM	Operating and Support Cost Analysis Model
OSD	Office of the Secretary of Defense
PSA	Post-Shakedown Availability
PEO	Program Executive Office
RCOH	Refueling Complex Overhaul
SCN	Shipbuilding and Conversion, Navy (budget category)
SUPSHIP	Supervisor of Shipbuilding Office
UIC	Unit Information Code
VAMOSC	Visibility and Management of Operating and Support Costs
VBA	Visual Basic for Applications

BACKGROUND

The end of the Cold War created a challenging environment for military planners. Shifting defense priorities resulted in dramatically reduced budgets and procurement levels.¹ As a result, the U.S. industrial base has grown smaller and more consolidated, with two large defense contractors now owning the nation's six largest shipyards. These transformations have posed still more challenges to those responsible for ensuring that the United States meets its force structure requirements. Military decisionmakers have found themselves under unprecedented pressure to employ the nation's shrinking industrial base resources more efficiently to meet current and future defense needs. The terrorist attacks of September 11, 2001, only raised the stakes further, demonstrating that, despite budget reductions, U.S. forces must be in a state of constant readiness to face increasingly complex and daunting global contingencies.

Given these many programs and sizable production runs, the Department of Defense (DoD) could treat the shipbuilding sector of the industrial base almost as a public utility; it was there whenever it was needed. But as defense budgets began to shrink, the DoD faced, and continues to face, major policy dilemmas. On the one hand, the fleet must be affordable, given reduced funding. On the other hand,

¹Although recent events have prompted the possibility of increased defense spending, it is unlikely that shipbuilding rates will approach prior-year levels. The annual rate of ship orders in 2002 was roughly one-quarter of the 1980s rate.

the nature of the dangers the United States faces has changed radically. No longer does the nation's fleet confront a lone adversary or a static set of threats. Now it must be adaptable and responsive to an ever-wider array of contingencies.

As a result, the Office of the Secretary of Defense (OSD) and the Navy have taken a more active role in monitoring and shaping the evolution of the shipbuilding industrial base. They must now take pains to ensure that current industrial capabilities are adequate to meet future defense needs in a timely and efficient manner. Further, they must be certain that the capabilities that do remain are the most critical and that marginal contributors to the force do not siphon off critical resources.

Ultimately, to obtain maximum force structure from limited ship construction dollars, OSD and the Navy must make *informed* shipbuilding decisions. However, understanding how best to use the nation's shipyards to support national defense is not a simple task. A wide range of acquisition, industrial base, and economic questions must be considered. For instance, because defense procurement and repair work dominate the domestic shipbuilding industry, the U.S. Navy's shipbuilding decisions have a direct and profound impact on the industrial base. Shipbuilding also tends to be highly labor-intensive, requiring the coordination of multiple skills and trades. Likewise, labor rules, hiring limitations, unions, and training needs all complicate the establishment of a sufficient workforce. Further, resource constraints may often limit flexibility. For instance, the amount of work that can be done at any given time is constrained both by the number of available building docks and the fact that shipyards must maintain threshold work levels in order to be viable.

Given such complexities, informed policy decisions require analysis that is attuned to the multifaceted nature of these shipyard and industrial base issues. Inevitably, such analysis begins with the use of analytical models, and a number of models have been developed to help defense analysts with these matters.² The issue is whether

²Two examples of the development and use of analytic tools to answer complex force structure questions for specific programs are described in John Birkler et al., *The U.S. Submarine Production Base: An Analysis of Cost, Schedule, and Risk for Selected Force Structures*, RAND Corporation, MR-456-OSD, 1994, and John Birkler et al., *The U.S.*

existing models are sufficient to answer the host of questions that arise when policymakers approach force structure evaluations.

In 1998, the Navy and OSD asked RAND to examine the analytic models that support shipbuilding decisions. Specifically, they asked the researchers to identify the ongoing shipbuilding issues that emerge during defense reviews of force capability, describe the models available to address those issues, recommend improvements to those models, and point out when new models might be needed to replace or augment them.

PAST STUDIES: METHODS AND THEIR LIMITATIONS

Since the end of the Cold War, numerous defense reviews have examined ways for our military services to align themselves with the new political and military environment. These studies include the Bottom-Up Review (1993), the Commission on Roles and Missions (1995), the National Defense Panel (1997), and the Quadrennial Defense Review (1997, 2001)—all of which have focused on the future roles and composition of our military forces.³ In relation to the Navy, these studies considered the composition of future naval forces, the resources necessary to achieve the force structure objectives, and the makeup and use of a shipbuilding industrial base that could efficiently and effectively provide the necessary future force structure.

Through interviews with relevant personnel at OSD and Navy organizations and with individuals who either build or maintain models that examine shipbuilding issues, we identified the major ship force structure, budget, and industrial base issues that arose during these defense reviews and the models that Navy and OSD analysts have used to help address those issues. Specifically, we identified five persistent concerns:

Aircraft Carrier Industrial Base: Force Structure, Cost, Schedule, and Technology Issues for CVN 77, RAND Corporation, MR-948-NAVY/OSD, 1998.

³Les Aspin, Secretary of Defense, *Report of the Bottom-Up Review*, October 1993; *Direction for Defense*, Report of the Commission on Roles and Missions of the Armed Forces, May 1995; William S. Cohen, Secretary of Defense, *Report of the Quadrennial Defense Review*, May 1997; *Transforming Defense: National Security in the 21st Century*, Report of the National Defense Panel, December 1997.

- funding required versus funding available
- schedule, especially in relation to cost
- capacity (e.g., available capacity within the industrial base to produce a given ship type)
- shipyard performance (e.g., on-time completion rates, productivity measures)
- program management strategies (e.g., the effect of competition, the impact of dual sourcing or teaming on projects).

These concerns are deeply interrelated. For instance, cost is often a concern because of its effect on schedule, which is in turn affected by capacity, such as the availability of a shipyard to construct the needed type of ship.

After identifying these core concerns, we began a study of the analytical tools available to help decisionmakers weigh these issues as they develop policies for naval ship procurement and operations. We found, however, that the existing tools were limited. For instance, most of the tools focused on a single shipyard rather than allowing a consideration of multiple shipyards across the industrial base. Moreover, these models were typically focused on short-term issues, such as the cost to build the next submarine or surface combatant, and thus were too narrow to examine broader policy issues related to the overall Navy acquisition strategy.

Ultimately, we found that, since no inclusive, policy-oriented modeling capabilities to address the range of ship construction options were available, the Navy and OSD perpetually faced the choice of either assembling new databases and constructing new analytical methods or modifying existing models and tools. Rather than having a solid analytical base from which to start, they were forced to rebuild a base for each major defense review. Often, the results of several models had to be manually integrated to provide the necessary level of detail. In turn, since individual models were often developed by different organizations, the underlying assumptions, data, and analytic methods of the various models were not necessarily consistent, causing uncertainty about the validity of the integrated results.

All these factors made a periodic defense review an excessively time-consuming process with limited payoff. By the time researchers had developed the necessary databases and analytical tools, there was little time to identify and analyze policy options. As a result, the studies failed to examine the impact of various options or fully answer important questions and so their findings were typically less than satisfying.

A NEW MODEL: LEARNING FROM PAST LIMITATIONS

Since the cost of building, maintaining, and operating even a single ship is significant, naval force structure and shipbuilding issues will always be an important part of overall defense reviews. The same interrelated concerns over cost, scheduling, capacity, and shipyard performance will consistently reemerge, and various alternatives will require examination. In 1999, given these continuing needs and the limits of existing analytical models, the Assessments Division (N81) of the Deputy Chief of Naval Operations (Resources, Warfare Requirements, and Assessment) approached RAND for help in improving analytical capabilities in terms of the effects of various budgetary and acquisition strategies on force structure decisions. Based on the limits identified in past models, we proceeded to outline a new architecture based on the following principles:

- The new model should consider the *entire industrial base*, rather than focusing on a single shipyard.
- The model should integrate a range of influences—expenditures, schedule, workload, shipyard capacity, etc.—to formulate a *total resource requirement* for analysts, rather than forcing analysts to manually link together the results of calculations generated by multiple tools that each account for one part of the picture.
- The model should provide an *integrated capability* to identify and evaluate *in a systematic way* various naval force structure, funding requirements, and industrial base options, while also incorporating the *relationships between factors* that influence operating and ship construction costs.
- The model should help organizations build and overhaul ships at a *lower cost*.

- Finally, in contrast to past models, the model should be *well documented*, listing assumptions, definitions, and sources for all data.

A model with these components would be an invaluable tool to assist decisionmakers in understanding the cost implications of a wide range of options at the same time as it maintained data integrity and user flexibility.

The *Shipbuilding and Force Structure Analysis Tool* architecture described in this report embodies these principles by integrating several aspects of the shipbuilding funding and industrial base analysis. We completed an initial version of the tool in April 2001 and then went on to improve the tool and update some of its associated data. The result is the version outlined in this document.

SHIPBUILDING AND FORCE STRUCTURE ANALYSIS TOOL

The purpose of the ensuing chapters is to describe the structure and use of the Shipbuilding and Force Structure Analysis Tool. The tool's primary user is meant to be an analyst seeking to determine the industrial base and resource implications of a desired force structure choice.⁴ It produces estimates suitable for the planning and programming phases of the DoD Planning, Programming, and Budgeting System (PPBS) cycles. Before using these estimates for the annual Budget Estimate Submission and the President's budget cycles, the Navy Comptroller's office (NAVCOMP) would have to review them to ensure their accuracy and integrate them with other parts of the Navy.

We intend this document to provide the user with the tool's basic navigational capacities, guiding the analyst through the user interface, providing background concepts and a description of methodology, offering data field definitions, and pointing out limitations and potential improvements to the tool.

⁴This report is not intended as a tutorial on cost analysis, force structure analysis, or budgeting practices, nor is it a tutorial on Microsoft Access (the underlying engine of the tool).

Chapter Two serves as a basic introduction to the tool, describing its general architecture and outlining some basic concepts that may be necessary to understand before using the tool. Chapter Three offers more detailed discussion of the tool's most developed model, the Industrial Base Model. Chapter Four describes the tool's limitations and common issues an analyst is likely to face. The appendices serve as a user's guide and data dictionary for analysts interested in using the tool.

AN OVERVIEW OF THE ANALYSIS TOOL

The Shipbuilding and Force Structure Analysis Tool is designed to offer analysts a way to determine the industrial base and resource implications of a specific future force structure. Simply put, the tool is a computer program, with an associated database, that uses Microsoft Access as its primary engine.

To begin, the analyst must, at minimum, specify a time period and a desired force structure to be achieved over that period. The tool's database contains values—updated through internal and external Navy sources—for the various factors associated with the current force structure and with the shipyards that make up the industrial base. The analyst may use those values or enter new ones more appropriate for the specific analysis. The tool calculates the required shipyard labor, funding, and ship construction schedule needed to meet the force structure specified. Finally, it produces the annual Shipbuilding and Conversion, Navy (SCN); Operations and Maintenance, Navy (OMN); and Military Personnel, Navy (MPN) funding required over the period specified.

This chapter describes the overall structure and concepts that underlie the tool. First, we offer a larger view of the primary models at work, followed by a discussion of the tool's data sets and key components. (The appendices supply a screen-by-screen guide to using the tool and editing the information in the database.)

FUNDAMENTALS OF THE TOOL'S ARCHITECTURE

As discussed in Chapter One, the high-level architecture that forms the basis of the Shipbuilding and Force Structure Analysis Tool (see

Figure 2.1) was developed as part of our earlier analysis of the issues surrounding naval ship force structure, funding requirements, and industrial base issues. This architecture derives from the way naval decisionmakers plan for the future, weighing trade-offs between operational needs, force structure, and funding requirements and availability.

With all force structure decisions, analysts inevitably find themselves in one of two positions: one oriented toward a funding *requirement*, the other oriented toward a *force capability*. On one hand, funding goals may already be specified, and analysts are left to determine the most capable future force structure that the constrained resources can support. On the other hand, a desired future force structure may first be specified, and analysts must then seek to estimate the minimum future funding required to support that force structure. The Shipbuilding and Force Structure Analysis Tool addresses analysis related to the later question, i.e., understanding the implications of a given force structure.

When the analyst begins with a proposed force structure requirement, the current force structure serves as the baseline from which all force transition alternatives derive. Starting with this current force

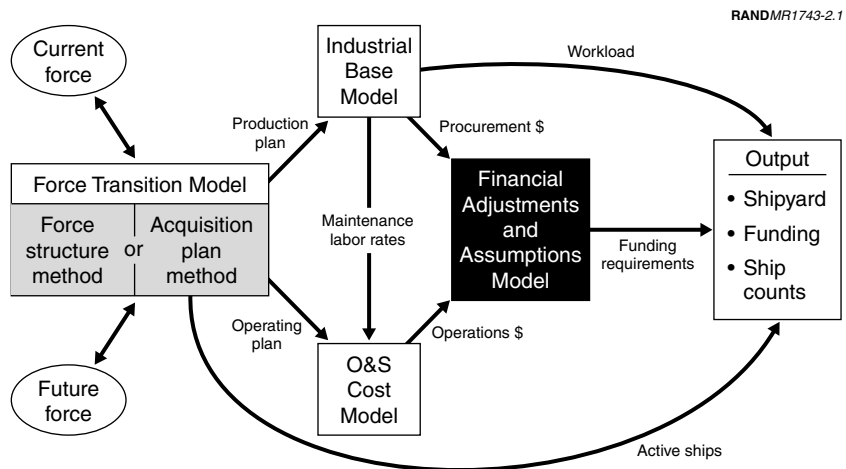


Figure 2.1—High-Level Architecture

structure and with the desired future force structure for each of the years in the period under analysis, the analyst needs three plans to describe how the fleet composition evolves:

1. a *retirement plan* that determines when specific ships will be retired
2. a *production plan* that determines how many of each type of ship to build and when to introduce them into the operating force
3. an *operating plan* that specifies how many of each type of ship are in the operational force each year.

The tool concentrates on the production plan and how the industrial base can meet that plan.¹ Specifically, the tool moves through a series of steps (left to right in Figure 2.1), using the four linked models that form the tool's high-level architecture: the Force Transition Model, the Industrial Base Model, the Operating and Support (O&S) Cost Model, and the Financial Adjustments and Assumptions Model.

The *Force Transition Model* is designed to produce a construction plan to meet the analyst's force level requirements. Based on the analyst's inputs and stored data, the model generates a list of needed ships, including the start and end year of construction, and all the work associated with that particular hull. The model assumes that ships are built in a just-in-time fashion (i.e., there are no early ship deliveries).² Further, this model accounts for retirements from the active fleet (the retirement plan) as well as the introduction of new ships currently under construction. The results from the Force

¹Previous ad hoc models projected the current force into the future using the age of existing ships and their expected useful lives. Analysts then compared the resulting future profile for the current force to the desired future force to reach an estimate of the number of new ships to acquire. This procurement plan would thus lead to a future ship construction budget. The new tool, however, can evaluate a more robust set of force transition options, including, for instance, extending the service lives of existing ships.

²Many construction plans could meet a given force structure, depending on user inputs and assumptions. For example, ships could be delivered before they are needed. Such a plan would also meet force-level requirements. Such an approach would front-load the acquisition funding requirements. By assuming a just-in-time delivery, we have taken the conservative view that procurement will be delayed as long as possible.

Transition Model are then factored into the Industrial Base Model and the O&S Cost Model.

The *Industrial Base Model* simulates how the shipyard industrial base reacts to changes in production levels and then generates the associated cost. Based on analyst inputs, the build plan generated by the Force Transition Model, and existing construction plans, the Industrial Base Model calculates workloads at each shipyard. From these workloads, the model determines general employment levels, productivity, and burden rates. From these rates and factors, the model calculates a total labor cost.

The *O&S Cost Model* determines the operating and support costs associated with a given force structure. Based on the operating plan determined in the Force Transition Model, the O&S Cost Model calculates the number and ages for each active ship by year. With these ship demographics, the model can then determine funding requirements based on all associated general maintenance, operations, and manpower costs. This model functions as a “pass-through” for the Navy’s Operating and Support Cost Analysis Model (OSCAM) or other O&S cost models and databases that supply O&S costs on an annual basis.

The outputs of these two models feed the *Financial Adjustments and Assumptions Model*. This model has several functions. One function is to aggregate the total acquisition costs using direct costs, burden rates, and material and equipment costs. These costs are then allocated to the appropriate fiscal years. The analyst is given a choice of summarizing the funding requirements for a particular acquisition on an “as-appropriated” year basis or leaving it on an “as-expended” basis.³ These costs are then converted, as will be discussed later in this chapter, into a fixed-year dollar basis for a specified base year and discounted to net present value (NPV), if appropriate. The second function of the model is to check and characterize specific data assumptions for consistency (e.g., the NPV discount rate used, peri-

³Congress normally appropriates all the funds required to build a ship in the first year that money is required to initiate a contract for the ship. This is called the “full funding concept.” These funds are expended over a number of years as the contractor(s) incrementally buys materials, completes work, and bills the Navy.

ods of the force level requirement, specified year for the constant-dollar basis, starting year for force structure requirement).

The Shipbuilding and Force Structure Analysis Tool thus enables the analyst to weigh a complex range of factors and to evaluate the effects of each factor on the entire funding requirement. Much of the tool's value lies in its flexibility as well as its capacity to calculate the ripple effects that changing one element of the model can have on all other elements.

KEY CONCEPTS OF THE TOOL

Now that we have considered the tool's high-level architecture, let us take a closer look by considering the tool's primary components. Figure 2.2 shows each model's key inputs and outputs. We will address these data and each model in the sections that follow.

Stored Data and Data Sets

The fuel that runs the tool is data. Therefore, an important requirement for use is that the analyst be able to work easily with different assumptions and baseline data. The rationale for developing the tool in a database platform was the recognition of the importance, scope, and complexity of the data needed for such an analytical approach.

A *data set* in this tool refers to a unique collection of inputs for an analysis, or one possible force structure/budget combination. It consists of all the data required to generate a funding requirements profile. Any change the analyst makes to the data will result in a new data set. These data sets allow the analyst to examine multiple assumptions quickly and to document and preserve each alternative. For example, the analyst could create two different force structure assumptions with two data sets and then compare and contrast the results of each. Moreover, each set contains all the data and information necessary to replicate an analysis or calculation. To perform a different analysis, the analyst must therefore create a different data set. A baseline data set, drawn from a variety of documented Navy internal and external sources, is provided with the tool.

RANDMR1743-2.2

Force Transition Model		O&S Cost Model	Industrial Base Model	Financial Adjustments and Assumptions Model
Force structure or method	Acquisition plan method			
<p>Key inputs:</p> <ul style="list-style-type: none"> • Current fleet • Current ships under construction • Desired force structure or • Acquisition plan <p>Key outputs:</p> <ul style="list-style-type: none"> • Production plan • Operating plan • Number of active ships 		<p>Key inputs:</p> <ul style="list-style-type: none"> • O&S costs by class and age • Annual personnel costs • Maintenance labor rates • Operating plan <p>Key output:</p> <ul style="list-style-type: none"> • Operations \$ 	<p>Key inputs:</p> <ul style="list-style-type: none"> • Production plan • Ship class data <ul style="list-style-type: none"> – Shipyard workload by role – Equipment and material cost – Learning – Construction time – Expected useful life • Shipyard labor data <ul style="list-style-type: none"> – Direct \$/hr – Burden rates – Hiring/training termination costs – Productivity <p>Key outputs:</p> <ul style="list-style-type: none"> • Production \$ • Shipyard workload 	<p>Key inputs:</p> <ul style="list-style-type: none"> • Production \$ • Operations \$ • Discount rate • Cash flow assumption (as appropriate or as expended) • Inflation indices <p>Key output:</p> <ul style="list-style-type: none"> • Funding requirements

Figure 2.2—Model Inputs and Outputs

Further, analysts should be careful to document the sources of the data they enter into the tool. Many of the problems with past models have arisen from a lack of data-source integrity. To avoid these problems, the tool is equipped with a form for analysts to enter an item, date, and description of the information; this sourcing information is then effectively linked to the data set (see Appendix E, “Data Sources”).

Main Inputs

What, then, do these data sets consist of? Let us briefly consider the kinds of inputs available in the tool. Many of these inputs are discussed in greater detail in Chapter Three and the Appendices.

When generating reports on specific force structure options, the analyst will use an array of inputs, including the number and type of

ships that need to be built and the time by which they must be introduced into the force.

Let us first consider data at the level of a ship class.⁴ The analyst can make regular updates and changes to the available ship classes, adding new ones, updating details about existing ships in production, extending ship “lives” when necessary, revising various material and equipment costs associated with each hull, and so forth. When adding a new ship, the analyst must specify the shipyard or shipyards able to do the work and in what capacity—that is, whether the yard is designing, building, or integrating the new ship, or some combination thereof (see Chapter Three, “Contractor Roles”).

In addition, the analyst must classify the new ship class into the tool’s two hierarchical categories. The top level is the ship’s role in the fleet (e.g., aircraft carrier, surface combatant). The second level is the hull type, which is a more refined definition of its role. For instance, there are two hull types for the ship role of “submarine”: ballistic missile submarine and attack submarine. (The classification scheme for the current fleet is shown in Appendix G.) These categories are useful to the analyst primarily at the output level; many of the reports generated by the tool allow analysts to summarize information using these three categories—for instance, a chart showing the number of ships of each hull type that are active in the fleet over a specific period (see Figure E.13).

Moving from ship class to shipyard-level inputs, the tool enables the analyst to specify the order in which ships are allocated to the shipyards and to enter values for such fields as workload (the number of hours to complete a task, etc.); hiring, termination, and attrition rates; wage rates; and the burden rate (see Chapter Three for discussion of these components).

Main Outputs

After the entry of any inputs needed for the analyst’s force structure and/or resource concerns, the analyst is ready to calculate the vari-

⁴A *ship class* is a specific hull type, such as the Arleigh Burke destroyer (DDG 51) or Virginia submarine (SSN 774).

ous outputs from the models within the tool. Let us step back a moment and look at the typical sequence leading up to the output function of the tool:

- Entry or modification of data, creating a new data set.
- Selection of the time frame for the analysis.
- Entry or calculations of either the known acquisition plan or a plan based on a desired future force structure.
- The Force Transition Model of the tool generates a list of the new ship construction activity by yard and time.
- Based on the new construction activity and ongoing work at the shipyard, the tool calculates (in the Industrial Base Model) the labor necessary to build these ships at the available shipyards, followed by a calculation of the workforce productivities at each of the shipyards.
- Finally, the Financial Adjustments and Assumptions Model in the tool calculates the spending profiles for the given plan, using the analyst-specified NPV and cash-flow assumptions.

The analyst is now ready to generate outputs based on these choices and calculations. The analyst chooses an output format (chart, table, or summary report) and category. The tool offers three core output categories:

1. *Shipyard Labor* reports show labor demands at each of the yards, as well as the associated burden (overhead, profit, and general and administrative [G&A] cost) rates and productivity for this labor.
2. *Funding* reports consist of funding profiles at varying levels of detail, from the total fleet level to individual class level. These reports are broken down into Navy budget categories—specifically, shipbuilding and conversion (SCN), operation and maintenance (OMN), and military personnel (MPN).
3. *Ship Count* reports feature the number of active ships in the fleet per year (grouped by role, hull type, or class).

Now that we have set out the inputs and outputs of the tool, we can begin to look at how the tool works. Because the Industrial Base Model involves so many constituent parts and is the most developed tool component, we devote a full chapter to it. First, however, we briefly consider each of the models in turn.

FORCE TRANSITION MODEL: AN OVERVIEW

As noted earlier, the Force Transition Model determines the requisite types and numbers of new ships by using future force level requirements or a preexisting acquisition plan.⁵ Thus, it gives two options for creating a building plan: the Force Structure Method or the Acquisition Plan Method. Generally, an analyst coming to the tool with very general force structure requirements would use the Force Structure Method, whereas an analyst with a set plan, including specific ships, timeline, and budget, would likely use the Acquisition Plan Method, which allows the analyst to dictate the acquisition profile. The overall flow of the model is shown in Figure 2.3 and is described below.

How the Model Generates a Shipbuilding Plan

Force Structure Method. We first follow the path an analyst might take through the Force Structure Method. The process has two parts. First, the analyst needs to specify force level requirements; then the model formulates a shipbuilding plan to meet those requirements.⁶

For instance, consider an analyst who comes to the tool knowing that six additional Virginia Class submarines (SSN 774s) are needed by the year 2010. The analyst proceeds to the data edit and entry portion of the tool and chooses **Force Structure** to enter the new six-submarine requirement. A submenu appears that allows the analyst to change any of the data regarding the current fleet, force

⁵The tool only allows the user to specify a requirement by class, not role or hull type.

⁶The model treats the requirements as the number of ships in the active inventory, not the number available for operational duty; i.e., it does not factor in unavailability due to overhaul, etc.

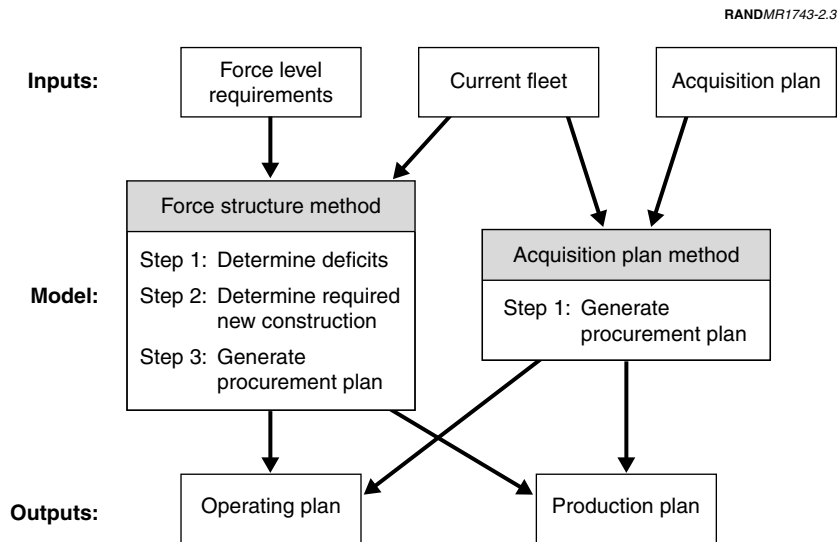


Figure 2.3—Flow Diagram for Force Transition Model

level requirements, and ships currently in production. The analyst chooses the option **Edit Force Level Requirements**, opening up a datasheet that contains the force level requirements for each class by year. These data are a key input to the Force Transition Model when using the Force Structure Method.⁷ Here, the analyst chooses the SSN 774 class from the “Class Name” and specifies the number of ships needed and the year by which they must be completed. The tool defines a force level requirement as the *minimum* number of a particular ship class that is needed by the fleet in a specific year.⁸

After entering these data, the analyst is ready to generate a production plan to achieve the Virginia Class requirement. In broad terms, if there are no ships of this class in the current fleet, the model will start the construction of six new submarines so that they are delivered to

⁷There are other important inputs, particularly the number and commissioning years of the existing ships of that class.

⁸The tool only allows the user to specify a requirement by class, not role or hull type.

the fleet by 2010.⁹ If SSN 774s are currently in the active fleet, the model will factor these existing hulls into the plan.

How does the tool make these determinations? Let us examine how the Force Transition Model actually generates a production plan based on these force level requirements. At the most basic level, the tool determines the plan using the demographics of the current fleet, force level requirements, and construction already in progress.

This method works in three sequential steps. The first step of the method determines the shortfall of active vessels relative to the force level requirements. The term used in the tool's code and queries is *deficit*. For example, a deficit of *two* means that the fleet has two fewer active vessels of the class than the force level requirements dictate. For each year, the model calculates a deficit and places the results in an array. Table 2.1 shows an example of the array values for one class.

For the third through seventh year, there is a deficit of two vessels. For the eighth through eleventh year, there is a deficit of three vessels. Note that this means not that you need to build three vessels, but only that the fleet needs three vessels.

The second step determines when a new ship needs to enter the fleet. The algorithm employed is a modification of an integer programming technique used for scheduling, which is found in basic

Table 2.1
Sample Deficit Array

Year	1	2	3	4	5	6	7	8	9	10	11
Deficit	0	0	2	2	2	2	2	3	3	3	3

⁹The current version of the tool does not incorporate any facility limitations; thus, if one of the shipyards has a capacity limit of three construction starts per year for this class, the user will have to manually “ramp up” the requirement over time. To account for the three-ship limit in this example, the requirement would be three new ships for 2009 and six (three from 2009 and three new) for 2010. If the capacity limit were two new starts per year, the force level requirements would be two ships in 2008, four ships in 2009, and six ships for 2010—reaching the final force objective of six by 2010.

operations research texts.¹⁰ This technique determines a build pattern such that ships arrive in the fleet in a just-in-time fashion. In other words, no new vessels are delivered *before* they are required.

The third step generates a new production plan based on the delivery plan determined in the previous step (see Appendix C for a description of the form to view the new production tables). This step is mostly a bookkeeping process and does not employ any elaborate techniques. First, the model determines the start and end dates for construction based on the nominal build time for the ship class and the delivery date. Next, the model determines the associated projects for the new construction by selecting a shipyard from one of the yards in the "Allocation Order" list. The model proceeds sequentially through the list to determine a builder. For the first new hull, the first shipyard on the Allocation Order list is the first, or "prime," builder (see the Shipbuilder Production Labor section in Chapter Three for details about builder categories). The second shipyard builds the second hull, and so on. For teamed production, all the allowed shipyards participate in construction, but the responsibility for final assembly and integration alternates by the order on the Allocation Order list. Finally, the model adds a work package, or "project," that represents the design and nonrecurring work for the first-of-a-class ship.

Acquisition Plan Method. The Acquisition Plan Method is the second option available within the Force Transition Model. Primarily for use by analysts with a specific acquisition plan already in place, this method generates a new construction plan based on the acquisition profile that the analyst defines. The analyst using the Acquisition Plan Method comes to the tool with a schedule of new-ship production already in hand, as opposed to the general force level requirements an analyst using the Force Structure Method would have.

To use the Acquisition Plan method, the analyst chooses the **Edit Acquisition Plan** option, which opens a datasheet that allows the analyst to choose ship classes from a pull-down menu and then to specify the number of ships of that class acquired for a given year. The analyst can also modify the start and/or end years of the acqui-

¹⁰For example, see Rick Hesse and Gene Woolsey, *Applied Management Science: A Quick and Dirty Approach*, Science Research Associates, 1980, pp. 248–251.

sition plan. An example of an acquisition plan datasheet is shown in Figure 2.4.

For the sample acquisition plan shown, a new LPD 17 amphibious transport dock would be acquired in 2002, 2004, and 2007. Further, one CVN (X) aircraft carrier would be acquired in 2006. The production begins the year following the “buy” (contract award) year; for the CVN (X) in the example, construction would begin in 2007. The method determines the build plan by doing the bookkeeping (i.e., setting starting years, durations, contractor roles, etc.) in a single step. In essence, this method bypasses the first two steps of the Force Structure Method and directly implements the third step.

The build plan generated by either one of these two methods then serves as a major input to the O&S Cost Model, which determines its associated costs, as we will see presently.

RANDMR1743-2.4

Ship Class	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LPD 17		1		1			1							
CVN (X)						1								

Figure 2.4—Example Acquisition Plan

THE INDUSTRIAL BASE MODEL: AN OVERVIEW

Although we cover the details of the Industrial Base Model fully in the next chapter, a quick overview is useful at this point in the discussion. This model forms the core of the tool and is focused on quantifying employment levels and labor costs at the shipyards based on the production plan generated by the Force Transition Model. The Industrial Base Model determines labor demands according to the production plan and then assesses the costs of those labor demands. One of the reasons this model is so complex is that it considers the entire workload at a shipyard, not just individual ship

programs. Example outputs from this model include direct labor costs, productivity of the workforce, and burden and overhead rates.

THE O&S COST MODEL: AN OVERVIEW

In the tool, the current force data and the build plan determined by the Force Transition Model serve as inputs to the O&S Cost Model. The model uses these two plans to determine the operating plan (the dates and ages of ships operated in the fleet). From this plan, the model next ascertains the operating plan's associated costs for general maintenance, operations, and manpower costs—all based on the hull's age.

As noted earlier, this model is currently a pass-through for other models, such as the OSCAM, or for aggregate data from the Visibility and Management of Operating and Support Costs (VAMOS) database. These other models provide data on direct costs—e.g., project-related personnel, repair, maintenance, engineering, and training expenses—as well as indirect O&S costs, such as overhead and administrative expenses.

THE FINANCIAL ADJUSTMENTS AND ASSUMPTIONS MODEL: AN OVERVIEW

Funding calculations, referred to in the tool as “Updating Funding Profiles,” are the final step after the analyst has worked through the Force Transition Model and the Industrial Base Model calculations (see Chapter Three). This last stage serves three functions. First, it collects and summarizes all the funding requirements data into one table based on the analyst's choice of whether to aggregate cash flow on an “as-expended” or “as-appropriated” basis by fiscal year (see footnote 3). The tool also breaks down the funding profiles into Navy budget categories—SCN, OMN, and MPN. Second, the costs are adjusted to a fixed-year (constant-dollar) basis using the inflation indices. Third, the analyst has the option to enter a fixed discount rate for all cost calculations. The tool then discounts the spending values by the NPV rate specified. Finally, as we discuss in the next subsection, these calculations are the basis of the tool's funding requirements *output*, enabling the analyst to view the funding associated with the force structure choice specified.

Constant-Dollar Basis and Net Present Value

To understand fully how the tool adjusts the funding values, the analyst should be comfortable with two key financial terms: constant-dollar basis and net present value. We discuss these concepts briefly in this subsection. Analysts unfamiliar with them, however, are strongly encouraged to consult a financial textbook or reference for more detail.¹¹

First, let us consider *constant-dollar basis*. Cost analysts generally use a constant- (“fixed-”) year dollar (often called a “base-year dollar”) to compare funding profiles over different periods and to remove the effect of inflation. Why is it important to eliminate inflation? First, analysts often use historical data as a basis for future costs. The purchasing power of a dollar ten years ago was much more than it is today. Thus, if you used historical costs as a proxy for future costs without any adjustment, you would be underestimating those future costs. Second, predicting inflation is often difficult or contentious, so to eliminate inflation predictions from analyses, funding values are frequently quoted in constant/base year dollars.

Within the tool, adjusting costs to a constant-dollar basis is done automatically provided that a base year is supplied for any cost factor entered and the inflation indices that remove the effects of inflation are up-to-date. The model selects an appropriate index based on the type of cost (SCN, OMN, MPN) in order to normalize costs from a then-year basis to a designated fixed-year basis.¹² To adjust to a fixed basis, the model divides the actual, historical costs by the index for that year. For example, the 2001 procurement deflator for outlays in 1997 was 96.1 (with 100.0 as the base for 2001). The 2001 constant-year basis for an expenditure of \$10 million in 1997 would be \$10.4 million ($\$10 \text{ million} / 0.961$). All financial outputs from the tool are thus adjusted to a fixed-year basis according to an index in the

¹¹For example, *Cost Considerations in Systems Analysis*, Gene H. Fisher, RAND Corporation, R-490-ASD, 1970; DoD Instruction 7041.3, *Functional Economic Analysis*, Department of Defense, 1995, located on website: <http://www.c3i.osd.mil>.

¹²The OSD Comptroller’s website publishes indices, in a document called the “Green Book,” that are appropriate for DoD budgets and expenditures. Available at <http://www.dtic.mil/comptroller/>.

“Inflation Indices” table of the tool’s data entry section (see Appendix C, Figure C.23).

The other important concept for the analyst entering financial data is *net present value*. NPV is used to equate cash flows at different periods, a process known as *discounting*. Underlying NPV is the principle that money has a time value. Suppose you were given a choice between \$100 today or \$116 in five years and that inflation is a constant 3 percent per year. If we adjust the future payment to today’s dollars using the inflation rate, the \$116 is really worth \$100 in today’s dollars. However having \$100 today is more valuable than having \$100 five years from now. If you can earn a real return of 5 percent on the \$100 received today, that \$100 will grow to about \$127 in five years or about \$110 in today’s dollars (after adjusting for inflation)—9 percent more than receiving \$116 in five years. The lower value of the future payout is a function of its limited usage—you can neither invest it nor use it to buy something today.

Most NPV calculations utilize a fixed rate of return (discount rate) to determine an effective investment that would be required today to produce some future revenue or expenditure. Using the previous example, the NPV of \$100 (in today’s dollars) in five years, with a discount rate of 3 percent, is about \$86. For DoD cost benefit analyses, the Office of Management and Budget (OMB) prescribes the discount rate and adjustment method.¹³

These concepts become crucial for calculating funding requirements in the tool. During the data entry stage, the analyst will encounter an “O&S Cost” subform that lists a combined dollar figure representing the total OMN and other support costs for each year of the hull’s life. The form also features two key input fields: (1) the MPN costs for the hull for one year, and (2) the base year the analyst has used to determine these costs. For example, if the data are in 1999 constant dollars for the OMN and MPN costs, the analyst would enter “1999” for the base year. The results of these inputs are then fed into the funding profile calculations.

¹³See OMB Circular Number A-94.

Assumptions Check

Given the significant amount of data entered into the tool, it is quite possible that some of the data or assumptions an analyst may use could be inconsistent with one another. The tool cannot check for all problems, but it does look for some very basic ones. Specifically, the tool evaluates the following conditions and values, flagging any problems and discrepancies that may emerge:

- The method by which new production was generated (either the Force Structure or Acquisition Plan Method, as discussed earlier).
- The funding assumption (as-expended or as-appropriated), discount rate, and discount “zero” year.
- The base year for dollar values.
- The last year a force level requirement is set.
- Whether new production starts before the analysis period. This check identifies a potential problem when new production is added prior to the analysis period in order to meet acquisition goals. It may indicate a force structure goal that is not practical.
- Whether new production is starting before the current year. If this condition is true, it may indicate another force structure goal that is unrealistic. New production is added to years that have already passed.
- Whether the end of new production finishes after the analysis period. If this does occur, it may indicate that the analysis window is too small: New ships purchased outside the analysis window are not included in the cost calculations. This condition does not always imply a problem, however. It merely indicates to the analyst that some acquisition costs may not be included in the analysis window.
- Whether maximum capacity limits are exceeded at a shipyard.
- Shipyards that have missing or invalid burden data.
- Ship classes that do not have a valid funding profile.

The funding reports of the tool begin by listing these key assumptions and discrepancies (see Appendix E, Figure E.9, for a sample).

THE INDUSTRIAL BASE MODEL

In a broad sense, the Industrial Base Model of the Shipbuilding and Force Structure Analysis Tool simulates the ways in which changes in acquisition levels affect shipyard labor and then determines the costs associated with those changes. Based on existing production plans and the new plans specified by the analyst, the model first calculates workloads at each of the shipyards. Next, based on these workloads, it calculates general employment levels, productivity, and burden rates. Finally, the model determines acquisition funding requirements using these costs along with material and equipment costs. It also calculates the effect on other shipbuilding work by adjusting burden rates for increased or decreased workloads resulting from proposed ship acquisition decisions.

The model is thus designed to reflect an array of factors—labor pool, experience levels, workload distribution, labor profiles, etc.—that can affect ship production within the industrial base. This chapter describes the Industrial Base Model, beginning with the model’s important concepts and components. The database contains values for these components but also allows new values to be entered when and where appropriate. (Appendix C describes the process of changing the current values stored in the tool’s database.) We also provide specifics on the methodology behind many of the calculations.

SHIPYARD PRODUCTION LABOR

Typically, it takes a shipyard several years to produce a ship from start of production to delivery. Over that period, the necessary labor

resources will vary considerably, often starting out low, rising to a peak about two-thirds of the way through production, and then trailing off for the remaining work. The production duration and speed also depend in large part on the ship class and the work practices of the shipyard. On an even more detailed level, the need for different labor trades (welding, electrical, assembly, etc.) will peak at different periods during the build cycle. These variations are part of the reason that shipyard resource loading (the amount of resources a given shipbuilding schedule requires during specific periods) is such a complex issue.

A variety of features are included in the tool to account for this complexity. We first discuss the tool's measurement for shipyard labor, then we proceed to the labor demands required for individual ships. Finally, we take a step back and look at the larger picture of shipbuilder production labor in relation to the full workload of a shipyard and, ultimately, to the work of all the shipyards, or the shipyard industrial base as a whole.

The Labor Metric: Full-Time Equivalent

Full-time equivalent (FTE) is the metric used to capture the size of the workforce at a shipyard. An FTE is analogous to a labor headcount but with the addition of fractional values for part-time workers and workers who are not required for the entire period. For example, if the specified work requires four full-time workers and one worker working one-quarter time (or a full-time person who was needed for only one calendar quarter of the period), the FTE value would be 4.25. The model converts hourly labor data into FTE units based on the standard hours per year for the shipyard. The number of hours per quarter for an FTE is typically about 465.¹ To determine an approximate, direct headcount, however, analysts can divide the total number of site hours worked in a quarter by 465. For example, if a shipyard books 25,000 hours of work during a quarter, that work would equate to 53.8 FTE.

¹The number of standard hours per year in an FTE varies slightly by shipyard and depends on benefits and local labor practices. A standard year is basically 2,080 hours (52 weeks times 40 hours per week) minus holidays, annual and sick leave hours, etc. Thus, 465 hours per quarter yields an FTE of 1,860 hours annually.

Although all labor data are currently entered into the tool in hours (because data on labor demands for a ship are provided in hours), workforce calculations in the model are based on this FTE metric.² The value of the FTE metric is that it accounts not just for labor hours but also for some of the indirect costs associated with changing workforce levels at a shipyard. These costs (productivity, hiring and training costs, etc.) are directly related to headcount and do not strictly represent total hours. Furthermore, the FTE metric allows the analyst to compare model output more directly with actual employment levels.

SHIP CLASS LABOR

Now that our labor metric is in place, let us describe the labor demands at the level of the individual ship. For each ship class, the tool contains a set of fields and values that the analyst can edit, including force structure data, production plans, shipyard data, and, for our purposes here, labor data.

Within the ship class data fields, the analyst can specify a great deal of information about each class, including the sequence in which new ships are allocated to the shipyards (the allocation order), a variety of O&S costs, and so forth (see Appendix C for further details). For our purposes here, we focus on two areas: how workload (labor) varies over multiple hulls of a given ship class and how the workload changes over the course of building a hull.

First-of-a-Class Versus Follow-on Ships

A comparison of the labor demand for the first (or lead) ship of a new class with that for a subsequent (follow-on) hull shows that the follow-on hulls have much lower labor demands than the first ship of a class, which typically requires more labor hours over a longer period. This additional labor arises for a variety of reasons. First, most of the engineering and design work is necessary only for the first ship (e.g., nonrecurring engineering). Second, building and integration

²The hours for a ship class used in the model are the actual hours required to build the ship. They are not the “standard hours” often used in an industrial engineering context.

issues are likely to surface with construction of the first hull. Once resolved, these issues are not likely to reappear for subsequent hulls. Last, a general improvement in labor efficiency typically emerges as the workforce becomes more experienced at building a particular class of ship. This improvement is generically called *learning*.³ Therefore, each subsequent hull in a class should take fewer hours to construct than its predecessor, with the most dramatic learning occurring between the first-of-a-class and the follow-on ship.

For example, Figure 3.1 shows the notional number of workers over time for the first hull of a class and a follow-on ship. Notice that there is an initial peak around 30 months for the first hull that is not present for the follow-on ship. The area under the curve out to about 40 months represents the design and nonrecurring construction work. The larger peaks between 40 and 80 months represents the majority of the recurring labor. The peaks are roughly the same shape, but the

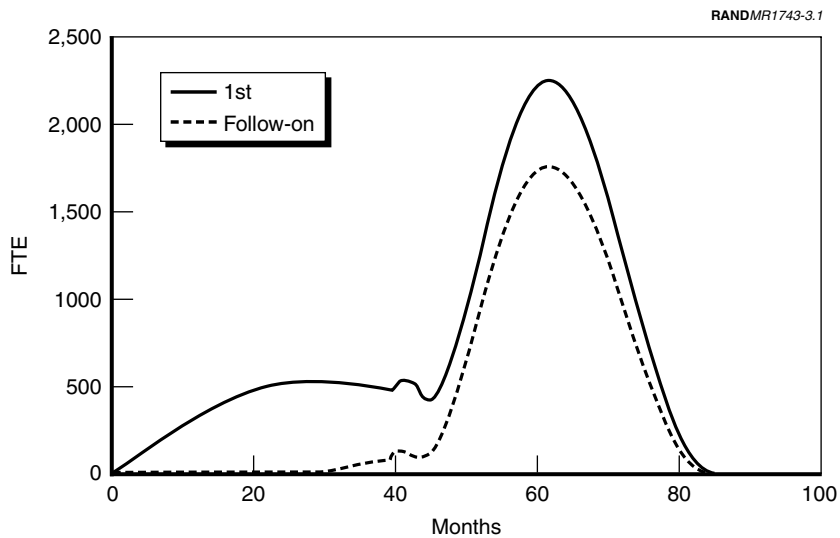


Figure 3.1—First-of-a-Class Versus Follow-on Ship Workloads

³For example, see D. Novick, *Use of the Learning Curve*, RAND Corporation, P-267, 1951, and Joseph P. Large, *An Introduction to Equipment Cost Estimating*, RAND Corporation, RM-5470-SA, 1968.

magnitudes are different. Subsequent hulls would have a similar workload plot as that of the follow-on ship. The peak might decrease for subsequent hulls through efficiency (i.e., the learning curve).

Why do these distinctions matter? In the course of using the tool—in particular, when editing ship class data or adding new ships—the analyst will need to provide data that describe how these workload curves change as a function of hull number for a given class. This distinction is made to model workloads more accurately at the shipyards. Specifically, the tool’s user will need to know the time distribution of hours in the nonrecurring work, the number of hours for recurring work for the first hull, the learning curve slope, and the design offset—the time between the beginning of the nonrecurring design for the first-of-class ship and the construction start (in the example above, it is about 30 months). (See Appendix C for more details.)

Workload, Labor Profiles, and Learning

The tool stores the workload for an individual ship in two parts: the total number of hours it takes to build the ship and its labor profile. In the tool, a *labor profile* is a list of the percentage of labor used on each task, by calendar quarter—rather than the absolute values (the number of FTEs or hours). This profile dictates the *shape* of the labor demand, but not the magnitude. The full workload profile can be derived by multiplying the total hours for the activity by the profile. We chose this split format to allow an analyst to use a similarly shaped profile for multiple projects even though the total hours might be different, thus saving time on data entry.

For example, in Figure 3.1, we saw the workload for a first-of-class and follow-on ship, with the workload plotted as the number of FTEs by month. If we converted the follow-on ship workload to the profile format as would be entered in the tool, the resulting profile is as shown graphically in Figure 3.2. The corresponding number of hours would be 7.44 million hours (a conversion from FTEs in Figure 3.1). In the tool’s “Labor” subform, the analyst chooses from a selection of labor profiles, such as “DDG 51-Prime.” (See Appendix C, “Edit Labor Profiles,” for details on the actual values associated with the profile names.)

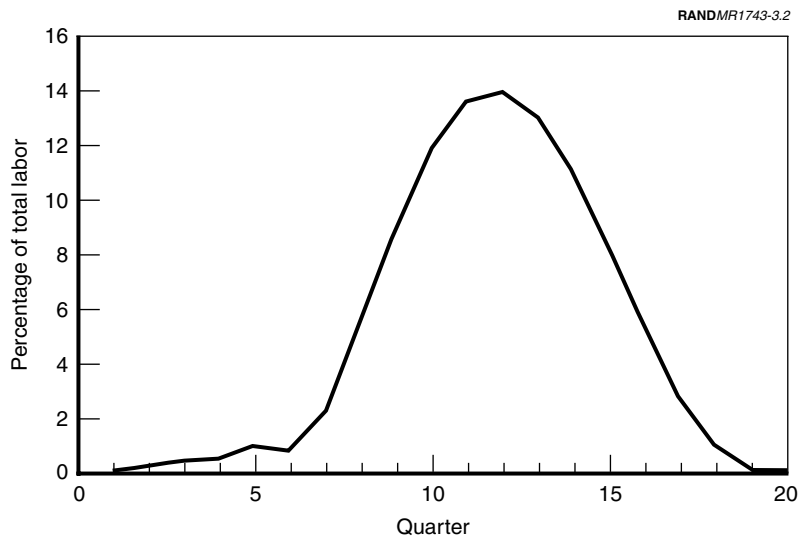


Figure 3.2—Example Labor Profile (as entered)

The final step in generating a labor profile for a specific hull is to adjust the curve based on learning. The model applies a unit learning curve to the baseline workload (as described above). The analyst is able to enter specific data relative to learning, such as the slope of the learning curve and the amount of prior production.

The “Project” Concept: When Labor Is Divided Across Shipyards

The view of ship production described above assumes that one shipyard does all the production work. However, in some cases the work may be split among multiple shipyards. A good example of such a case is the production of the new Virginia Class submarine (SSN 774). For this class, the production of each submarine has been split between Newport News Shipbuilding and Electric Boat. The two contractors have defined responsibilities for the production of modules on each hull (i.e., each contractor produces certain sections of the ship), and each alternates responsibility for the final assembly and integration of the modules.

To model the *sharing* of production on a single hull, the tool uses the concept of a “project” for ship labor. A *project* is a work package that a specific shipyard performs as part of the production of the entire hull. In the tool, a project includes the shipyard name and the contractor role (see the following section). The total production of one hull is made up of one or more projects. If one shipyard builds the entire hull, there is only one project for the ship’s production.⁴ If multiple yards produce a hull, there will be one project for each shipyard.⁵ Using the example of the Virginia Class submarine, Newport News and Electric Boat would each have a project for the production of every hull. However, the labor profile associated with each project might vary based on the role of the contractor on a particular ship.

Or consider a different situation. Suppose production of a class is shared, but shipyards alternate production of a complete ship, as was done initially for the Arleigh Burke class (DDG 51). For this example, each hull would have one project, but the shipyard responsible for that project would change.

The fact that the tool can account for this sharing, a common practice in the current industrial base, reflects its flexibility in terms of portraying actual shipyard practices.

Contractor Roles

Connected with each project is the role of the contractor. For a given class, a contractor might have a fixed role, or the role may vary from hull to hull. The tool sets out four types of roles that can be chosen (from a pull-down menu):

- *Designer*: A contractor that does the initial design work for the first of a class. Note that this role applies only for the first hull of a new class. Even though one shipyard might produce the hull,

⁴Design and nonrecurring work for the first-of-a-class ship is also considered a project. Thus, the first hull might have two projects even though one shipyard might build the entire ship.

⁵When ships are produced by multiple shipyards, it is fairly common for the work to be allocated by blocks or modules (major structural units). Thus, a shipyard will produce certain section of the ship for each hull. Examples of such an approach are the Virginia Class submarine and the United Kingdom’s Type 45 destroyer.

there will be two projects for the first hull: one project with the shipyard role as a Prime and the other project with the same yard as a Designer. For the follow-on hulls, there would be one project for each hull, with the shipyard having the Prime role.

- *Builder*: A contractor that produces only modules and is not responsible for final assembly and integration. The production of a hull is shared with other contractors.
- *Builder and Integrator*: A contractor that produces some of the modules and also performs the final assembly and integration.
- *Prime*: A single contractor that builds, assembles, and integrates the entire hull.

To make this information more concrete, consider a specific scenario. Figure 3.3 shows a sample construction plan for a series of ship classes taken directly from one of the current database's tables.

RANDMR1743-3.3

Ship Class	Hull #	Name	UIC	StartQtr	StartYr	EndQtr	EndYr
SSN 774	SSN 774	Virginia	23177	4th	1997	2nd	2004
SSN 774	SSN 775	Texas	22261	3rd	1998	2nd	2005
		Shipyard	Role	Project #			
		Electric Boat	Builder	40			
		Newport News	Builder & Integrator	41			
		*		toNumber)			
SSN 774	SSN 776	Hawaii	22252	3rd	2000	4th	2006
SSN 774	SSN 777	North Caroli	23190	1st	2001	4th	2007
AKR 310	AKR 314	Charlton	22260	3rd	1998	2nd	2000
DDG 51	DDG 100	No Name	23152	1st	2003	2nd	2006
		Shipyard	Role	Project #			
		Ingalls	Prime	47			
		*		toNumber)			
DDG 51	DDG 101	No Name	23151	1st	2003	4th	2006
		Shipyard	Role	Project #			
		Bath Iron Works	Prime	48			
		*		toNumber)			
AKR 300	AKR 303	Mendonca	22249	2nd	1997	1st	2001
CVN 68	CVN 77	No Name		1st	2001	1st	2008

Record: 1 of 39

Figure 3.3—Example Production Plan

(The data are an example only.) A new ship in the DDG 51 class is hull number DDG 100, as shown in the figure. It starts production in 2003 and is delivered in 2006. Ingalls Shipyard is the sole producer of that hull. Therefore, there is one project for the DDG 100 production with Ingalls serving in the Prime role. For the next hull produced in the class, DDG 101, Bath Iron Works is the producer. Similar to the DDG 100, there is one project for that ship production, with the contractor serving in the Prime role. For the production of SSN 775, however, there are two projects. The first project has Electric Boat Shipyard as Builder and the second has Newport News as Builder and Integrator, meaning that Newport News will build some modules and do the final assembly and integration.

These categories serve a larger purpose than just documenting the role each shipyard takes in a hull's production. They are important for determining workloads, labor profiles, build times, and full-scale industrial base schedules, because each contractor role carries with it a different demand on a shipyard.

SHIPYARD LABOR AND COSTS

Let us now move from individual ships to a discussion of the workload for an entire shipyard and related costs. First, we discuss how different types of work at the shipyards are categorized.

New Production, Existing Production, and Other Work

In the tool, all the production work performed at each of the shipyards is distinguished by one of three categories:

- *New Production* consists of future work on ship production. It is a speculative category and therefore no funding is associated with it in the tool. This category changes when new ships are added by the Force Transition Model.
- *Existing Production* means ship production currently under way (or already planned and programmed to begin). Work is added to these tables when new ships are authorized, and it remains in this category until delivery, at which time the analyst should re-

move the “work” from this category and add it to the existing fleet list.⁶

- *Other Work* is production work that is part of the overall industrial base but is not related to building a new ship or submarine for the U.S. Navy. All the ship availability and repair work done at private shipyards would fall into this category. For example, a Refueling Complex Overhaul (RCOH) for a nuclear aircraft carrier is a major production for which the resource demands are significant. Such work, however, does not produce an additional ship in the fleet. Another example of a type of work that falls under this category is work for non-U.S. Navy customers. For instance, Newport News at one time produced tankers for a private customer. This work influenced the industrial base even though the U.S. Navy did not pay for it and the production did not result in a new ship for the fleet.

These categories are necessary as a result of the way the tool calculates various quantities. For example, because Other Work does not result in new ships for the U.S. Navy, these activities are excluded from any of the ship count calculations. In turn, because Existing Production is considered fixed in time, the Force Transition Model does not change the start and end dates for such work. Ultimately, then, these categories offer different ways of distinguishing between production that influences the schedule and costs.

Now let us turn from the categories of production that make up shipyard workloads to measures of aggregate workload and efficiency. Specifically, we consider three sets of labor calculations: effective versus required labor; the effect of attrition, hiring, and termination rates; and, finally, shipyard productivity.

Effective Versus Required Labor

At the shipyard level, one of the important distinctions of the tool is the difference between effective and required labor. The Industrial Base Model assumes that shipyard workload is a summation of indi-

⁶The Naval Sea Systems Command (NAVSEA) 017 produces a quarterly report of ongoing work at <http://www.navsea.navy.mil/sea017/INDEX.html>.

vidual ship production activities. Therefore, one can determine the time-varying workload at a shipyard by knowing the timing of the individual ship constructions and their associated labor demands. The direct sum of all the work is termed *required labor*, which is the minimum labor necessary to complete all the work at a shipyard to fulfill its orders.

Shipyards, however, rarely staff to the required workload. At certain times, the shipyard may need to employ a larger labor pool than required to meet future demands or to comply with union agreements. Similarly, the shipyard may not be able to reduce the labor pool as rapidly as the requirement falls. *Effective labor* is the tool's term for the labor resulting not from the required numbers of workers at a shipyard but from the actual number of workers. Effective labor, which is always equal to or greater than the required labor value in the tool, is more representative of the actual employment at a shipyard because it reflects the inefficiencies of expanding and contracting the workforce. All acquisition costs are calculated based on the effective workload. For more detail, see "Running the Models" in the next chapter.

Attrition, Hiring, and Termination Rates

The distinction between effective and required labor is based on the fact that shipyard labor pools are not static. Each shipyard has factors that dictate how quickly the workforce (in FTE units) can change from quarter to quarter. The rates of change are expressed as percentage changes from the total labor pool.

The attrition rate is the percentage of the labor base lost because of attrition for each calendar quarter as a result of retirements and resignations. The hiring rate, a function of the local labor base, the work type, and the economic conditions, is the maximum percentage by which the labor base can increase for one quarter. Likewise, the termination rate is the maximum percentage by which the labor base can decrease. This rate is determined, in part, on company policies and labor contracts.

When the tool runs its calculations, these three rates are combined to limit how much the labor workforce can change in a given quarter. It thus has a direct impact on questions of effective and required labor

calculations. (See the section entitled “Industrial Base Model in Action” below for specific details as to how these attrition, hiring, and termination rates operate as constraints in effective labor calculations.)

Productivity

The final labor calculation in the Industrial Base Model is workforce productivity. The calculation of effective labor, described above, assumes that the shipyards make rational employment decisions based on long-term workload and labor conditions. The effective employment levels are set such that there are a sufficient number of workers and that hiring and firing are kept to a minimum. However, the above calculations do not account for the experience level of the workforce. Workers with some experience are generally more productive than inexperienced workers. Thus, for a workforce with a higher proportion of inexperienced workers, additional effort is needed to complete an identical task. This additional work might be done using temporary workers, overtime, additional full-time employees, or even lengthening the ship production schedule.

The Industrial Base Model calculates relative productivity for a steady-state workforce—that is, a workforce that is held at a constant level for a long time. Thus with normal attrition, some baseline hiring of workers is necessary. This long-term productivity level is defined at 1.0. When the workforce needs to expand, more workers are hired than the steady-state level. Therefore, the overall productivity will be lower. When the productivity of the workforce drops below 1.0, the model assumes that the work shortfall is addressed through the use of overtime and not through additional hiring. The assumption is a reflection of the belief that shipyards will try to minimize their permanent workforce levels.⁷

⁷An alternative strategy would use temporary/contract labor. Typically, this temporary labor is targeted at a specific trade or activity and not general productivity. Union agreements limit where and how temporary or contract labor can be used. For simplicity, we assumed that extra work resulting from productivity shortfalls would be addressed through overtime work.

Burden Costs

Burden costs (or indirect costs) for shipbuilding are costs associated with work at a shipyard that cannot be connected with a specific ship. While these burden costs are related to, and scale with, the total direct labor for a shipyard, the relationship is not strictly linear. Indirect costs include both fixed and variable components. The tool is designed to reflect the fact that the overhead and G&A rates decrease as the number of direct labor hours at a site increase because the relatively fixed overhead and G&A costs are spread over a greater number of hours.⁸

Each shipyard has its own practices with respect to direct and indirect costs. Generalizing, indirect costs consist of the following:

- *Overhead expenses*, the largest of the indirect costs, are those related to production activities that cannot be charged on a direct basis for a particular product for reasons of either practicality or accounting convention. They typically include the costs of fringe benefits, indirect labor, depreciation, building maintenance and insurance, computer services, supplies, travel, and so forth.⁹
- *G&A expenses* relate more to the company as an entity than to activity levels at only one plant. These include such general business costs as executive salaries, human resources costs, and the costs of staff services such as legal, accounting, public relations,

⁸To reflect the relationship between direct hours and the indirect cost rates, we use the following formulation:

$$rate_k = \frac{A_k}{Total\ Direct\ FTEs} + B_k ,$$

where $rate_k$ is the indirect rate, and A_k and B_k are constants. The constants A_k and B_k are obtained through regressing the burden rate sensitivity versus the inverse of the total direct FTEs. A_k is the slope of the regression, and B_k is the constant (see Appendix C for more detail).

⁹*Indirect-Cost Management Guide: Navigating the Sea of Overhead*, published by the Department of Defense Systems Management College Press, October 2001, Fort Belvoir, Va. Available at http://www.dau.mil/pubs/gdbks/icm_guide.pdf.

and financial functions.¹⁰ G&A costs are typically incurred and accounted for at the corporate level, whereas overhead tends to be a site-specific cost.

- *Other components* relate to such indirect costs as cost of money, overtime premium, fee, etc.

THE INDUSTRIAL BASE MODEL IN ACTION

All these industrial base factors, while individually useful for analysts, work toward the broader goal of creating a tool that allows decisionmakers a greater degree of integration and depth in the array of elements that affect procurement decisions. Further, the tight integration of these components reproduces the way that naval production operates—influenced as it is by factors both large (for instance, the capabilities of the limited number of U.S. shipyards left) and small (for instance, the peak productivity rates of welders versus electrical engineers). Thus the tool moves toward the goal of creating more-robust analytical capabilities for decisionmakers. Of course, the tool's value depends not just on the accumulation of various specification capabilities; it also depends on the way the tool actually works—the means by which it produces outcomes.

Let us now consider the flow of the Industrial Base Model as shown in Figure 3.4. Using the production plan produced in the Force Transition Model, the Industrial Base Model first calculates the required labor (step 1). (As stated earlier, required labor is the minimum labor necessary to complete all the work at a shipyard for a given quarter.) Calculation of effective labor, which is more representative of the actual employment at a shipyard, is step 2 of the model. Next, the model calculates productivity and burden rates using effective labor (steps 3 and 4). Finally, in step 5, production labor costs (direct and indirect) are determined. We describe the methodology for steps 1 through 3 below. step 4, burden rate calculations, was described fully above. Step 5, the production labor cost calculations, is a simple aggregation process.

¹⁰“Evaluating Indirect Costs,” *Contract Pricing Reference Guides: Volume 4—Advanced Issues in Contract Pricing*. Available at the Department of Defense Procurement website at http://www.acq.osd.mil/dp/cpf/pgv1_0/pgv4/pgv4c2.html.

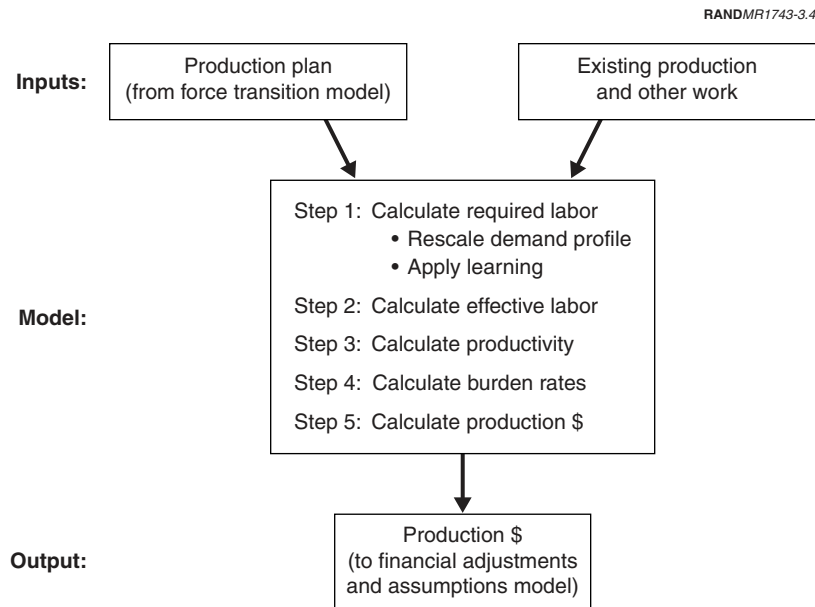


Figure 3.4—Flow Diagram for the Industrial Base Model

Required Labor Calculations

The required labor portion of the Industrial Base Model works by summing all the labor demands for a site by quarter. Normally, a query object within MS Access could directly handle such a simple calculation; no Visual Basic for Applications (VBA) programming would be necessary. However, because the tool allows the analyst to shorten or lengthen build durations from their typical values, the required labor calculations are more complicated. This rescaling of the workload profiles requires a custom program. The current rescaling method works in two steps:

- First, the labor profile is expanded or contracted from the default length to the desired duration while preserving the overall curvature of the labor distribution (the first derivative of the curve). This process is done through piecewise, linear interpolation.

- Second, the labor profile is adjusted so that the total sum remains the same.

Thus, rescaling does not change the total FTEs for a project, just their distribution. The method chosen was a compromise to preserve the relative “curvature” of the distribution while fixing the total FTEs.

The exceptions to the rescaling method are the projects in which the contractor has a Designer role. Those projects are not scaled based on the start and end dates; they are fixed. Some care must be exercised when rescaling the construction duration for the first of a class so that the Designer and Prime distributions overlap correctly.

Effective Labor Calculations

The effective labor calculations are based upon a constrained growth methodology. That is, employment levels are restricted by how rapidly they can expand or contract. The model uses a linear programming (LP) method to “solve” for the minimum employment level that satisfies the growth constraints and the demand. The LP model specification is as follows:

Objective Function:

Minimize

$$\sum_{t=1}^{t=n} E_t$$

where E_t is the effective labor for quarter t (which runs from 1 to n, the total number of quarters being analyzed).

Constraints:

$$E_t \geq R_t$$

where R_t is the required labor for quarter t.

$$E_t \leq E_{t-1} * (1 + k_{grow} - k_{attr}), \text{ for all } t > 1$$

where k_{grow} is the maximum growth rate and k_{attr} is the overall attrition rate

$$E_t \geq E_{t-1} * (1 - k_{term} - k_{attr}), \text{ for all } t > 1$$

where k_{term} is the maximum termination rate

$$E_t \geq 0.$$

Note that the effective labor for the first quarter (where $t = 1$) is unconstrained except for $E_1 \geq R_1$. We deliberately did not constrain the initial value so that the analyst would not try to solve an infeasible problem. That is, the algorithm will always find a solution to this particular specification, but the analyst should determine whether the solution is realistic, particularly with respect to the initial effective labor value and the actual shipyard employment.

Once the required and effective labor calculations are complete, the analyst can calculate the workforce productivities at each of the shipyards. Those calculations are based on the effective labor calculations and on productivity data, as described earlier in this chapter. In turn, a variety of reports can be generated from these calculations, including required labor at a given shipyard by class, required labor with a new build table, and required labor compared with effective labor.

Productivity Calculations

In the tool, productivity for each trade is determined by calculating the number of workers at discrete experience levels, using a forward propagation technique. From quarter to quarter, workers move to the next highest experience level until they reach the highest level. However, not all workers progress to the next level. Some might be let go because of declining workload at the shipyard, and some are lost because of attrition.¹¹ If the workload increases, additional workers might be added to a particular experience level through hir-

¹¹We do not address the situation for which workers do not progress because of lack of ability. That is, we directly model not competence level but seniority. We assume that there is a one-to-one correspondence.

ing. The following assumptions were made concerning the productivity calculations:

- Because we do not have experience data from the shipyards, the first quarter is assumed to be in a steady-state condition; i.e., most of the workers are at the highest level of experience with a few workers at the lower levels to replace those lost because of attrition.
- If workers must be let go, the more inexperienced workers are let go first.
- For situations in which the product of the productivity and effective labor is less than the required labor, the work shortfall is overcome through the use of overtime. There is no limit set to the amount of overtime used. However, the amount used is typically small because the required labor is close to the effective labor and the majority of the workforce has some prior experience (i.e., the workforce does not comprise mostly inexperienced workers).
- The productivity rate never exceeds 100 percent.
- The experience level of newly hired workers is based on an analyst-specified probability distribution. That is, a newly hired worker might not be inexperienced. (The probability of a new hire being at level i is prb_i .)

For a specific trade, the number of workers (x) at a level (i) at quarter (t) is given by:

$$x_{1,t} = h_{1,t}, \text{ for } t > 1$$

$$x_{i,t} = x_{i-1,t-1} * (1 - k_{attr_{i-1}}) + h_{i,t} - l_{i,t}, \text{ for } t > 1 \text{ and } 1 < i < n,$$

$$x_{n,t} = x_{n-1,t-1} * (1 - k_{attr_{n-1}}) + x_{n,t-1} * (1 - k_{attr_n}) + h_{n,t} - l_{n,t}$$

where

$h_{i,t}$ is the number of workers hired for the i^{th} level at quarter t ;
 $l_{i,t}$ is the number of workers laid-off for the i^{th} level at quarter t ;
 n is the total number of levels.

Note that we must have that

$$\sum_{i=1}^n x_{i,t} = E_t .$$

Either $h_{i,t}$ or $l_{i,t}$ may be zero for a given quarter depending on the number of workers remaining. These specific relationships are:

$$\text{If } E_t \geq \sum_{j=1}^n x_{j,t-1} * (1 - k_{attr_j})$$

(the case where workers need to be hired), the expected level of new hires is

$$h_{i,t} = prb_i * \left\{ E_t - \sum_{j=1}^n x_{j,t-1} * (1 - k_{attr_j}) \right\} \text{ and } l_{i,t} = 0 \text{ for } t > 1,$$

where prb_i is the probability of hiring a new worker at experience level i .

Otherwise,

(the case where workers need to be let go)

$$x_{1,t} = 0 \text{ (no new entry-level workers)}$$

$$l_{i,t} = \text{Min} \left\{ \sum_{j=1}^n x_{j,t-1} * (1 - k_{attr_j}) - E_t - \sum_{j=2}^{i-1} l_{j,t} \text{ or } x_{i-1,t-1} * (1 - k_{attr_{i-1}}) \right\}$$

for $1 < i < n$;

$$l_{n,t} = \text{Min} \left\{ \sum_{j=1}^n x_{j,t-1} * (1 - k_{attr_j}) - E_t - \sum_{j=2}^{n-1} l_{j,t} \text{ or } \left[x_{n-1,t-1} * (1 - k_{attr_{n-1}}) + x_{n,t-1} * (1 - k_{attr_n}) \right] \right\}$$

$$h_{i,t} = 0$$

The net productivity of the workforce for a quarter, then, is calculated by weighting the relative productivity for each level by the

number of workers employed at that level. The net productivity is normalized such that the steady state (the first quarter) has a productivity of 100 percent:

$$prod_t = \frac{\sum_{i=1}^n pd_i \cdot x_{i,t}}{\sum_{i=1}^n pd_i \cdot x_{i,1}}$$

where pd_i is the relative productivity of the workers at level i .

These productivity calculations then lead to the final set of calculations: generating the funding requirements by year and budgetary account. After generating funding requirements, the analyst is ready to view the outcomes for the force structure set forth.

Having set out the basic architecture of the Shipbuilding and Force Structure Analysis Tool and explored how it works, we turn in this chapter to the details of how it should be used, its limitations, and issues that may confront the analyst in the course of use.

SUMMARY

Recall that the tool is a collection of four interlinked models that allow an analyst to understand the industrial base, funding, and fleet size consequences of various force structure or acquisition assumptions. The following summarizes the analysis process:

- Create a new data set to store a record of the assumptions and inputs used.
- Enter new data and modify existing data to meet the given scenario.
- Choose a time period, and then calculate the build table using the Force Transition Model (see Chapter Two).
- Run the Industrial Base Model as follows:
 - Generate the required labor needed to carry out the build table. To do so, the tool determines the minimum labor (FTEs) necessary to build the specified ships at the shipyards. To make these calculations, the tool uses the labor, learning, or project data that has been entered for each ship class.

- From here, determine the effective labor required to build the required ships at the shipyards based on contractions and expansions of the labor pool.
- Next, calculate the workforce productivity at each of the shipyards. The calculations are based on the effective labor profiles and the productivity data for the shipyard's workforce. This step also calculates burden rates and the overall production labor costs.
- Update funding profiles. This series of calculations consists of running the O&S Cost Model, adjusting costs to a constant-year basis, allocating costs to fiscal years on an as-expended or as-appropriated basis, calculating NPV, and generating notes on important financial parameters and inconsistencies. This last step serves as the final stage in the calculations process before the analyst is ready to generate the output reports on the specified force structure plan.

When ready to view the results of the calculations in various forms, the analyst returns to the top-level menu and chooses the **Reports** option. The analyst can run reports in three categories: shipyard labor, funding, and ship counts. (See Appendix E for sample reports.)

Shipyards labor reports provide the analyst with a range of outputs focused on labor, overhead, and productivity. The analyst can specify such elements as the labor data type (required, effective, required versus effective, burden rates, or productivity) and the labor units (FTEs or hours), as well as the output format (chart or table).

As discussed in Chapter Two, funding reports highlight a variety of funding profiles at different levels of detail, from the total fleet level to the individual class level. The output is available in chart, table, or report summary format.

Finally, ship count reports allow the analyst to view output of the number and hull type of active ships over time, a table of requirements by ship class, or a table of the new construction starts, for all shipyards or a particular shipyard.

RUNNING THE MODELS

After entering all relevant data, the analyst can return to the tool's top-level menu and begin to run the models. Most often, the analyst would approach the calculations in the order that the menu lists them:

- **Update Year List**
- **Calculate Build Table** (runs Force Transition Model)
- **Generate Required Labor Profiles** (step 1 of Industrial Base Model)
- **Generate Effective Labor Profiles** (step 2 of Industrial Base Model)
- **Calculate Productivity** (steps 3–5 of Industrial Base Model, which include productivity, burden rate, and production cost calculations)
- **Update Spending Profiles** (runs Financial Adjustments and Assumptions Model).

LIMITATIONS OF THE TOOL

Data Updates Required

A considerable amount of data is required to make full use of the tool. We have done our best to populate it with all available data, but analysts will need to supplement, modify, and update the data provided to make valid assessments. The tool's "Data Sources Report" contains the documentation of sources used. Because the financial data change regularly, we suggest that the following data should be collected or updated before running any of the models. We suggest that these data be updated every 3–12 months (depending on type) to ensure that the latest data are used for analyses. The most likely source of the required data is shown in parenthesis.

- Labor hours and material and equipment costs for all ship classes need to be gathered (ship Program Executive Offices [PEOs] or NAVSEA 017). Note that in the database supplied with the tool, the material and equipment costs are entered as "0."

- Accurate learning curve information for each ship class needs to be entered into the tool. The data currently entered are only a “placeholder.” (NAVSEA 017)
- Overhead, G&A costs, fees, and so forth are currently rolled into one burden rate. In the supplied dataset, there are no shipyard-specific data for the slopes of these rates as a function of workload. Thus, the burden rate is static and does not vary by workload. The specific rates should be updated with the latest data from the Defense Contract Management Agency [DCMA] representative at each shipyard. (shipyard DCMA or Supervisor of Shipbuilding [SUPSHIP] office)
- O&S cost data exist for only a few classes. The data are based on a mix from two existing systems that track O&S costs: the VAMOSC tool and the OSCAM. Specifically, the O&S data in the Shipbuilding and Force Structure Analysis Tool are from the VAMOSC class averages from 1997 and from a series of OSCAM runs. These values may contain maintenance, overhead, and repair costs. Some of the data, however, might already be included in the Other Work items (specifically, carrier availabilities at Newport News Shipbuilding). In practice, the analyst should avoid double-counting these costs (once in Other Work and once in the O&S data) by removing them from the O&S data if they also appear as workload at a shipyard.¹ (www.navyvamosc.com, <http://www.oscamtools.com/>, and ship PEOs)
- Labor data for some ships now under construction should be added. For other classes in which more than one yard can build a ship, the current data use the same labor profile for each yard. (NAVSEA 017 and PEOs)
- The hiring, termination, and attrition rate data for shipyard labor are used to test the model and do not reflect actual values. (shipyards)
- The productivity data, as discussed in Chapter Three, are based on assumptions rather than fact. In particular: (1) It takes three

¹Note that the RCOH costs for nuclear carriers have already been removed from the OSCAM output because the RCOH costs are included as part of the Other Work category in the tool. The work is done at a private shipyard.

years to become fully proficient at a trade; (2) worker productivity improves linearly with experience to a fully qualified status, beyond which no further productivity is modeled; (3) a worker with no experience has a productivity of two-thirds that of a fully proficient worker; and (4) the chances of hiring a worker at any experience level are identical. (shipyards)

Before using the tool, an analyst will need either to resolve these data deficiencies or to take into account that some of the results will be incomplete or are only representative of actual situations.

In addition to these data issues, analysts should be aware of two sets of limitations for the tool, which we discuss below.

Force Transition Model Limitations

The Force Transition Model has several important limitations. First, the force level requirement must be specified by ship class (e.g., DDG 51) and not by hull type or role (e.g., Guided Missile Destroyer, Surface Combatant). Second, as described earlier, the model does not account for any shipyard facility constraints; that is, it allows each shipyard to produce (or start) a number of ships that, in reality, would be impractical. For example, you could create a data set in which Newport News builds five new aircraft carriers at once. In reality, however, dock and pier facilities preclude Newport News from building more than two new aircraft carriers at any given time. Therefore, you must be careful about how force level requirements or acquisition plans are set. The best way to avoid this problem is to increase force level requirements or acquisition amount by a reasonable number from year to year. For the above carrier example, one additional carrier added to the fleet every three to four years would be a reasonable increase. A good source to discuss these limitations with would be the shipyards and the local SUPSHIP offices.

Industrial Base Model Limitations

The Industrial Base Model is limited in that it assumes that workload can be scaled linearly for a project when its duration is changed. That is, if the duration of a project changes, the total aggregate FTE workload does not change. In practice, the aggregate workload might de-

pend on project duration. In addition, long-lead-time items may limit the degree to which a schedule can be shortened. Thus, the analyst should be careful not to shorten or extend schedules by more than a year or two.

DEALING WITH REAL-WORLD PROBLEMS

An analyst is likely to encounter a number of common issues when employing the tool. This section discusses those issues and how to address them with the tool.

Implications of Changing Ship Life

A familiar analysis problem is how modifying the active life of a ship class changes force structure and O&S costs. For instance, what are the resource and force-level implications if we extend the life of a class by a few years?

The analyst needs to address two issues to answer this question. The first is to understand how the count of active ships changes over time. To change the active life of a ship class, the analyst needs to change the "Ship Life" field on the "Edit Ship Class Data" form (see Figures 4.1 and C.2). This field determines the retirement year for all active ships that do not have an explicit "Out Year" value entered (on the "Edit Active Fleet Information" form, see Appendix C). The same field also determines the retirement year for all new ships. Based on the force level requirements, the number of new ships for that class built may change, resulting in a different acquisition funding profile. Further, the number of active ships may change as well.

The more difficult part of the problem is determining the effect of the life extension on O&S costs. For some ship classes, data may be available to enable the analyst simply to add new records to the O&S costs for the additional years (as shown on Figure 4.1). For other ships, particularly nuclear ones, the issue becomes whether a refueling or major overhaul is necessary to extend the life. If so, the analyst will need to add the appropriate availabilities to the Edit Other Work List (see Figure C.9) (one major overhaul and/or refueling for each hull whose life is extended) if the work would be performed by one of

RANDMR1743-4.1

Ship Class Data

Class Name		Type of Ship (Hull Type)	
DDG 51		Guided Missile Destroyer	

Ship Life	Build Time	Teamed	Exclude	New Class?	Design Offset:
35	22	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0

Allocation Order | Learning Data | Material & Equipment Costs | O&S Costs | Labor | Funding Profile

Operation & Maintenance Cost Data (OMN only)	
Period	O&M Cost
1	\$10,563,000
2	\$13,195,000
3	\$10,563,000
4	\$16,772,000
5	\$10,563,000
6	\$13,195,000
7	\$9,797,000
8	\$9,797,000
9	\$13,195,000

O&S Costs Base Year:

Annual Personnel Cost:

Record: ◀◀ ▶▶ 27 ▶▶▶ of 55

Figure 4.1—Edit Ship Class Data

the private shipyards (see Appendix C). Otherwise, the cost should be added to the O&S category.

Early retirement is a simpler issue. The analyst can take two approaches. One is to shorten the life of all the ships of that class. Again, modifying the Ship Life field easily modifies the active life. An alternative approach would be to selectively retire hulls early using the Out Year field for the active ships. For early retirement, it is not necessary to modify the O&S costs, since the model will do it automatically.²

²We have not addressed the decommissioning or scrapping costs for the ships. These costs are beyond the scope of the tool. The analyst should be aware that there may be other budget implications to the retirement of ships that the tool also does not address (e.g., defueling).

Detecting Industrial Base Problems

Recognizing industrial base problems in an analysis is often a qualitative process. A useful place to start after entering the data set is to examine the Required Labor chart (see Figure E.2), which shows the labor demands over time. The analyst should be looking for rapid changes in employment levels (FTEs). Deep gaps, valleys, or spikes may indicate temporary problems with workload. Furthermore, rapid changes in employment levels could indicate a potential problem. A steep labor profile is disruptive to the shipyards. It means they either are laying off a good number of workers or are hiring and training many new ones. Both of these situations are costly and inefficient. There are no hard and fast rules as to what is a “significant” change, but shipyard workforce turnover is about 3–4 percent annually, so a greater turnover could be considered significant. Some judgment is required.

Another chart that might illustrate a problem is the Burden Rate chart (see Figure E.2). Big swings in the burden rate also indicate a highly variable workforce. Often, a shipyard will have a range of reasonable burden rates it can maintain. Moving outside that range could mean that the shipyard will need to modify its infrastructure in order to sustain a given workload. However, the burden rate in the tool only changes if the appropriate data are supplied.

Extending or Moving Construction Time for a Ship

The analyst may also confront the need to move or extend construction time. Program issues, budgeting concerns, or industrial base considerations might cause the schedule change. To modify a particular hull, the analyst needs to edit the Start and End fields (Quarters and/or Years) of either the “In Production” or “New Production” forms (see Figures C.5 and C.8 in Appendix C). The Industrial Base Model automatically rescales the workload profile.

There are some practical limits to how well the rescaling works. Changing the build time by more than two to three years from its nominal value could result in unrealistic profiles. Recall that the rescaling algorithm fixes the total workload demand for a class. If the construction were extended dramatically, this assumption might no longer be correct; fixed resource and management demands would

not diminish proportionally to the duration. Thus, the total number of hours might be greater for a very extended schedule.

Furthermore, the projects in which the contractor has the Designer role are not rescaled by this method. The workload profiles remain static. As discussed earlier, if the construction period is shortened or lengthened, the analyst should make certain the Design Offset value and workload profile for the nonrecurring work is consistent (see the top level of the form shown in Figure C.10, described in Item 8).

Changing Force Structure

Some care must be exercised when changing force levels. If the number of ships in the fleet is increased, the analyst will need to ramp up the force level requirements gradually so that the new construction does not overwhelm the industrial base. For example, suppose there is a requirement for 12 ADC (X) ships by 2009 and ships of that class exist. If the analyst entered a single requirement, 12 ships in 2009, the *Force Transition Model* would build 12 new ships, all starting in 2005 and finishing in 2008. Remember that the model builds new ships only when needed. To avoid this problem, the analyst should set an increasing series of requirements until the final level is reached. Table 4.1 shows how the analyst might set the requirements for the example of 12 ADC (X).

In no case are more than three new ships started in one year, yet by 2009 the force structure goal of 12 active ships will be met.

Table 4.1
Example Force Level Requirement

Year	ADC (X)
2004	1
2005	4
2006	6
2007	9
2008	11
2009	12

CONCLUSION

The strength of the Shipbuilding and Force Structure Analysis Tool is its integrated architecture. Existing tools offer capabilities for analyzing individual facets of the industrial base, weighing force transition options, or determining various funding options. Until now, however, no modeling environment has captured all these components in one tool and assisted decisionmakers in weighing trade-offs among operational needs, force structure, and funding decisions. Further, existing tools focus on individual shipyards rather than considering the entire shipbuilding industrial base. In addition, because past models were often developed by different organizations, their associated data sources and analytic methods were not necessarily consistent, resulting in uncertainty about the dependability of the integrated results.

The Shipbuilding and Force Structure Analysis Tool, however, provides that integrated capability. In the past, analysts needed to string together the results from a range of tools, subjectively formulating an overall force structure picture. Now, analysts will be able to identify and evaluate various naval force structure, resource requirements, and industrial base options *in a systematic way* while also incorporating various *relationships between the factors* that influence operating and ship construction costs. Specifically, this tool allows the analyst to integrate an array of influences—resource requirements (funding), schedule, workload, shipyard capacity, etc.—to formulate a *total resource requirement*. Finally, in contrast to past approaches, the tool allows users to *fully document* their analysis by listing assumptions, definitions, and data sources, thus ensuring the integrity of the results.

We hope that the tool will simplify and improve the process of analyzing future naval force structure options for defense reviews, helping analysts by means of its integrated capabilities and helping policymakers by providing integrated results that will enable more-informed decisions. In the end, the tool should enable the rapid screening of multiple options and alternative strategies and allow the Navy to better understand the industrial-base and resource-allocation implications of its acquisition strategies.

In 2001, the Shipbuilding and Force Structure Analysis Tool was put into use by RAND researchers conducting an analysis for the United Kingdom's Ministry of Defence (MOD). The RAND team examined options open to the MOD to acquire and produce the Royal Navy's next-generation destroyer, the Type 45. Using the tool, the team evaluated various options for acquiring and building the Type 45 and the effects of these options on the United Kingdom's shipbuilding labor force and infrastructure.³

Specifically, the team considered whether the Type 45 should have one or two producers; whether, if two producers were used, the work should be open to competition or whether it should be allocated directly to specific shipbuilders; and whether the Type 45 should be constructed in its entirety in one shipyard or assembled from segments or blocks produced in several shipyards. The analysis involved a quantitative comparison of the advantages and disadvantages of having either one or two shipbuilding companies produce the Type 45 over the next 15 years. The team also compared building the Type 45 in its entirety in one shipyard versus assembling it from segments or blocks produced in various shipyards. The tool enabled the team to address the production labor costs, the indirect costs, and the industrial base implications of various acquisition strategies.

The RAND analysis aimed to help MOD policymakers in two ways: first, to gain an understanding of the costs and benefits of different Type 45 acquisition and production strategies, and, second, to gauge the effect of those strategies both on the shipbuilding industrial base and on the costs of other current and future MOD ship programs. The tool thus proved to be a valuable asset in terms of both expediting the analysis itself and offering policymakers a comprehensive and fully documented view of the effects and implications of a force structure change.

³See John Birkler et al., *The Royal Navy's New-Generation Type 45 Destroyer: Acquisition Options and Implications*, RAND Corporation, MR-1486-MOD, 2002.

MICROSOFT ACCESS AND TOOL INSTALLATION

MICROSOFT ACCESS

The underlying engine for the Shipbuilding and Force Structure Analysis Tool is Microsoft Access 2000. We chose Access over other possible platforms, such as Excel, for a number of reasons:

- MS Access has the functionality of a true database and is able to store, manipulate, and aggregate data efficiently. Most of the work done by the tool is this type of data manipulation.
- Access can easily accommodate data changes and additions. For example, it is relatively easy to add a new ship class to the Access tool simply by filling out a form. In the equivalent spreadsheet solution, columns or rows would need to be added to several pages and formulas copied and updated, making maintenance exceedingly difficult. Spreadsheets are good for static models; databases are good for models in which data and scope might change or evolve over time.
- Because Access uses an interface similar to that of other common MS Office products, such as Word and Excel, we hope there will be less of a learning curve for a new user.
- Access is very “extensible,” meaning that it is relatively easy to customize by adding code. This customization is done using VBA, which is an integral part of all MS Office products. Behind the tool is a fair amount of VBA code that implements the core tool calculations.

Access differs from other MS Office products, such as Word and Excel, in one very important respect. Because Access is a multiuser database program, it updates changes to the source data file immediately (or nearly so). Thus, you never need to save a database file after working with it to make changes permanent; the changes are already saved. However, the downside of this feature is that it is nearly impossible to undo any changes or revert to an older version. We cannot emphasize this point enough: *You should always keep a backup copy of the database file* (called a data set; see Chapter Two, “Stored Data and Data Sets”) or work from a copy when making changes. By always keeping an older copy, you can recreate or back-track to an earlier version.

A MS Access database has six basic objects:

- *Tables* store and organize data.
- *Queries* manipulate data from the tables and summarize them (if desired).
- *Forms* lay out fields to simplify data entry.
- *Reports* format queries into a more printable layout.
- *Macros* store user commands to automate and facilitate repetitive database actions.
- *Modules* are groups of VBA code that extend the functionality of MS Access.¹

All the objects of the database are accessible; we have hidden nothing. Therefore, it is possible to modify them should the need arise. With the possible exception of minor format changes to the reports, we strongly recommend that you do not modify any of the existing objects unless you are very familiar with Access and VBA. Even

¹These descriptions gloss over many of the important details and functionality of the objects. Interested users should consult one of the many books on the subject of MS Access. For example, for new users, *Access 2000 for Dummies*, John Kaufeld, IDG Books Worldwide, 1999; for VBA and Access, *Teach Yourself Microsoft Access 2000 Programming*, Paul Kimmel, SAMS Publishing, 1999; and for advanced programming, *Microsoft Access 2000 Power Programming*, F. Scott Barker, SAMS Publishing, 1999.

renaming an object can cause errors in various parts of the tool. In most cases, it would be best to make a copy of the object and then make changes or modifications to it.

Before using the tool, you should be alert to the fact that pasting records into a MS Access Table is a bit different than it is for pasting cells into a MS Excel spreadsheet. There is no simple way to copy a single element and paste it across multiple records. From our perspective, the easiest way to do this task is to create the data entries in MS Excel, where it is easy to copy and paste. Note that the columns in the spreadsheet must match the fields in the table or form within MS Access. After you have created a range in Excel that mimics the new data you want to add to the Access table or form, use one of the following two methods:

- To overwrite existing data: (1) copy the range from Excel; (2) highlight the fields to be replaced in the MS Access object; and (3) paste the changes into MS Access. Note that the biggest difference is that you need to highlight the entire range, not just the first cell as you would in Excel.
- To add new data to the MS Access object: (1) copy the range from Excel; (2) select the MS Access form or table; and (3) use the **Paste_Append** command from the Edit menu.

INSTALLING THE DATABASE FILES

The tool comes as two MS Access database files in a self-extracting zip file (.exe extension). The file names for the front and back ends on the zip file are

- Front End: Shipbuilding 1.1a.mdb
- Back End: realdata4c.mdb

To install the files, double click on the icon. A menu should appear asking for a directory to unzip the files. Select any directory you want. You will always open the front-end database from the directory you select.

MISSING OR INCORRECT REFERENCES IN VBA

Over time, Microsoft updates its programs and driver files. The current version of the tool is based on SR-1 for MS Access 2000 and MS Jet 4.0 SP6. It is unlikely you will have this exact configuration; thus, you will need to reconfigure the VBA References for MS Access before you are able to run the tool for the first time. MS Access does not update these driver references automatically. If problems with the VBA references exist, a warning pop-up window will indicate that there are broken references. Below are the seven steps you should follow to correct the problem:

1. On the warning message, click the **OK** button.
2. Select the VBA window that is open.
3. Select the **Tools—References...** command. A window should open that looks like Figure A.1. The figure shows a list of the six references needed. If one is missing, the word “MISSING” should appear right after the check box. Make a note of the missing references. Uncheck the items that are missing and press the **OK** button.
4. Replace the references you removed. Note that you must close the References window opened in the prior step before proceeding. Now, reopen the References window by selecting the **Tools—References...** menu item again. From the list, select the item that best matches the missing component(s) you unchecked. For example, if you have an original version of Microsoft Access 2000 without any service pack updates, you will likely need to make the following substitutions:
 - “Microsoft ADO Ext. 2.1 for DLL and Security” for “Microsoft ADO Ext. 2.5 for DLL and Security.”
 - “Microsoft Jet and Replication Objects 2.1 Library” for “Microsoft Jet and Replication Objects 2.5 Library.”

Note the only difference is the version number of the two references; in the example above, you are selecting an earlier version. Select the **OK** button.

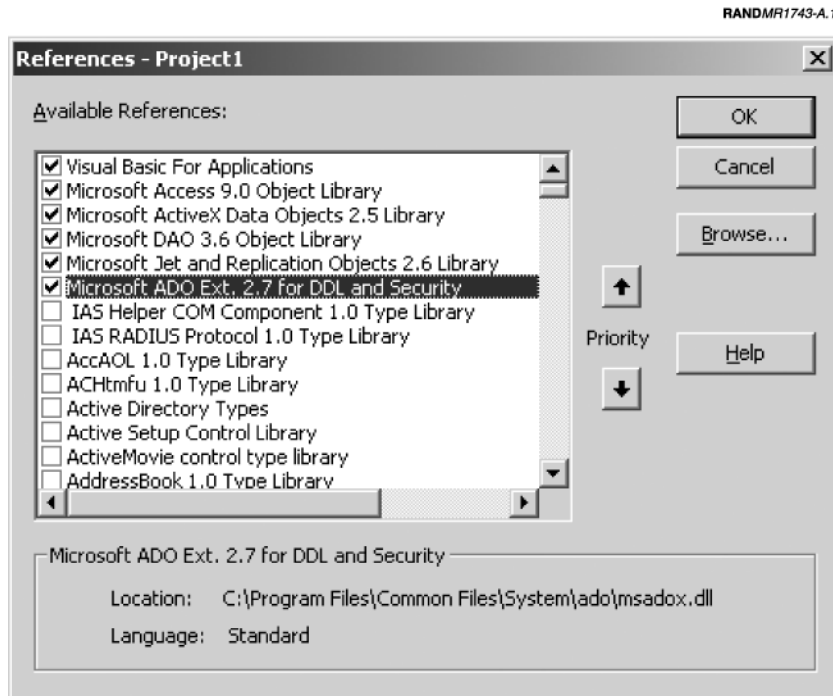


Figure A.1—Needed References for VBA

5. Save the changes by using the **File—Save Shipbuilding** command from the main menu. It is the first option in the **File** list. There will be a number following the word **Shipbuilding** that is the version number.
6. Select **File—Close and Return to Microsoft Access**.
7. On the warning screen, select the **Continue** button.

Another possible symptom of this problem is an error after clicking the **Continue** button on the warning screen. You will see a message with the text “Microsoft Visual Basic Error...Compile Error: Can't find project or library.” Below are the steps you should follow to correct the problem:

1. On the Error message, click **OK**.
2. Stop the program from running by selecting **Run—Reset** from the menu interface (the **Reset** option from the **Run** command).
3. Follow instructions above starting with #3.

INSTALLING OPTIMIZATION DLL ROUTINES

The Industrial Base Model determines effective labor loading at a shipyard using a linear programming approach. A Dynamic Link Library (DLL), produced by Frontline Systems, Inc.,² determines the LP solution.³ Each user must have a license to use this library, available from Frontline Systems, Inc. Your office may already have a user/site license, however. The software vendor provides the library file and a key string. The manufacturer provides general instruction on how to install the library. To use the library with this tool, you need to complete two steps:

- Copy the DLL file into the Windows system directory (e.g., C:\WINNT\system32 for a Windows NT computer).
- Enter the key string. (This step should not be necessary for the latest version of the tool delivered to N81 because the key field should already be entered.) The key string can be found in the file *Frontkey.bas*, which is included on the distribution disk that comes from Frontline Systems. To enter the key into the tool, open the tool and go past the warning screen. Close the tool's main menu. Open the *Key* module object with the VBA editor (double click on the object). Between the quotation marks after the equals sign, enter the license string provided by the vendor (see Figure A.2). Next, exit Access and restart the application. Access will prompt you to save the changes to the *Key* module. Respond with YES. Finally, restart the tool.

If you do not own a license for the DLL, you should leave the license key string field empty (do not put anything between the quotation

²See www.frontsys.com.

³See "Solver User's Guide" for Dynamic Link Library Version 3.5 by Frontline Systems Inc.

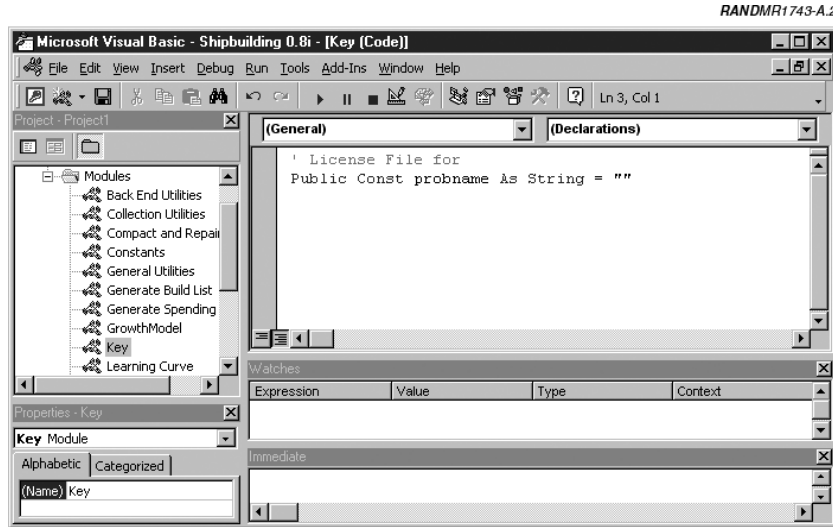


Figure A.2—Entering the Solver DLL Key String in VBA Editor

marks). When doing calculations, you will still need to “run” the model (**Calculate Effective Labor** option on the **Calculations** sub-menu) to get the spending calculations to evaluate properly. If this field is blank, the tool directly substitutes required labor for effective labor, bypassing the Industrial Base Model.

START-UP AND CREATING A DATA SET

OVERVIEW

In Appendices B–F, we will walk through each of the menus in the tool and describe how they are used. The order of the topics is roughly equivalent to the sequence used to analyze a data set.

Warning and Top-Level Menus

When the tool first starts, a warning screen, shown in Figure B.1, appears first. The intent of the window is to inform the user of the sensitive nature of much of the data and output. A good deal of the input data is proprietary and/or business-sensitive. The same restriction applies to some of the reports and charts generated. In no way should the user release any of the information outside of the government.

After the user presses the **Continue** button on the warning screen, the main menu should appear as shown below in Figure B.2. (If you get an error message at this stage, see Appendix A for instructions on how to correct the problem.) As a general convention used for all the menus, any menu item ending with an ellipsis (...) indicates that the menu command opens another menu. The order of the top-level menu items should generally be the order you need to approach an analysis:

1. Create or open a data set.
2. Edit or enter relevant data/assumptions for the data set.

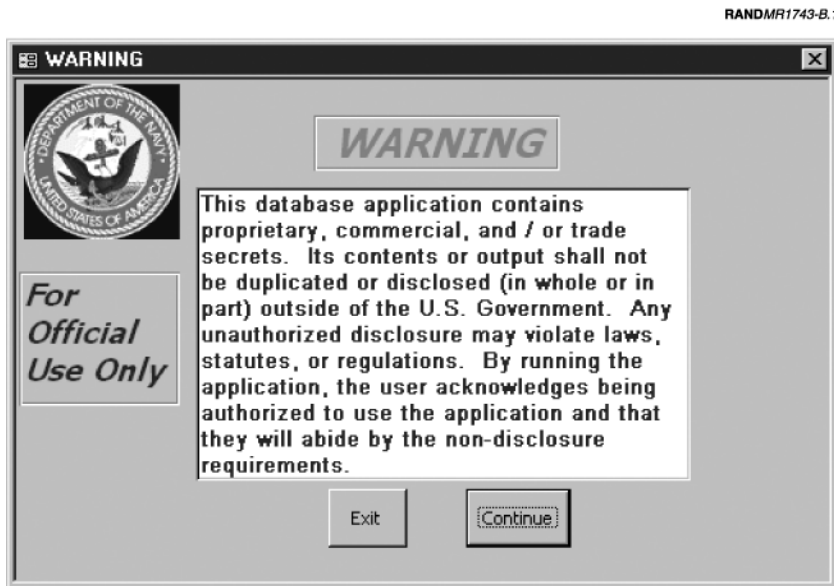


Figure B.1—Warning Screen

3. Calculate the results.
4. View and print the summarized results.
5. Exit the program.

Manage Data Sets

We have split the tool into two parts: front-end and back-end database files. This technique is designed to avoid the common problems associated with copying the entire database file each time you want to create a new data set. Copying is inefficient because it would duplicate all the menus, reports, queries, etc., that do not change from data set to data set. Splitting the database solves this problem by having the back-end file store all the data associated with the data set and nothing else; it is an MS Access database file consisting only of tables. The front-end file then stores the user interface, code, queries, and reports; these objects do not change. The tables

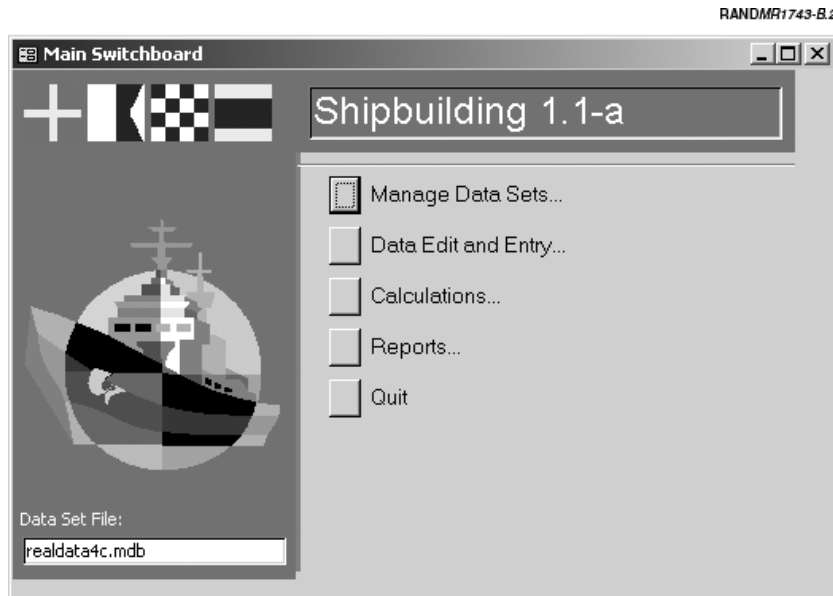


Figure B.2—Top-Level Menu

from the back end are then linked¹ to the front-end database. An interface form allows the user to manipulate and link to different data sets.

Each data set contains all the data and information necessary to replicate an analysis or calculation. To do a different analysis (or case study), you need to create a different data set. Alternatively, to modify an existing study, you will need to link to that data set. To perform either of these tasks, you will need to open the “Manage Data Sets” form. Selecting the first button on the main menu opens the form.

Figure B.3 shows an image of the “Manage Data Sets” form.

¹The term *link* arises from the concept of front-end and back-end databases. The data tables reside in a different file (back-end) but can still be manipulated in the current one (front-end). The back end holds all the data set information and is linked to the front end through file references. In the table object window, an arrow shows that tables are linked rather than residing in the front end.



Figure B.3—Manage Data Sets Form

The first item on the form is a file box that allows you to select a data set from a list of .mdb files in the current directory. If the file you want is not in the list, click the **Browse** button. This action will open a MS Windows standard **File Open** window.

Figure B.4 shows a data set selected. However, you have not linked to that data set yet. All you have done is select the file name. To complete the linking action, you must click the **Link Data Set** button. If the linking action is successful, the main menu will display the new

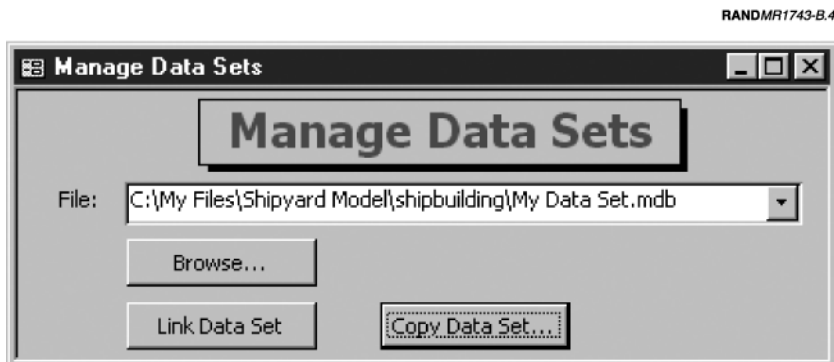


Figure B.4—A Selected Data Set

file name in the Data Set File box located on the lower left of the main menu (see Figure B.5).

If the program cannot link to the file you have selected, the tool displays an Error Message and relinks to the last, valid data set. Therefore, the combination of the **Browse** and **Link Data Set** buttons allows you to link to an existing data set.

If you want to create a new data set, you will need to use a combination of the **Copy Data Set** and **Link Data Set** buttons. The **Copy Data Set** button copies the currently linked data set to a new file. The button opens a standard MS Windows **Save** menu. After you have selected and saved the new file name, you will still need to link to that file. Otherwise, you will be modifying the old data set of which you just made a copy. The name of the copied data set file will appear in the File box. *IMPORTANT:* You must close all reports, tables, and forms (except the main menu and “Manage Data Sets” form) before copying a data set. Otherwise, an error message will open stating that the file is open and that it cannot be overwritten.



Figure B.5—Successful Link to a New Data Set

OVERVIEW

The Data Edit and Entry Menu selections allow you to display and edit data (see Figure C.1). The menu items and submenus under this item segregate the information by type (force structure, production plans, etc.). Most of the commands bring up a form to manipulate

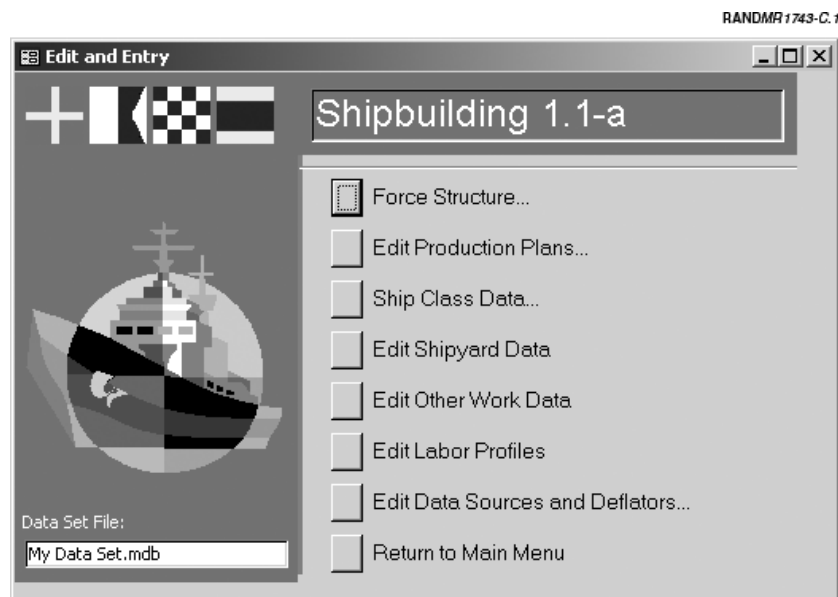


Figure C.1—Data Edit and Entry Menu

the data. Some of the form objects may have more than one activation command. In other words, it may be possible to open the form from multiple locations of the submenus. This replication was done to facilitate data manipulation of like information from the same base menu.

The data or examples shown below do not necessarily represent actual data. Proprietary information has been modified in the figures.

STATUS BAR

The status bar provides useful information for the analyst when entering data or performing a calculation. The status bar is the lowest part of the Access window. During a calculation, the status bar shows a progress meter. When entering data into a table form, the status bar shows a description of the selected field. In Figure C.2, the status bar shows an expanded description of the “CFE Cost” field as “Contractor Furnished Equipment Cost.”

FORCE STRUCTURE

The **Force Structure** submenu allows you to change any of the data regarding the current fleet, force level requirements, and ships currently in production at the shipyards. All these items affect ship counts and the Force Transition Model. The menu elements are

- Edit Active Fleet Information
- Edit Force Level Requirements
- Edit Ships in Production.

Edit Active Fleet Information

The **Edit Active Fleet Information** menu option opens a datasheet form to modify the data on the active fleet. An example of the datasheet is shown in Figure C.3.

There are eight fields for each record. Each record is an active ship in the fleet. (At the end of the explanation of each field throughout this appendix, we include in parentheses the type of response required.)

RANDMR1743-C.2

Ship Class Data

Class Name: ADC (X) Type of Ship (Hull Type): Auxiliary

Ship Life: 40 Build Time: 15 Teamed: Exclude: New Class?: Design Offset: 3

Allocation Order | Learning Data | Material & Equipment Costs | O&S Costs | Labor | Funding Profile

M&E Acquisition Costs

	Shipyard	GFE Cost	CFE Cost	Material	Base Year
▶	Bath Iron Works	\$0	\$0	\$0	2003
*		\$0	\$0	\$0	2003

Record: 1 of 55

Contractor Furnished Equipment Cost NUM

Figure C.2—Example of Active Status Bar

1. *Hull Number*: The hull number for the ship as found on the Naval Vessels Registry (NVR) website. For example, the hull number for the *USS Carl Vinson* is CVN 70. (text)
2. *Ship Class*: Designates the class of ship for a particular hull. Select the value from a pull-down menu. (list selection)
3. *Name*: The name of the ship. (text)
4. *UIC*: The Unit Information Code for the hull. It is not used in any of the calculations, so it is an optional field. (integer)
5. *In Qtr*: The calendar quarter during which the ship is delivered to the Navy (the quarter it enters the fleet). This field has no effect in

RANDMR1743-C.3

Hull Number	Ship Class	Name	UIC	InQtr	In Year	OutQtr	Out Year
CG 65	CG 47	Chosin	21625		1990		
CG 66	CG 47	Hue City	21656		1991		
CG 67	CG 47	Shiloh	21657		1992		
CG 68	CG 47	Anzio	21658		1992		
CG 69	CG 47	Vicksburg	21684		1992		
CG 70	CG 47	Lake Erie	21827		1993		
CG 71	CG 47	Cape St. George	21828		1993		
CG 72	CG 47	Vella Gulf	21829		1993		
CG 73	CG 47	Port Royal	21830		1994		
CV 63	CV 63	Kitty Hawk	3363		1961		2008
CV 64	CV 63	Constellation	3364		1961		2003
CVN 65	CVN 65	Enterprise	3365		1961		2013
CVN 68	CVN 68	Nimitz	3368		1975		
CVN 69	CVN 68	Dwight D. Eisenhower	3369		1977		
CVN 70	CVN 68	Carl Vinson	20993		1982		
CVN 71	CVN 68	Theodore Roosevelt	21247		1986		
CVN 72	CVN 68	Abraham Lincoln	21297		1989		
CVN 73	CVN 68	George Washington	21412		1992		

Record: 1 of 303

Hull Number (e.g., DDG 79) NUM

Figure C.3—Edit Active Fleet Information Form

the model and can be left blank. (The field is for potential upgrades of the tool.) (list)

6. *In Year*: The year the ship is delivered to the Navy (the year it enters the fleet). (integer)
7. *Out Qtr*: The last calendar quarter the ship is active in the fleet. This field has no effect in the current version of the model and can be left blank. (The field is for potential upgrades of the tool.) (list)
8. *Out Year*: The last year the ship is active in the fleet. If the field is left blank (as it is for many of the hulls shown in the example), the nominal ship life is used to calculate the out year (found on the “Ship Class Data” form). You only need to enter a value in this field if the planned ship life is longer or shorter than typical for ships of the class. Such a case might be the early retirement of a hull (integer) or a core life that is shorter than expected.

Edit Force Level Requirements

This datasheet (Figure C.4) contains the force level requirements for each class by year. Each record (row) specifies the minimum number of hulls required for a given class for a given year. The datasheet is a key input to the Force Structure Method of the Force Transition Model. It is not necessary to enter a requirement for every ship class and every year of the analysis. Not entering any requirements for a ship class will mean that there will be no new construction for that class and that the existing hulls of that class will be retired when they reach the end of their nominal life.

RANDMR1743-C.4

Ship Class	Year	Min #
ADC (X)	2004	1
ADC (X)	2005	4
ADC (X)	2006	6
ADC (X)	2007	9
ADC (X)	2008	11
ADC (X)	2009	12
AKR 310	2004	5
CVN (X)	2014	1
CVN (X)	2020	2
CVN (X)	2026	3
CVN 68	2009	10
DD 21	2010	1
DD 21	2011	1
DD 21	2012	4
DD 21	2013	7

Record: 1 of 61

Class of ship for requirement: NUM

Figure C.4—Force Level Requirements

The fields for each record on the form are

1. *Ship Class*: Select from a pull-down menu. (list selection)
2. *Year*: The year for the requirement. (integer)
3. *Min #*: The minimum number of hulls required for the class for that year. For example, the first entry shows that there will be one active ADC (X) by 2004. Notice that by 2006, the requirement has risen to a minimum of six hulls. (integer)

Edit Ships in Production

The **Edit Ships in Production** option opens a data entry form (Figure C.5) that allows the analyst to edit data for the ships already under construction.

RANDMR1743-C.5

Ships in Production

Hull Number: DDG 88

Ship Class: DDG 51

Hull Name: Preble

UIC: 23145

Start: Quarter: 3rd, Year: 1999

End: Quarter: 1st, Year: 2003

Shipyards Doing Work

Shipyards	Contractor Role
Ingalls	Prime

Record: 14 of 39

Figure C.5—Ships in Production Data Entry Form

The form fields are

1. *Hull Number*: The hull number for the ship as found on the NVR website. For example, the hull number for the *USS Preble* is DDG 88. (text)
2. *Ship Class*: Designates the class of ship for a particular hull. Select the value from a pull-down menu. (list selection)
3. *Name*: The name of the ship. (text)
4. *UIC*: The Unit Information Code for the hull. Since the tool does not use these data in any of the calculations, it is an optional field. (integer)
5. *Start Qtr*: The calendar quarter that the construction began. (list selection)
6. *Start Year*: The year that the construction began. (integer)
7. *End Qtr*: The last calendar quarter of construction. (list selection)
8. *End Year*: The last year of construction (the year construction was completed). (integer)
9. *Shipyards Doing Work Subform*: Lists all the projects that comprise the ship construction. The fields on this subform are
 - a. *Shipyard*: The shipyard doing the project work. Select a value from a pull-down list. (list selection)
 - b. *Role*: The nature of the work the shipyard is performing for the construction of the hull. For the example shown, Ingalls is the Prime builder of the ship. (list selection)

EDIT PRODUCTION PLANS

This submenu brings up forms that manipulate all the production data, both planned and ongoing, at the shipyards.

Edit Acquisition Plan

The **Edit Acquisition Plan** command opens a datasheet view of a table so that you can modify the existing acquisition plan. Figure C.6 shows an example of the form. Each row represents a different ship

RANDMR1743-C.6

Ship Class	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DDG 51		2	2	2	1	2															
DD 21					1		3	3	3	3	3	3	3	3	3	2	2				
SSN 774			1	1	1	1	2	2	3	3	2	3	3	3	3	2	3	3	2	2	
LPD 17		2	2	2	2							1									
LH (x)					1			1					1		1			1			
ADC (x)		3	2	3	2	1															
JCC (x)				1	1	1	1														
MCS (x)										1										1	2
AD (x)																					

Figure C.6—Example Acquisition Plan

class. Classes can be added or subtracted as typical records in Access. The subsequent fields (column headings) denote the year of acquisition.

The form fields are

1. *Ship Class*: Designates the class of ship for a particular hull. Select the value from a pull-down menu. (list selection)
2. *Number Acquired*: The number of ships of the particular class acquired for a given year (starting year for construction). In the figure example, one LPD-17 is acquired in 2002. Note that the values of the years and their number (column headings) may vary based on the user-defined scenario. In the example below, the range of years runs from 2001 past 2014 (the list actually goes to 2021 but cannot fit in one window). The year values are modified with the next command, **Modify Acquisition Table**. (integer)

The Force Structure Model uses the Acquisition Plan to generate the new production plan if the analyst selects the Acquisition Plan method of calculation. This table is not used if the method is based on the force structure.

Modify Acquisition Table Format

This menu option opens a pop-up form to modify the acquisition table, which we described previously. The form allows the analyst to

delete the first year in the table, to add a new year to the end, or to totally restructure the table with defined starting and end years (Figure C.7).

The first button deletes the first year column of the table but preserves the rest of the data. For the example Acquisition Plan, the column for the year 2001 would be removed. Similarly, the second button adds an additional year to the end of the table. For the Acquisition Plan example in Figure C.6, the last year in the table is 2021. So a new column would be added to the end of the table for 2022. The last button completely rebuilds the table based on the “Start Year” and “End Year” fields at the bottom of the table. Note that all data in the table are *erased* when the table is rebuilt.

Edit New Ship Construction

The **Edit New Ship Construction** menu option opens a form (see Figure C.8) to edit the new ship construction plan calculated by the

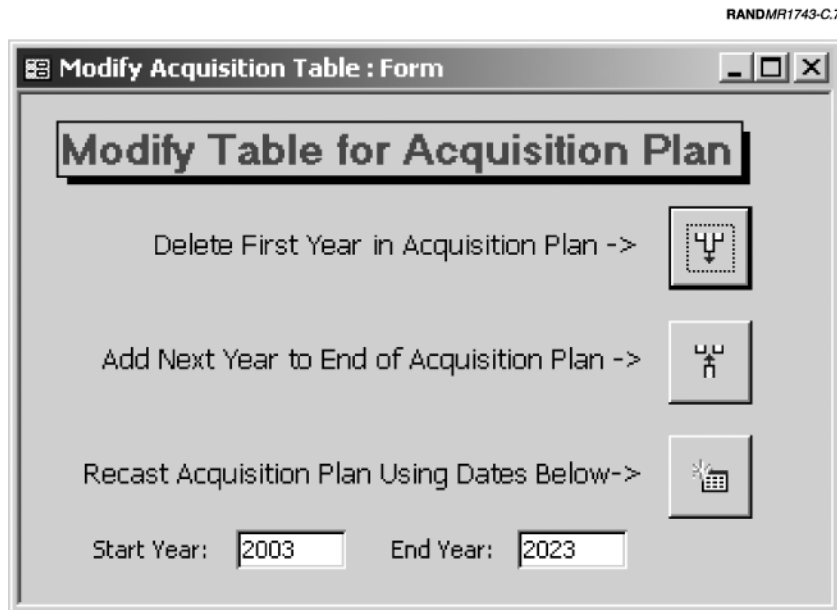


Figure C.7—Modify Acquisition Table Format

RANDMR1743-C.8

New Production

Build #:

Ship Class:

Start: Quarter Year

End:

Shipyards Doing Work

	Shipyard	Contractor Role	Project #
▶	Bath Iron Works	Prime	1
*			

Record: of 118

Ship Class NUM

Figure C.8—Edit New Production Plan

Force Transition Model. In general, you should rarely have to edit this list. In fact, changing date fields may alter the actual force structure, giving results that are inconsistent with the required force structure or acquisition plan. Further, the record IDs (Build # and Project # fields) are not automatically generated. The analyst will need to enter these fields manually. The analyst will know how to make these modifications by understanding how key fields work in a relational database. The only fields that you can change without causing significant errors are the Start Year, Shipyard, and Contractor Role fields. The form's fields are

1. *Build #*: A key index for the ship construction. It uniquely identifies the hull. (integer)
2. *Ship Class*: Designates the class of ship for a particular hull. Select the value from a pull-down menu. (list selection)
3. *Start Qtr*: The calendar quarter construction began. (list selection)
4. *Start Year*: The year that the construction began. (integer)
5. *End Qtr*: The last calendar quarter of construction. (list selection)
6. *End Year*: The last year of construction. (integer)
7. *Shipyards Doing Work Subform*: Lists all the projects that make up the new ship construction. The fields on this subform are
 - a. *Shipyards*: The shipyard doing the project work. Select from a pull-down list. (list selection)
 - b. *Role*: The nature of the work the shipyard is performing for the construction of the hull. For the example shown, Bath Iron Works is the Prime builder of the ship. (list selection)
 - c. *Project #*: The key index uniquely identifying the project for new construction. (integer)

Edit Ships in Production

This option opens the “Ships in Production” form shown in Figure C.5.

Edit Other Work List

This menu item (see Figure C.9) opens a datasheet to edit work at the shipyard that does not result in a new or additional active ship for the Navy, such as ship availabilities (the assignment of a Navy ship to maintenance or repair work), commercial work, and sustaining work done at private shipyards. (See Chapter Two for more detail on the difference between other work and new ship construction.) The fields on the form are

RANDMR1743-C.9

Build ID	Work Type	Shipyard	StartQtr	Start Year	EndQtr	End Year	Ship Class	Account
3	RCOH (1)	Newport News	2nd	2001	1st	2004	CVN 68	SCN
5	RCOH (1)	Newport News	1st	2004	3rd	2008	CVN 68	SCN
6	RCOH (2)	Newport News	1st	2007	2nd	2012	CVN 68	SCN
7	RCOH (2)	Newport News	2nd	2008	2nd	2014	CVN 68	SCN
8	RCOH (2)	Newport News	1st	2009	1st	2018	CVN 68	SCN
9	RCOH (2)	Newport News	1st	2011	1st	2021	CVN 68	SCN
10	PSA	Newport News	1st	2001	3rd	2001	CVN 68	OMN
11	ESRA (3)	Newport News	4th	2001	4th	2002	CVN 68	OMN
12	PSA	Newport News	2nd	2003	4th	2003	CVN 68	OMN
13	ESRA (3)	Newport News	1st	2004	4th	2004	CVN 68	OMN
14	ESRA (3)	Newport News	3rd	2005	2nd	2006	CVN 68	OMN
15	PSA	Newport News	2nd	2007	2nd	2008	CVN (X)	OMN
16	PSA	Newport News	3rd	2007	4th	2008	CVN (X)	OMN
17	ESRA (3)	Newport News	1st	2010	3rd	2010	CVN (X)	OMN
18	ESRA (3)	Newport News	3rd	2012	3rd	2013	CVN (X)	OMN
19	Other Work (2)	Electric Boat	1st	2000	4th	2022	None	
20	RCOH (1)	Newport News	2nd	1998	3rd	2001	CVN 68	SCN

Record: 14 of 23

Type of Construction (Ship Class) NUM

Figure C.9—Edit Other Work List

1. *Build ID*: An automatically generated field that serves as the key index for the table. You should not edit this field. (auto number)
2. *Work Type*: The values for this field are brief descriptions of the type of work done (e.g., RCOH, Post-Shakedown Availability [PSA], commercial tanker) and is selected from a pull-down list. The list is generated from the items entered in the “Edit Other Work Data” form. The analyst can only select, not create, items from this list. (list selection)
3. *Shipyard*: The shipyard doing the project work. Select the value from a pull-down menu. (list selection)
4. *StartQtr*: The calendar quarter the work began. (list selection)
5. *Start Year*: The year that the work began. (integer)
6. *EndQtr*: The calendar quarter the work ends. (list selection)
7. *End Year*: The last year for the work. (integer)
8. *Ship Class*: Designates the class of ship associated with work. Select the value from a pull-down menu. This field is optional and

should be selected for availabilities so that the item costs can be allocated to one of the budget accounts (acquisition or O&S). The field is grayed out if “None” is selected for the Account field. (list selection)

9. *Account:* Describes the budget account (SCN, OMN, MPN, or None) in which the costs are placed. For example, labor costs for carrier RCOHs are generally placed in the Acquisition account. Other availabilities (depot repair work) are placed in the OMN account. The value of “None” is for work that will not be included in the funding calculations but will be part of the overall industrial base calculations. (list selection)

SHIP CLASS DATA FORMS

The same form is used to add a new ship class or to edit ship class data. This form is the most complex in the tool. Most of the data used by the tool are organized by ship class.

Add a New Ship Class

This form is identical to the “Edit Ship Class” form described below except that all the fields are initially blank.

Edit Ship Class Data

This form allows the analyst to edit any of the data associated with a ship class. Because there are so many data to manage, the form has a number of subforms that are accessed through menu tabs. There are six submenus:

1. **Allocation Order:** Allows the analyst to specify how new ships are allocated to the shipyards.
2. **Learning Data:** Allows the analyst to specify the cost improvement/learning data.
3. **Material & Equipment Costs:** The submenu for editing Material and Equipment Cost.

4. **O&S Costs:** The submenu for editing Operating and Support Costs.
5. **Labor:** The submenu for editing production labor for one hull (both total hours and profile).
6. **Funding Profile:** The submenu for editing how the total cost is spread over different fiscal years.

Figure C.10 shows the form as it appears when opened. The first tab, Allocation Order, is selected by default. We first describe the fields for the top-level form, then describe the fields for each of the subforms in turn.

RANDMR1743-C.10

Microsoft Access

File Edit View Insert Format Records Tools Window Help

Ship Class Data

Class Name: DDG 51 Type of Ship (Hull Type): Guided Missile Destroyer

Ship Life: 35 Build Time: 22 Teamed: Exclude: New Class?: Design Offset: 0

Allocation Order | Learning Data | Material & Equipment Costs | O&S Costs | Labor | Funding Profile

Allocation Sequence to Shipyards

Shipyards
Bath Iron Works
Ingalls
*

Record: 27 of 55

Shipyards Name NUM

Figure C.10—Edit Ship Class Data Form

Top-Level Form

The top level of the form (the top half of the form, which does not change when a tab is selected) holds the generic information for the class.

1. *Class Name*: The hull symbol for the class. Figure C.10 shows data for the DDG 51 class. (text)
2. *Type of Ship*: Describes the ship type in a more generic way than a hull symbol. The “Type of Ship” field is the ship’s hull type. As Figure C.10 shows, the hull type for the DDG 51 is a “Guided Missile Destroyer.” The choices for the field are given in a pull-down list. This field cannot be left blank/empty. (list selection)
3. *Ship Life*: The notional life of the ship in whole *years* (rounded-up). It is the number of years that a typical hull stays active in the fleet. The DDG 51’s life is 40 years, as shown in Figure C.10. The “Ship Life” field is used to determine the number of active hulls for a class as a function of time. For this example, all DDG 51s will be active for 40 years and then retired. This generic ship life can be overridden for a single hull by entering a specific year in the “Out Year” field from the “Edit Active Fleet Information” form. (integer)
4. *Build Time*: The number of *quarters* (whole number, rounded-up) it takes to build a typical hull. Note that this value determines the default building time for new hulls. It does not need to match the number of entries for each labor profile (see the “Labor” sub-form). If the number of entries does not match the build time value, the Industrial Base Model rescales the labor profile. The analyst must exercise care, however, because drastic rescaling may distort the profile shape. The “Build Time” field can be blank (null) if there will be no additional ships of the class constructed (i.e., no future requirements beyond those vessels already active or in production). (integer)
5. *Teamed*: A check box denoting whether construction is part of a teaming arrangement by multiple yards; that is, more than one shipyard participates in the production of each hull. The Virginia Class (SSN 774) attack submarine is an example in which two shipyards construct each hull. (yes/no)

6. *Exclude*: A check box allowing you to exclude a class from any of the cost calculations. The element is still included in the labor calculations, however. (yes/no)
7. *New Class*: Denotes a new class in which no prior hulls exist or are in production; i.e., the first of a class does not exist. Checking this box indicates that the Force Transition Model should add a Design project to the first hull built. Refer to Chapter Three for a general discussion of first-of-a-class and follow-on hulls. (yes/no)
8. *Design Offset*: Only active when the new-class box is checked. The field holds the number of *quarters* that the nonrecurring work begins prior to the start of the recurring construction for the first of a class. It is the number of years that the Design labor is offset from the start of construction. For example, it takes six years to build a vessel. However, for the first hull in the class, it takes eight years to build the vessel because of the additional design and development effort. The Design Offset value for this case is the difference between the two build durations: $(8 - 6) \times 4 = 8$ quarters. (integer)

Allocation Order Subform

The first tab on the “Edit Ship Class” form is the “Allocation Order” subform. This subform is also shown in Figure C.10. The subform lists each of the shipyards that can build the ship class in the sequence that new ships are allocated to each of the shipyards. In the example, both Bath Iron Works and Ingalls can build the DDG 51 class. The order that the shipyards are listed is very important. The order on the subform is the order that the Force Transition Model assigns additional construction work to each of the shipyards. For the example shown, Bath Iron Works would build the next required hull and Ingalls would build the second. The tool restarts from the beginning of the list when it reaches the end. For the example, construction of the DDG 51 class would alternate between Bath Iron Works and Ingalls.¹ A shipyard can appear multiple times on the list so that complex sequences may be used. The one field on this form is

¹It is important to note that this sequence begins from the first hull added to the new production list. This hull may not be the very first hull of the class. To make certain that the two shipbuilders always alternate production, you must determine the ship-

1. *Shipyard*: The name of the shipyard that is allowed to build the class. Select the value from a pull-down list. (list selection)

Learning Data

The “Learning Data” subform is the second tab on the form, as shown in Figure C.11. The five fields on this subform are

1. *Shipyard*: The name of the shipyard that is allowed to build the class. The value is selected from a pull-down list. (list selection)

RANDMR1743-C.11

Ship Class Data

Class Name: DDG 51 Type of Ship (Hull Type): Guided Missile Destroyer

Ship Life: 35 Build Time: 22 Teamed: Exclude: New Class?: Design Offset: 0

Allocation Order **Learning Data** Material & Equipment Costs O&S Costs Labor Funding Profile

Learning Data (Allowed t					
	Shipyard	Labor Type	Slope	Cum. Prod.	Max. Prod.
▶	Bath Iron Works	General	1	0	
	Ingalls	General	1	0	
*					

Record: 27 of 55

Shipyard NUM

Figure C.11—Learning Data Subform

yard building the last ship of the class from the Ships In Progress list (see the “Edit Other Work List” section). Then you can sequence the yards appropriately.

2. *Labor Type*: The type of labor (labor, engineering, etc.) for the requirement. (list selection)
3. *Slope*: The unit learning curve slope in a decimal format. Learning/cost improvement curves describe the phenomenon that recurring unit labor tends to decrease with more production experience. A slope of 1.0 means that there is no decrease in recurring labor. A value of 0.95 means that the recurring labor falls by 5 percent every time the cumulative production quantity doubles. Historically, ship production slopes have been very flat (i.e., slopes close to 1.0). The general format of the unit the learning curve is

$$L_i = L_1 * i^{\frac{\ln(\text{slope})}{\ln(2)}}$$

where

L_i = total labor for unit i

L_1 = total labor for the first hull (unit #1)

$\ln(\text{slope})$ = natural log of the learning curve slope in decimal form

$\ln(2)$ = natural log of 2.0

i = unit number (e.g., the second hull produced would be two).

4. *Cum. Prod.*: The Cumulative Production field holds the values for the prior/cumulative production to date. The field determines which unit number ("i" in the formula) is produced next. If the value is 0, there is no prior production. If the value is 1 or greater, the next unit in production will be that value plus 1. (integer)
5. *Max. Prod.*: The Maximum Production field denotes the maximum annual production rate for a given class at a specific shipyard. This value is only checked for the Notes section of the funding summary reports. It does not alter the calculations. (integer)

Material & Equipment Costs Subform

The "Material & Equipment (M&E) Costs" subform holds all the cost associated with material and equipment costs for new acquisitions. The subform is shown on Figure C.12.

RANDMR1743-C.12

Ship Class Data

Class Name: DDG 51 Type of Ship (Hull Type): Guided Missile Destroyer

Ship Life: 35 Build Time: 22 Teamed: Exclude: New Class?: Design Offset: 0

Allocation Order Learning Data **Material & Equipment Costs** O&S Costs Labor Funding Profile

M&E Acquisition Costs

Shipyard	GFE Cost	CFE Cost	Material	Base Year
Bath Iron Works	\$0	\$0	\$0	2001
Ingalls	\$0	\$0	\$0	2001
*	\$0	\$0	\$0	2003

Record: 27 of 55

Shipyard NUM

Figure C.12—Material and Equipment Subform

The subform has five fields:

1. *Shipyard*: The shipyard doing the project work. Each shipyard that is capable of building a hull must have its own M&E cost record. Select the value from a pull-down list. (list selection)
2. *GFE Cost*: The cost for the government-furnished equipment. It is the total price to the government, including any fees, in dollars. (currency)
3. *CFE Cost*: The cost for the contractor-furnished equipment. It is the total price to the government, including any fees, in dollars. (currency)

4. *Material*: The cost for any material used that is not part of either of the equipment costs. It is the total price to the government, including any fees, in dollars. (currency)
5. *Base Year*: The base year for costs on the record. For example, if the costs were reported in 1999 constant dollars, the base year would be 1999. Similarly, if the M&E costs were based on actual acquisition costs from 1995, the base year would be 1995. (list selection) Note: If actual costs for any of the above items are from different FYs, the costs will have to be changed to a common FY before entry into the model.

O&S Costs Subform

Figure C.13 shows the subform when the “O&S Costs” tab is selected. This subform has the fields for the operating and support cost data. The O&S costs are a list of

- operation and maintenance expenditures by the age of the hull (OMN)
- annual military personnel costs (MPN).

The example in Figure C.13 shows the OMN costs for the first nine years (periods). The values shown are made up and do not represent actual values. For each year that a hull can be active, a corresponding record needs to be added to this subform. If a ship life is 40 years, then 40 records need to be added to the OMN table. The annual personnel costs for the DDG 51, as shown by Figure C.13, are \$1,234,567 per year.

The four fields on the subform are

1. *Period*: The hull's age in years as of the end of the period. The value of 5 is the record for the ship class when the hull is five years old. The numbers should sequentially run from 1 to the maximum life of the class. You cannot repeat entries. In other words, there cannot be two values for the same age of the ship. (integer)
2. *O&S Cost*: Contains the dollar value of the operations, maintenance, and support costs for the hull at that particular age. It in-

RANDMR1743-C.13

Ship Class Data

Class Name: DDG 51 Type of Ship (Hull Type): Guided Missile Destroyer

Ship Life: 35 Build Time: 22 Teamed: Exclude: New Class?: Design Offset: 0

Allocation Order | Learning Data | Material & Equipment Costs | **O&S Costs** | Labor | Funding Profile

Operation & Maintenance Cost Data (OMN only)

Period	O&M Cost
1	\$1,000,000
2	\$2,000,000
3	\$1,000,000
4	\$3,000,000
5	\$1,000,000
6	\$4,000,000
7	\$1,000,000
8	\$5,000,000

O&S Costs Base Year: 2001

Annual Personnel Cost: \$123,456.00

Record: 27 of 55

Period for Operating & Support Costs (assumed years) NUM

Figure C.13—Operations and Support Costs Subform

cludes all costs except those charged as SCN (i.e., an RCOH). (currency)

3. *O&S Cost Base Year*: Specifies the base year for the O&S cost values (both O&M and Military Personnel). For example, if the costs were reported in 1999 constant dollars, the base year would be 1999. (list selection)
4. *Annual Personnel Cost*: The military personnel cost for a single ship for one year. Note: Since military personnel are assigned to a ship even when it is in overhaul, the model treats the personnel costs as a constant throughout the life of the ship. (currency)

Labor Subform

The fifth tab on the “Edit Ship Class Data” form is the “Labor” subform. This subform contains the labor data that each shipyard requires to build the vessel. As described earlier, workload is described by (1) total number of hours and (2) labor profile. Figure C.14 shows the labor information for the DDG 51 class. There is one entry per shipyard per role per labor type. So if there are two shipyards with one role and one labor type, there should be two entries on the table. This situation is exactly the case for the DDG 51. Although the labor profile and the total hours are identical for both shipyards on Figure C.14, neither is a necessary assumption for the tool. You could use a

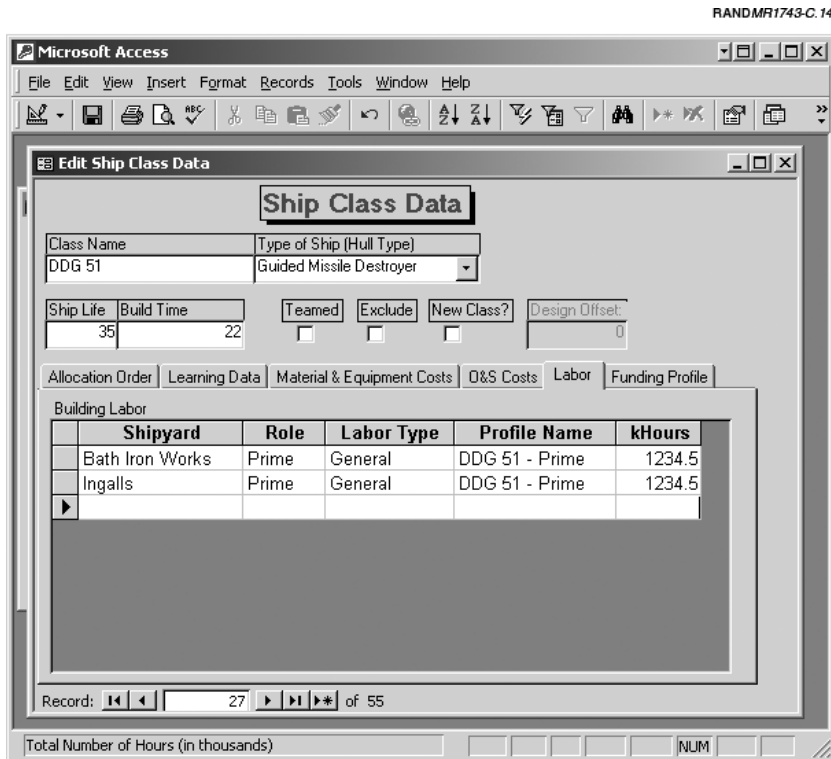


Figure C.14—Labor Subform

different number of hours, a different profile, or both for each shipyard.

If there are multiple labor types, an entry would be needed for each type. So if labor was differentiated between production and engineering for the DDG 51 case, each shipyard would have two entries on the subform.

The subform has five fields:

1. *Shipyard*: The shipyard doing the project work. The value is selected from a pull-down list. (list selection)
2. *Role*: The contractor's role. (list selection)
3. *Labor Type*: The type of labor (e.g., engineering, labor, and support) for the requirement. (list selection)
4. *Profile Name*: The shape of the labor profile. (list selection)
5. *kHours*: The summation of the required number of hours for all quarters divided by 1,000. It corresponds to the total number of hours in thousands. The value is for the first hull for a given role (unit #1 or the T1 value). The tool calculates the subsequent hull values using the learning curve slope and prior cumulative production entered on the "Learning Data" tab. (number). Note: The values shown in Figure C.14 are made up and do not represent actual values.

Funding Profile Subform

The last tab on the "Edit Ship Class Data" form is the "Funding Profile" subform. The data on this subform describe how the total cost of the ship is spread over multiple budget years. For example, some of the costs for a ship may be incurred before the production work starts. Typically, these advanced costs are for long-lead-time items. In other cases in which the total cost is very large (e.g., an aircraft carrier), the costs may be spread over a few fiscal years. This spreading is typically done to minimize large spikes in the budget and to purchase long-lead-time items.

To describe how the total cost is spread over different fiscal years, the user enters a profile on this subform as the fraction of total cost rela-

tive to the production start. An example of the subform is shown in Figure C.15. For the data shown, the total estimated cost is required in full in the same fiscal year the production starts. If a quarter of the total cost were required one year prior to the build start and the rest at the start, the profile would have two entries: one entry at minus one year prior to the start with a % total of 25 percent and another entry at zero with a % total of 75 percent. The subform has two fields:

1. *Years Relative to Build Start*: Designates the fiscal year relative to the start of the build. Negative numbers indicate fiscal years before the start and positive ones after the start. (integer)

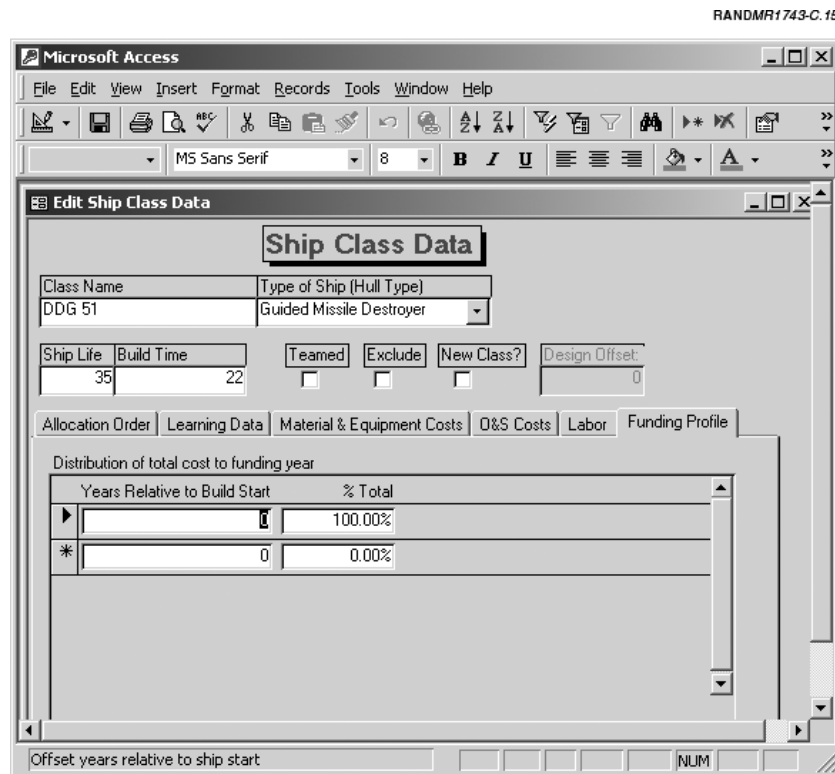


Figure C.15—Funding Profile Subform

2. *% Total*: The percentage of the total cost required for a specific year relative to the build start. (percentage)

Edit Force Level Requirements

This menu action, which opens the form that allows you to edit force structure requirements, was described earlier.

Edit Hull Types

This menu action opens a form to edit hull types and is shown in Figure C.16. The form has two fields:

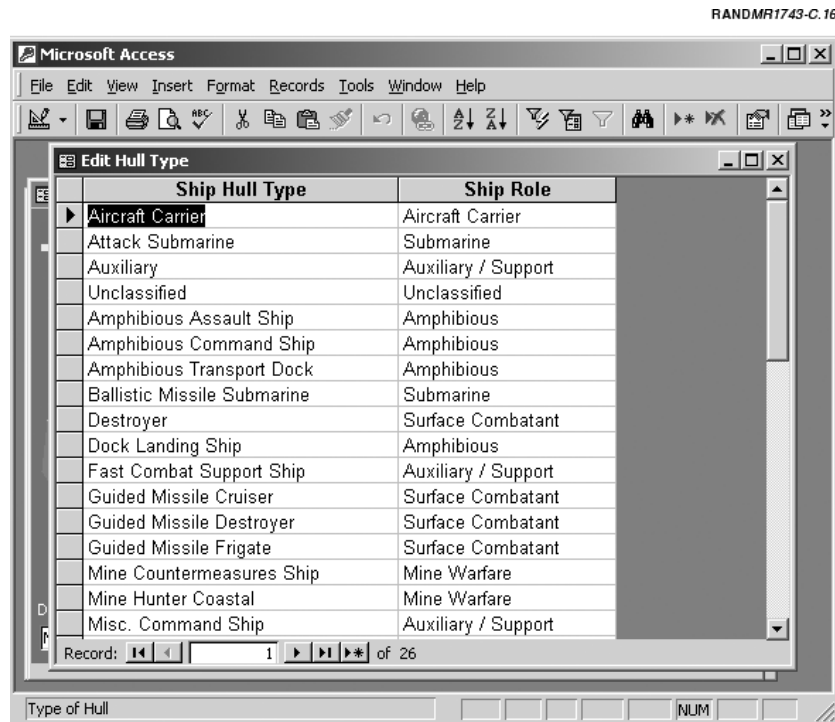


Figure C.16—Edit Hull Types

1. *Ship Hull Type*: Describes the ship type in a more generic way than a hull symbol. This field is described more in Appendix G (“Ship Roles, Hull Types, and Classes”). (text)
2. *Ship Role*: High-level categorization of the ship’s role in the fleet (e.g., aircraft carrier, amphibious, surface combatant). (list selection)

Edit Ship Roles

This form has only one field (see Figure C.17):

1. *Ship Role*: High-level categorization of the ship’s role in the fleet (e.g., aircraft carrier, amphibious, surface combatant). (text)

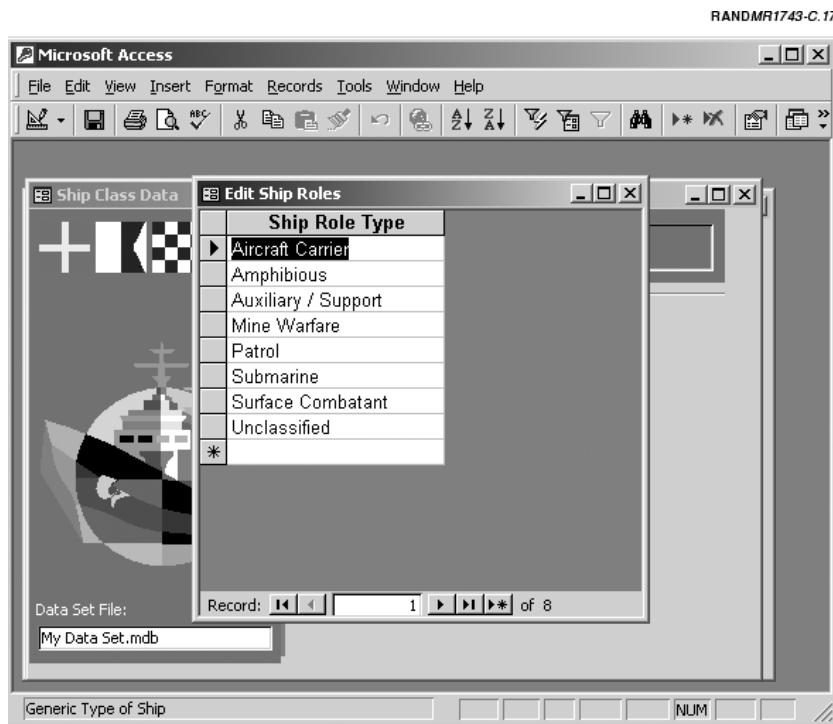


Figure C.17—Edit Ship Roles

EDIT SHIPYARD DATA

Each of the private shipyards has data corresponding to its wage rates, labor pool, and burden rates. The menu item **Edit Shipyard Data** opens a form to edit this information.

Labor Data Subform

The first tab on the form shows the labor data for the yard comprising the wage rate and labor pool data. This tab is active in Figure C.18. There are nine fields to this subform:

1. *Labor Type*: The type of labor (e.g., engineering, labor, and support) for the labor data. (list selection)

RANDMR1743-C.18

Microsoft Access

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Shipyard Labor Data

Shipyard Data

Yard Name: ABC

Labor Data Burden Rates Productivity

Wage and Labor Data

Labor Type	Wage Rate	Standard Hours Per Year	Overtime Premium	Attrition Rate	Hiring Rate	Termination Rate	Hiring Cost
General	\$18.28	1960	150%	0%	200%	100%	\$2,500
*							

Record: 1 of 7

Shipyard Name NUM

Figure C.18—Shipyard Labor Data

2. *Wage Rate*: The direct, average *hourly* wage rate for workers at the yard.² (currency)
3. *Standard Hours per Year*: The number of hours per year that an average worker is employed. This value is the same as the number of hours per FTE (normally 1,860 hours per year. See Chapter Three, footnote 1). It does not include overtime, which is figured in the following field. (integer)
4. *Overtime Premium*: If the workforce is not 100 percent efficient, additional labor must be used to complete a given task. The productivity model assumes that the additional work is done through overtime. This field allows the analyst to set the overtime pay rate relative to the wage rate. A value of 150 percent means that workers are paid $1.5 \times$ their normal rate for overtime work. (percentage)
5. *Attrition Rate*: The percentage that the labor base at the yard would shrink if there were no new hires and no reductions in the workforce (quarter to quarter). The field is the overall attrition rate used for the effective labor calculations (whereas productivity splits attrition rate by experience level). The analyst should use an average value or the value for the most experienced workers. (percentage)
6. *Hiring Rate*: The hiring rate is the *maximum* rate allowable in any given quarter relative to the current level. (percentage)
7. *Termination Rate*: This field is the *maximum* rate by which the shipyard can reduce its labor force every quarter. A value of 50 percent implies that the most the yard can reduce the labor pool is to cut it in half in one calendar quarter. (percentage)
8. *Hiring Cost*: The one-time cost for a new hire. It could be for training costs, recruiting costs and/or recruiting bonuses. (currency)
9. *Termination Cost* (not shown): The one-time cost when a worker is terminated. It could be for severance pay, accrued leave, outplacement and/or unemployment fees. (currency)

²Note that in previous versions of the model, an annual wage rate was used. The change was made to remove ambiguity.

10. *Base Year* (not shown): This is the base year for costs on the record. For example, if the costs were reported in 1999 constant dollars, the base year would be 1999. Similarly, if the M&E costs were based on actual acquisition costs from 1995, the base year would be 1995. (list selection)

Burden Rates Subform

The burden rate is the combined rate for overhead for direct labor hours, G&A costs, and profit/fee. In other words, it encompasses all the indirect costs. The burden rate times the direct labor hourly rate yield the total hourly cost (“wrap rate”). This rate will be a function of the overall workload at the site. Being able to assess the change in the burden rate compared with the change in work hours is important in determining the impact of adding or reducing these hours to all programs at that shipyard. The function for the burden rate is

$$\text{Burden Rate} = (\text{burden slope}) / (\text{total direct work at site in FTEs}) \\ + \text{burden base}$$

The “Burden Data” subform (see Figure C.19) shows the two parameters (slope and base). If you do not know the slope or want to assume the burden rate is independent of total work done at the site, you can enter 0 percent for the slope and the fixed rate in the Base field. The figure shows an example in which the burden rate for Newport News is fixed to 173 percent. The five fields are

1. *Burden Slope*: The slope for the burden rate (see the above equation). The slope is the result of a regression of the burden rate on the reciprocal of the total direct work (specified in FTEs). It is the slope from the regression. (percentage)
2. *Burden Base*: The base, or the result of a regression of the burden rate on the reciprocal of the total direct work (specified in FTEs). It is the constant from the regression. (percentage)
3. *Burden Minimum*: This field sets the lower limit for the burden rate. An empty field means there is no minimum value. (percentage)

RANDMR1743-C.19

Microsoft Access

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Shipyards Labor Data

Shipyards Data

Yard Name: ABC

Labor Data Burden Rates Productivity

Burden Rate Data

	Burden Slope	Burden Base	Burden Minimum	Burden Maximum	Effective Year
	0.00%	173.00%			2000
▶	0.00%	173.00%			2005
	0.00%	173.00%			2010
*					2000

Record: 1 of 7

Shipyards Name NUM

Figure C.19—Shipyards Burden Rates

4. *Burden Maximum*: This field limits the maximum value for the burden rate. An empty field means there is no maximum value. (percentage)
5. *Effective Year*: The first fiscal year that the burden rate parameters (slope and base) are effective. For each quarterly overhead calculation, the tool selects the corresponding parameters with the highest value for the Effective Year such that the fiscal year is greater than or equal to the Effective Year. (integer)

Productivity Subform

Data for the productivity calculations are entered on the third tab of the “Shipyards Data” form shown in Figure C.20.

For every labor type (trade), you need to enter the productivity of workers with differing experience levels. Each level represents one

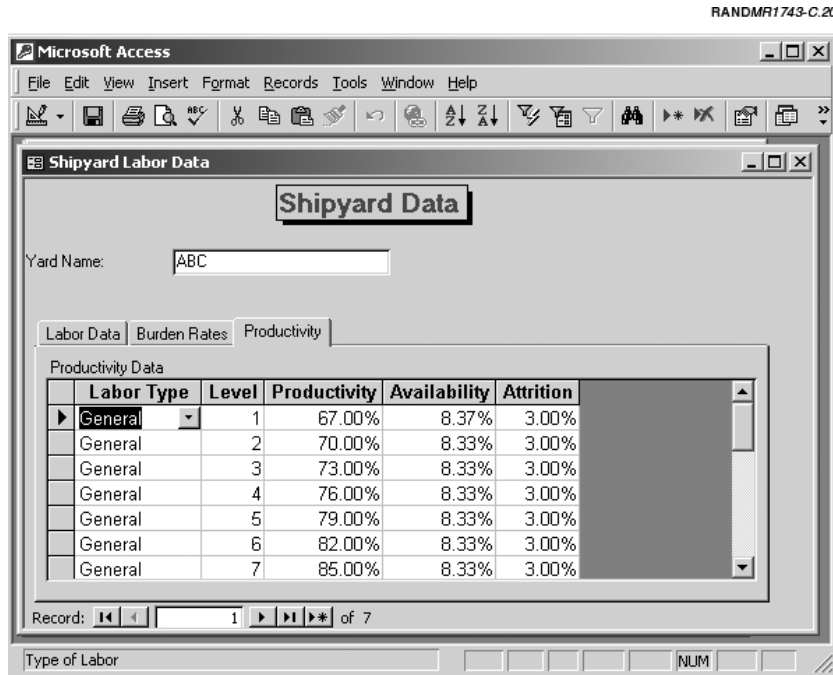


Figure C.20—Productivity Data

quarter of experience and increases with the level. Thus a Level 1 worker is a new worker with no experience; a Level 2 worker has one quarter of experience; and so on. If it takes three years to become fully proficient, there would be a total of 12 levels. Any experience beyond the last level does not result in greater proficiency. Figure C.20 shows an example in which the first seven levels begin with inexperienced workers at a 67 percent proficiency relative to a fully proficient worker (Level 12 is 100 percent, which is not shown). The subform has five fields:

1. *Labor Type*: The type of labor (e.g., engineering, labor, and support) for the labor data. (list selection)
2. *Level*: The level of experience for the worker. The lowest level is always 1 and the highest is the level at which the worker becomes 100 percent proficient. Levels are in experience steps by calendar

quarter. If it takes four years to become fully proficient, the last level would be 16. (integer)

3. *Productivity*: The productivity for workers of a given level relative to 100 percent. A worker with 50 percent productivity would accomplish a similar task in twice the time as a fully proficient one. (percentage)
4. *Availability*: The fraction of new hires in the labor pool at a particular experience level. This field allows the analyst to specify the experience distribution as described in Chapter Three, "Productivity." For example, if all new hires had no prior experience, the value for level 1 would be 100% and all other levels 0%. As shown in the figure, all levels have the same availability (8.3%). (percentage)
5. *Attrition*: This field is the attrition rate for workers of that level. It represents the number of workers lost per quarter. (percentage)

EDIT OTHER WORK DATA

As with new ship construction, the "Other Work" at each of the shipyards requires information on material and labor cost. On the main form, there is one field:

1. *Type Name*: A short description or title for the "Other Work" Item. In the example in Figure C.21, the name is RCOH (1). (text field)

Material & Equipment Cost Subform

This subform is identical to the one used for ship class data. The data on this form are the material and equipment costs for the work item. If the government does not pay for the work, these fields can be left blank. An example might be private commercial work at one of the shipyards. It is not necessary to enter material costs for such items. This subform has five fields:

1. *Shipyard*: The shipyard doing the project work. Each shipyard that is capable of building a hull must have its own M&E cost record. Select the value from a pull-down list. (list selection)

RANDMR1743-C.21

Other Work Cost And Labor Data

Type Name
RCOH (1)

Material & Equipment Costs | Labor

Other Work M&E Costs

	Shipyard	GFECost	CFE Cost	Material	Base Year
⌘	Newport News	\$0.00	\$0.00	\$0.00	2001
*		\$0.00	\$0.00	\$0.00	2003

Record: 2 of 12

Material Costs | NUM

Figure C.21—Other Work Material and Equipment Subform

2. *GFE Cost*: The cost for the government-furnished equipment. It is the total price to the government, including any fees, in dollars. (currency)
3. *CFE Cost*: The cost for the contractor-furnished equipment. It is the total price to the government, including any fees, in dollars. (currency)
4. *Material*: The cost for any material used that is not part of either of the equipment costs. It is the total price to the government, including any fees, in dollars. (currency)
5. *Base Year*: The base year for costs on the record. For example, if the costs were reported in 1999 constant dollars, the base year would be 1999. Similarly, if the M&E costs were based on actual acquisition costs from 1995, the base year would be 1995. Note: If actual costs for any of the above items are from different FYs, the costs will have to be changed to a common FY before entry into the model. (list selection)

Labor Subform

Again, this subform is similar to the “Labor” subform used for the ship class data. The only exceptions are that there is neither a learning curve nor a contractor role associated with this work. The four fields on the form (shown in Figure C.22) are

1. *Shipyard*: The shipyard doing the project work. The value is selected from a pull-down list. (list selection)
2. *Labor Type*: The type of labor (e.g., engineering, labor, and support) for the requirement. (list selection)
3. *Profile Name*: The shape of the labor profile. (list selection)
4. *kHours*: The summation of the required number of hours for all quarters divided by 1,000. It corresponds to the total number of hours in thousands. (number). Note: The values shown in Figure C.22 is made up and does not represent the actual value.

RANDMR1743-C.22

The screenshot shows a Microsoft Access window titled "Microsoft Access" with a menu bar (File, Edit, View, Insert, Format, Records, Tools, Window, Help) and a toolbar. The main window is titled "Edit Other Work Type Data" and contains a subform titled "Other Work Cost And Labor Data". The subform has a "Type Name" field with the value "RCOH (1)". Below this are two tabs: "Material & Equipment Costs" and "Labor". The "Labor" tab is active and contains a table with the following data:

Shipyard	Labor Type	Profile Name	kHours
Newport News	General	RCOH (1)	1234.5

At the bottom of the subform, there is a record navigation bar showing "Record: 2 of 12". The status bar at the bottom of the window displays "Total Number of Hours (in thousands)" and a "NUM" field.

Figure C.22—Other Work Labor Data Subform

EDIT LABOR PROFILES

This menu option allows you to edit and view the labor profiles that describe the shape of the workload for an activity. The top field on the form is

1. *Profile Name*: A string describing the profile. In the example of Figure C.23, the profile name corresponds to a ship class and role. However, we could have chosen a more general name, such as “Generic Profile A,” and used this profile with many activities. (text)

The subform lists the labor profile. The number of records for each profile will generally correspond to the build time for that activity. In Figure C.23, the “Generic Profile A” profile has multiple entries.

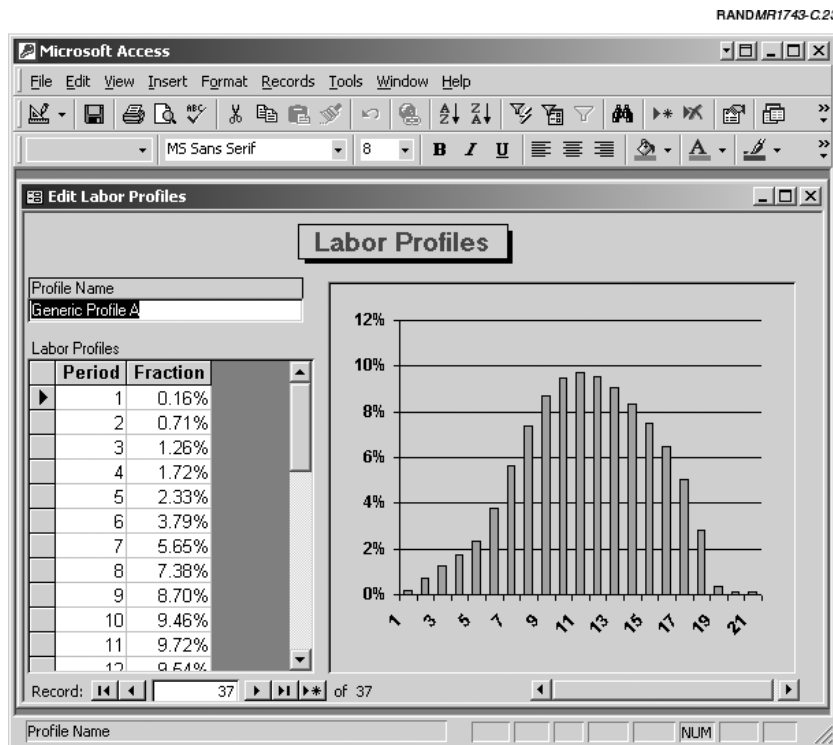


Figure C.23—Edit Labor Profile

There are a total of 22 entries (only eleven are shown in the figure), because it takes 22 quarters, or 5 1/2 years, to build the ship. The two fields on the table are

1. *Period*: The sequential quarter for the labor demand. For example, a period value of 12 corresponds to the last quarter of the third year for the construction. (integer)
2. *Fraction*: The percentage of the total work needed for that quarter. For example, the Fraction value would be 2 percent for a period if the number of hours worked that period were 200 out of a total of 10,000 for the entire task. (percentage)

To the right of the subform is a graph of the profile.

EDIT DATA SOURCES AND INFLATION INDICES

This next menu option groups two somewhat unrelated items: deflators and data source documentation.

Edit Inflation Indices

The first item on this submenu, **Edit Inflation Indices**, allows you to adjust costs to a constant dollar basis. This form has five fields (shown in Figure C.24):

1. *Year*: The year for the index value. (integer)
2. *O&M*: The Operation and Maintenance index. It adjusts O&M data from the *O&S Cost Model* (OMN). (percentage)
3. *Procurement*: An index to deflate procurement expenditures. It adjusts all labor, material, and equipment costs (SCN). (percentage)
4. *MilPers*: An index to deflate military personnel cost (MPN). (percentage)
5. *Overall*: Overall index for inflation. (percentage)

RANDMR1743-C.24

Year	O&M	Procurement	MilPers	Overall
1989	69.86%	76.15%	65.45%	70.98%
1990	72.24%	79.28%	65.75%	73.06%
1991	78.33%	82.68%	69.53%	76.31%
1992	78.67%	85.17%	71.44%	78.64%
1993	81.10%	87.21%	74.58%	81.18%
1994	82.97%	88.95%	76.71%	83.16%
1995	84.47%	90.64%	78.37%	84.62%
1996	86.38%	92.46%	79.60%	86.43%
1997	88.71%	94.12%	82.41%	88.59%
1998	90.83%	94.78%	85.31%	90.49%
1999	92.35%	95.54%	87.87%	92.12%
2000	94.28%	96.88%	91.96%	94.47%
2001	97.83%	98.43%	94.56%	97.16%
2002	100.00%	100.00%	100.00%	100.00%
2003	102.03%	101.60%	103.28%	102.25%

Record: 1 of 53

Year for Deflation Index

Figure C.24—Edit Inflation Index Data

Edit Data Source Documentation

Part of any good cost analysis is documenting the sources of the data used to generate the results. Often, questions asked about the validity of the results will focus on the assumptions and the data sources used. Anytime you modify or update data for a data set, you should document those changes. To keep the documentation with each data set, the tool has a documentation form to enter an item, date, and description of the information. You should expand and modify the list as given. The list in the example data set is intended as an example only. To bring up the form, select **Edit Data Source Documentation**. A user form should appear as shown below in Figure C.25. This form has three fields:

RANDMR1743-C.25

Microsoft Access

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Data Sources and Deflators

Edit Data Source Documentation

Sources of Information / Data

Element: Current Fleet

Update Date: 10/10/2001

Notes: Information for current fleet, both active and reserve, were obtained from the NVR website: <http://www.nvr.navy.mil/>. The start year (active in fleet) corresponds to the delivery year.

Record: 1 of 11

Data Set File: My Data Set.mdb

Data Element: NUM

Figure C.25—Data Source Documentation Form

1. *Element*: Briefly describes the data element. The example figure shows the data description for the O&S data. (text field)
2. *Update Date*: You should enter the date the data was changed or modified. (date field)
3. *Notes*: A field to hold the full description of the data source. It might describe the source and any limitations or assumptions used for the data. This field is a free-form text field and can be as long as the analyst wants. (memo field)

RUNNING THE DATA SET—CALCULATIONS

The next step after editing the data is to calculate the various outputs from the models within the tool. Figure D.1 shows an image of the **Calculations** submenu. In general, you will want to start with the first item on the form and proceed sequentially down the list. The first step is setting the bounds for the time frame of the displayed output for the analysis. The last step is calculating the funding profiles. The

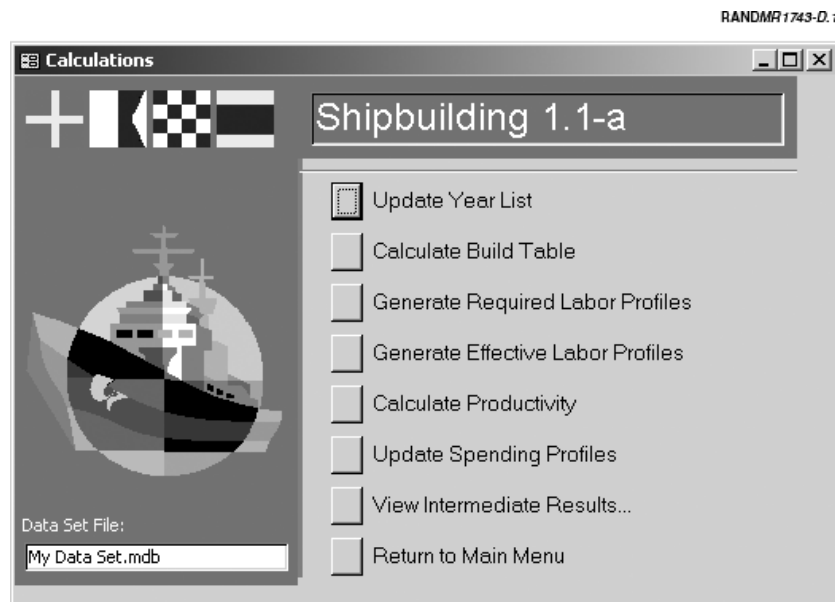


Figure D.1—Calculations Form

tool formats and displays results of the calculations through a submenu described in Appendix E.

UPDATE YEAR LIST

The first step in the calculations is to define the boundary range of fiscal years for the results (see Figure D.2). For example, you might only be interested in results from FY2000 through FY2015. By setting a range for the output, the tool is able to truncate calculations and not waste time determining values for unwanted periods. Once these bounds are set, they remain in place until changed. Therefore, you should only need to set them once at the beginning of the calculations. When the button is pressed, a pop-up window appears asking you to enter a "Starting Year," which is the first fiscal year shown for the output. The field has a default value of the current year. After entering the starting year, you are next prompted to enter the ending year in a similar box. The default value for the ending year is 20 years from the current year.

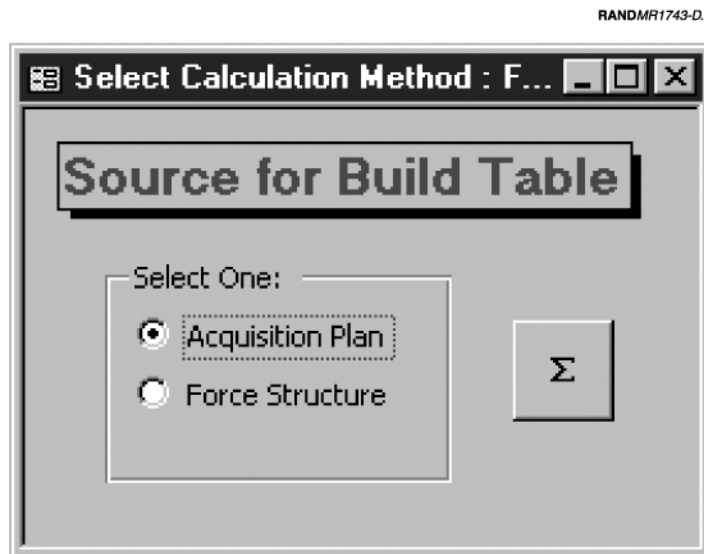


Figure D.2—Select Calculation Method

CALCULATE BUILD TABLE

The second step is to calculate a new “Build Table” (the information you can edit in the form “Edit New Ship Construction”). This menu item runs the Force Transition Model, which generates a list of the ship build requirements in order to meet force-level requirements. The table lists the type of ship, the start and end year of construction, and all the “projects” associated with that particular hull. When you press the button, a pop-up window opens prompting you to select the calculation method used to generate the new production table.

On the form, select one of the two methods and press the **Calculate** button (a summation sign). Next, another pop-up window opens asking you to confirm the deletion of the current contents of the table. The analyst needs to click **OK** to proceed with the calculation. The status bar will show the progress of the calculations.

GENERATE REQUIRED LABOR PROFILES

The third step is to calculate the minimum labor (FTEs) necessary to build the ships at the shipyards. The concept of required labor is discussed in Chapter Three. Similar to the above command, a pop-up box will prompt you to overwrite the existing data in the appropriate table object. Confirming with **OK** allows the calculations to proceed. If the tool cannot find labor, learning, or project data for a particular ship class in the course of determining the required labor, it will display a form (see Figure D.3) listing the missing information. In the case of missing labor data or project information, the missing values are assumed to be 0 for that item. When the learning data are missing, the slope is assumed to be 100 percent.

GENERATE EFFECTIVE LABOR PROFILES

Running the Industrial Base Model is the fourth step in the process of calculating output. This model determines the effective labor required to build the required ships at the shipyards. As before, you are prompted to overwrite the contents of the table holding the existing output data. Recall that if the software key field has not been entered

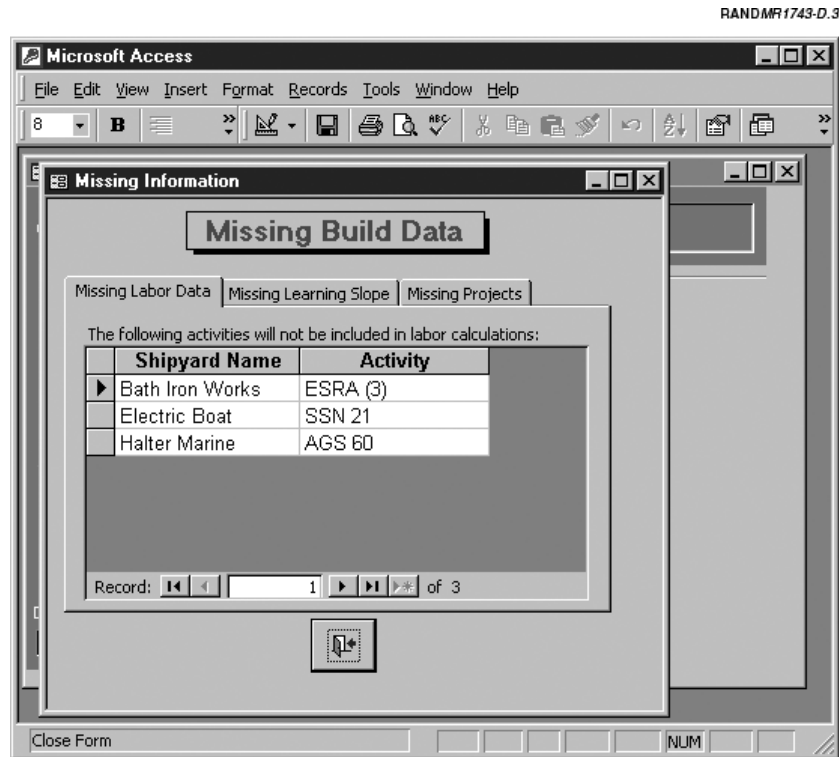


Figure D.3—Missing Production Data Warning

for the LP DLL, the tool will bypass the calculation and set the effective labor equal to the required labor. You still *must* do this calculation for the spending results to be up-to-date. After you confirm overwriting the existing output data, the status bar shows the progress of the calculations.

CALCULATE PRODUCTIVITIES

The fifth step is to calculate the workforce productivities at each of the shipyards. The calculations are based on the effective labor profiles and the productivity data on the “Shipyards Data” form. You will

be prompted if you want to overwrite the existing data. If you confirm by selecting **yes**, a progress bar shows the status of the calculations.

UPDATE FUNDING PROFILES

The last step in the calculations is to generate the funding requirements by year and account. This calculation also runs the O&S Cost Model embedded in the tool. When the button is pressed, a window opens for the analyst to set the NPV and Cash Flow assumptions (see Figure D.4). For the NPV parameters, the default “zero” year is the present year (you should almost never need to change the zero year from the default value). The other NPV item on the form is the discount rate. The default discount rate is 0 percent. If you are looking

RANDMR1743-D.4

Enter Funding Assumptions

Funding Assumptions

Starting Year: 2003

Discount Rate %: 0.0

Cash Flow

As-Expended

As-Appropriated

Σ

Figure D.4—Funding Assumptions Form

at budget projections,¹ you should leave this rate at 0. However, if you are examining the cost-benefits of alternative plans, you will need to set an appropriate rate, which is usually specified by the Office of Management and Budget.

For determining how expenditures are tracked over time, the cash flow box contains two options: **As Expended** and **As Appropriated** (default). The first method models the cash flow as work is accrued by the yards. In other words, only work and expenses charged in a particular year are allocated as costs for that year. The second method models funding required to the appropriation year (first year of construction/work). Using this method, all funding required for an item, which may span several years of work, is attributed to the first year. When you press the button with the sigma (summation) on it, the status bar shows the calculation progress with a meter.

If certain values used in the funding calculations are invalid, a pop-up window appears warning the analyst of the data problems (see Figure D.5). Two problem issues are checked: burden values not covering the full range of the analysis and budget profiles that do not sum to 100 percent.

VIEW INTERMEDIATE RESULTS

This command brings up menu options that allow the analyst to view the intermediate results of the calculations. There are two options for this submenu. The first option, **View and Edit New Production List**, opens a form that allows you to view and edit new ship production generated by the Force Transition Model. This is the same form as the one described in Appendix C. Again, you should exercise caution when editing this table.

The second menu option is **View and Edit Required Labor**. The form that opens allows you to modify the labor demands generated by the **Generate Required Labor** menu option. Listed in the table are all the elements associated with each shipyard project for every hull. The list can be quite large, easily over a thousand records. You should

¹Recall that the tool reports all costs on a constant-dollar basis, which is different from the discounting issue.

RANDMR1743-D.5

frmBadSpendingData : Form

Missing Funding Data

Incomplete Burden Rates | **Bad Funding Profiles**

The following shipyards have incomplete burden data. The burden rate over the missing years is 0%.

Shipyards with missing burden data

Shipyards Name

⏪

Figure D.5—Invalid Funding Data Warning

exercise care when modifying the data on this form. In fact, there are very few reasons to edit the information. However, the data are available to import into another application, such as MS Excel, for further analysis.

GENERATING REPORTS

The last major menu item opens a submenu for the pre-generated report objects (see Figure E.1). These objects are formatted charts and tables based on the calculations and data entered by the analyst. There are three main categories of output. The first, Shipyard Labor, produces charts to analyze the FTE loadings at each of the yards as



Figure E.1—Reports Menu

well as the burden rate effect. The second, **Funding**, generates charts and tables for required funding aggregated at varying levels of detail. The third, **Ship Counts**, produces tables and charts related to the number of active ships per year. The other item on this menu is **Data Sources**, which formats a report of the data source information. To print any of the reports, click the **Print** button on the Access toolbar (or select **File—Print** from the main Access menu).

REPORT FORMATS

Most of the chart reports have a landscape orientation and the table reports have a portrait orientation. A bug in the initial release of Access 2000 causes report orientations to reset to the default settings (usually portrait).¹ This problem is fixed in SR-1a. However, if you have an early version of Access, you can fix the problem by disabling the auto-rename feature. The steps are

1. On the **Tools** menu, click **Options**.
2. In the **Options** dialog box, click the **General** tab.
3. Click to clear the **Perform Name AutoCorrect** check box.
4. Click **OK**.
5. Quit and then restart Access.

To reset a specific report:

1. Select **Page Setup...** option from the **File** menu.
2. Under the **Margins** tab, set all margins to 0.5" for landscape and 1.0" for portrait reports.
3. Under the **Page** tab, select the proper orientation.
4. Close the report and save if prompted.

¹See Microsoft Knowledge Base article Q240826—ACC2000: *Lost Printer Settings When Name AutoCorrect Is Enabled*.

SHIPYARD LABOR

Selecting the **Shipyards Labor** option from the **Reports** menu opens a form where you can select different reports on shipyard labor, overhead, and productivity. The form is shown in Figure E.2.

To view a particular labor output, select a type and format of the output from the various option boxes. Note that not all options are available for each type of output. Various selection choices will “gray out” if the choice is not appropriate. Once all choices have been made, press the **Preview Report** button to display the results.

The main choice is “Labor Data Type.” You have four options:

1. *Required Labor*: Displays a chart or table of required labor.
2. *Effective vs. Required Labor*: Displays a chart of total effective labor at a shipyard contrasted with the total required labor.
3. *Burden Rates*: Displays the burden rates for all shipyards.
4. *Productivity*: Displays the productivity for a shipyard by the labor type.

After you have selected the data type, some additional options may be available. The **Shipyards** option, if active, allows you to select the

RANDMR1743-E.2

The screenshot shows a software window titled "Shipyards Labor Reports" with a subtitle "Labor Output". The window contains several groups of radio buttons and checkboxes. The "Labor Data Type" group has four options: "Required Labor", "Effective vs. Required Labor", "Burden Rates", and "Productivity". The "Labor Units" group has two options: "Workers (FTE)" and "Hours". The "Output As" group has two options: "Chart" and "Table". The "Group By" group has two options: "Ship Class" and "Labor Type". There is also a checkbox for "Include New Build Plan". At the bottom left, there is a "Shipyards" section with a "Show all" checkbox and a dropdown menu. A "Preview Report" button is located at the bottom right.

Figure E.2—Labor Output Form

output for a particular shipyard. The **Show All** check box displays all the yards at once in a summary figure. The **Labor Units** option lets you format the output labor in units of either FTE (heads) or hours. The **Group By** option lets you aggregate by either labor type or ship class. The **Output As** option allows you to select the format of the output. The table option for this selection lets you easily cut and paste data into other programs (such as Excel). The check box **Include New Build Plan** will produce a combined chart and table for the required labor chart by appending a table of the starts for new ships.

Example Output

The next several charts display the various output formats (Figures E.3 through E.7). The data presented do not represent actual values.

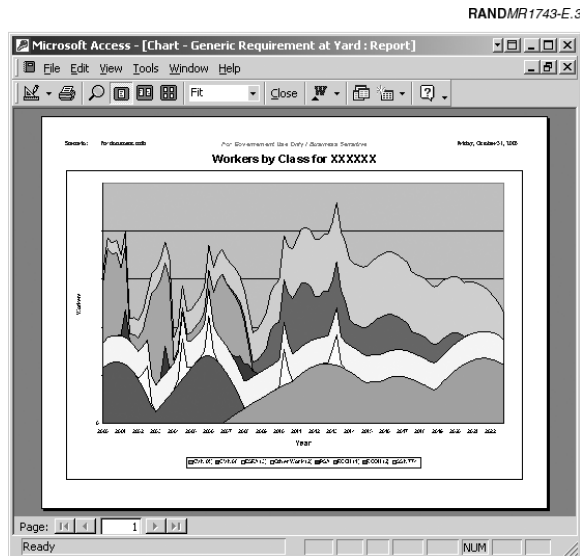


Figure E.3—Required Labor (FTE) at a Shipyard by Class

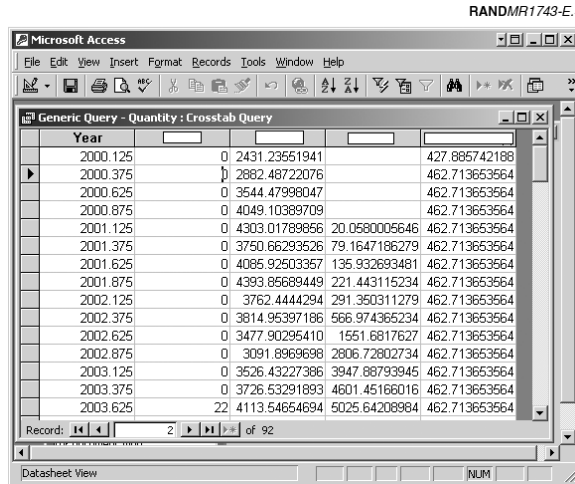


Figure E.4—Required Labor (FTE) by Class as a Table

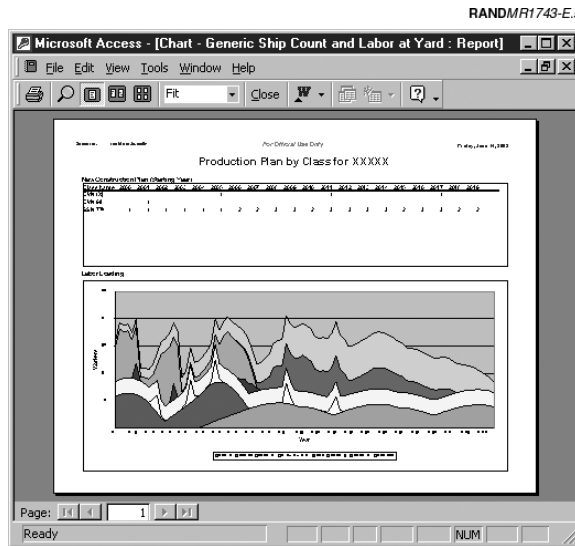


Figure E.5—Required Labor with New Build Table

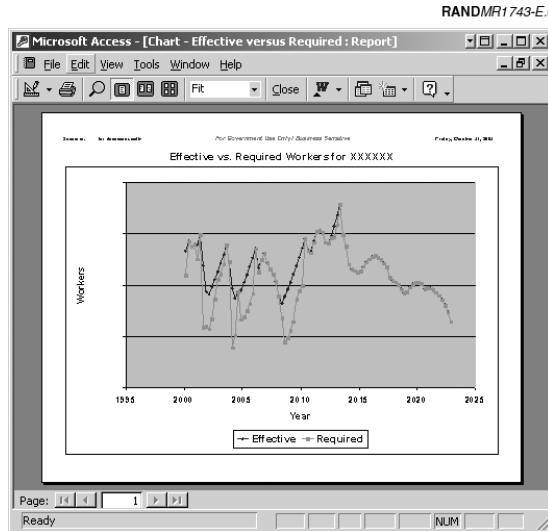


Figure E.6—Required Versus Effective Labor

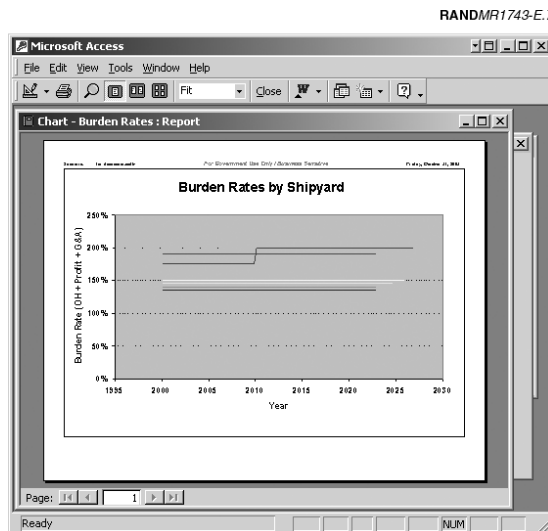


Figure E.7—Burden Rates Report

FUNDING

Figures E.8–E.10 display the funding profiles at varying levels of detail—from the total fleet level to individual class level. The selection form is shown below in Figure E.8. Each level of detail has three different output types:

- Chart: Chart of the data
- Table: Table of numbers to export data
- Report: Formatted table of numbers to print.

At the beginning of the reports, key assumptions (such as the discount rate used) are summarized. Furthermore, any mismatch between the analysis period and the force requirements are noted. An example can be seen in Figure E.9. Note 5 on the report indicates that

The screenshot shows a software window titled "Funding Reports" with a file name "RANDMR1743-E.8". The main content area is titled "Funding Output". It contains two groups of radio buttons. The first group, labeled "Funding Data", has four options: "Summary" (which is selected), "Role", "Hull Type", and "Class". The second group, labeled "Output As:", has three options: "Chart" (which is selected), "Table", and "Report". Below these groups is a button labeled "Preview Report".

Figure E.8—Funding Output Selection Form

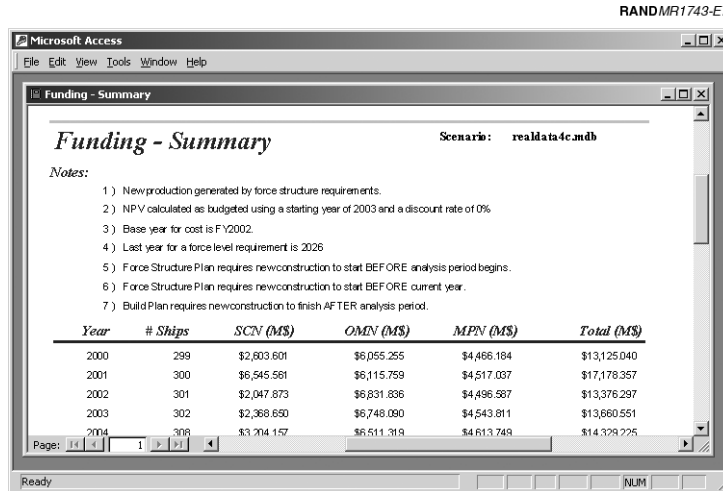


Figure E.9—Detail of Summary Funding by Year Report

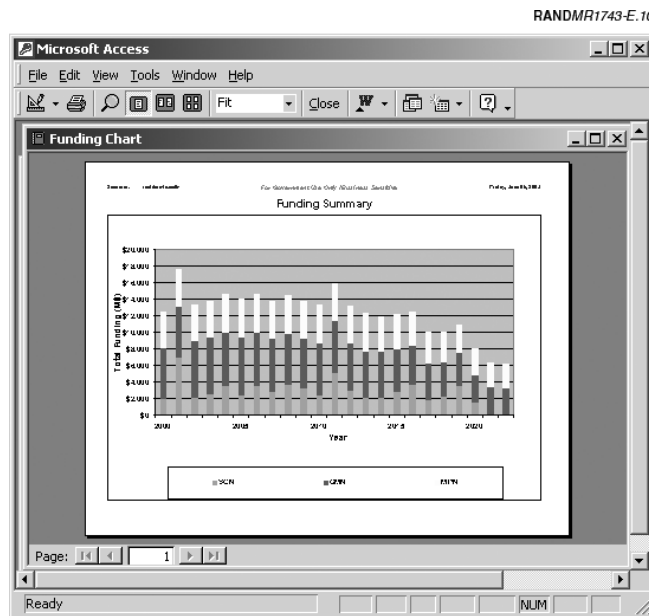


Figure E.10—Chart of Summary Spending

the new construction must begin before the analysis period in order to meet the force level requirements. Further, Note 6 indicates that the new construction starts before the current year. These notes indicate potential problems of either infeasible force structures or possible truncation of the funding data. You will need to use your judgment as to whether the results are misleading. For the example, Note 6 indicates a possible problem with an infeasible force structure. However, the data set was created so that the Force Transition Model would generate new hull construction before the current year as a check to actual plans.

SHIP COUNTS

This group in the **Reports** submenu displays ship count reports.

The four main choices for this output form are

- *# of Active Ships*: Displays the number of ships active in the fleet.
- *Requirements*: A table of the requirements by ship class.
- *New Production—All*: A table of the new construction starts for all shipyards.
- *New Production—Shipyard*: A table of new construction starts at a particular shipyard.

Example Output

Figures E.11–E.15 show sample output for the ship count reports.

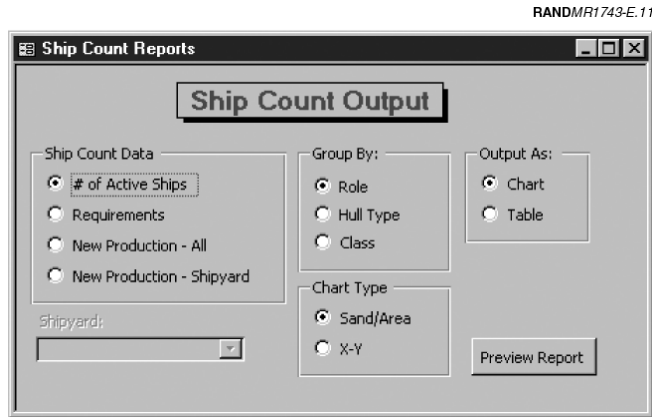


Figure E.11—Ship Count Reports

RANDMR1743-E.12

Year	Aircraft Carrier	Amphibious As	Amphibious C	Amphibious I	Attack Submal	Auxiliary
2000	12	11	2	11	56	
2001	12	11	2	11	55	
2002	12	11	2	11	53	
2003	12	12	2	11	52	
2004	12	12	2	12	51	
2005	12	12	2	15	53	
2006	12	12	2	16	48	
2007	12	12	2	16	47	
2008	12	12	2	17	44	
2009	12	12	2	17	40	
2010	12	13	1	16	38	
2011	12	13		14	37	
2012	12	13		14	36	
2013	12	14		14	36	
2014	12	14		14	35	
2015	11	14		14	35	
2016	11	13		14	36	
2017	10	13		14	34	
2018	10	12		14	33	
2019	9	11		14	34	

Figure E.12—Table of Hull Types by Year

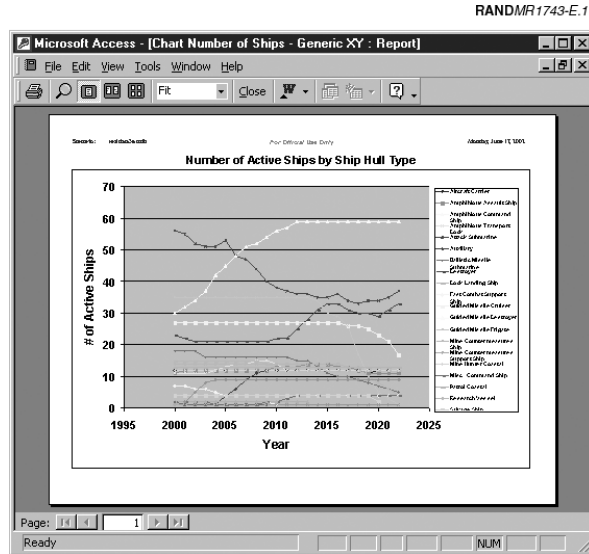


Figure E.13—Hull Types by Year, XY Plot

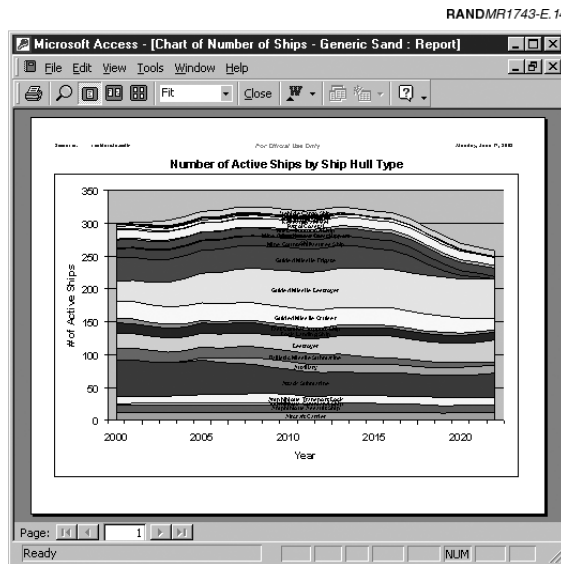


Figure E.14—Active Hull Types by Year—Sand Chart

RANDM11743-E.15

Year	ABC (X)	ABR (Y)	CVN (X)	DD (Z)	DDG (Y)	J
2014						
2015	4					
2016	6					
2017	5					
2018	4					51
2019	4					54
2020						56
2021						57
2022						58
2023				4		
2024				7		
2025				10		
2026				13		
2027				16		
2028				19		
2029				22		
2030				25		
2031				28		
2032				31		
2033				34		

Figure E.15—Table of Ship Requirements

DATA SOURCES

This submenu item (Figure E.16) displays the data source comments entered by the analyst from the form described in Appendix C, “Edit Data Source Documentation.”

QUIT

This main menu item closes the application. Using this method of closing the tool is preferable to using the Access Menu or the **Close** button (the upper-rightmost “x” button). When you end the application with the **Quit** command, the back-end database is compacted and cleaned before the application terminates. This database maintenance should be done routinely because Access tends to create wasted file space after manipulating the data. If you use one of the other methods by accident, it will not harm the file, but the back-end file might be unnecessarily large. Using the **Quit** command before you use that data set for a subsequent session should correct the problem.

RANDMR1743-E.16

The screenshot shows a Microsoft Access window titled 'DataSources'. The report displays a table with the following data:

#	Element	Update Date	Notes
1	Current Fleet	10/10/2001	Information for current fleet, both active and reserve, were obtained from the NVR website: http://www.nw.navy.mil/ . The start year (active in fleet) corresponds to the delivery year.
2	Production in Progress	10/11/2001	Information for current production at the shipyards comes from NAVSEA 017 "Naval Sea Systems Quarterly Progress Report for Shipbuilding and Conversion" dated 01 Jul 2001. It can be obtained on the SEA.017 website.
3	Construction Labor FTE	8/15/2001	FTE for construction activity come from a variety of sources. All new construction comes from labor data provided to RAND from SEA.017 (and converted from by month to by quarter). The NNS availabilities come from NNS proprietary submissions to RAND.
4	Inflation Index	7/19/2002	Deflator index for cost escalation comes from the "Defense

Page: 1

Figure E.16—Data Source Comments Report

COMPARISON UTILITY

During the development of the Shipbuilding and Force Structure Analysis Tool, one of the improvements we were requested to make was adding the ability to compare the results of two data sets. In this appendix, we describe a utility that was created to do just that. The utility is a Microsoft Access file that links the output tables of two data sets created with the tool. With the utility, an analyst can examine how labor, budgets, and ship counts differ between two data sets. This comparison ability allows an analyst to look quickly at the effects of changes in acquisition strategy and force structure plans.

MAIN SCREEN

The opening screen (a switchboard) of the utility is shown in Figure F.1. The main screen has two sections: right and left. On the right side of the switchboard are the menu selection commands. The main options are

- *Select Data Sets*: The user selects the comparison data sets using a standard pop-up window.
- *Update Year List*: The user selects the fiscal years over which the comparison is performed.
- *Labor Differences*: A set of charts and tables appears to allow the user to compare the differences in labor demands between the two comparison data sets.
- *Funding Differences*: Charts and tables show the funding difference between the two comparison data sets.

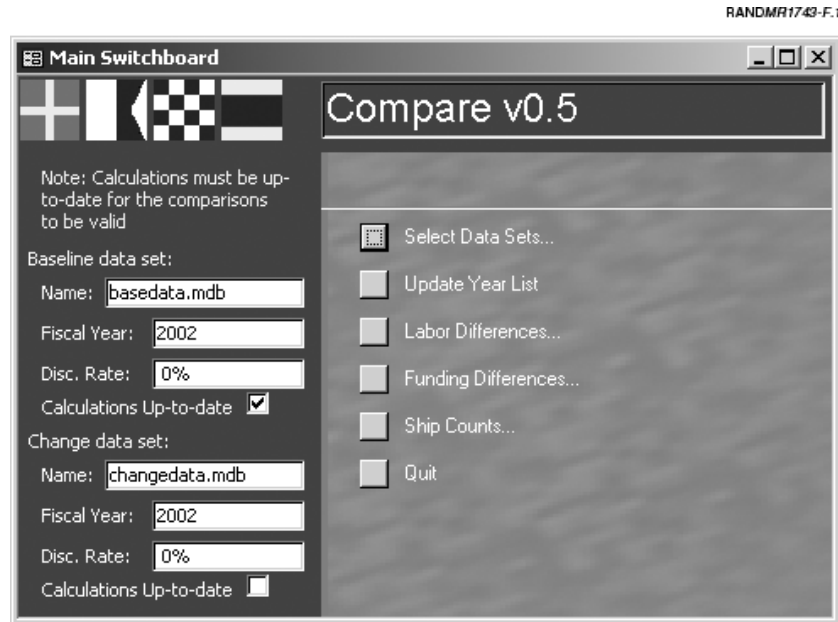


Figure F.1—Main Screen

- *Ship Counts*: Tables and charts show the differences in the number of active ships.
- *Quit*: Closes the utility.

We explore the details for each of these options later in this appendix.

The comparison utility is designed to examine two data sets. On the left side of the switchboard the two datasets are listed. The “Baseline Data Set” serves as the basis from which the changes are measured and the “Change Data Set” is the set after modifications have been made. All the analysis screens and output of the comparison utility show the impact of the “Change Data Set” relative to the “Baseline Data Set.”

The left half of the main switchboard also provides key information about each of the comparison data sets. First, the file names of the

data sets are listed. Next, the base fiscal year and discount rates used for the funding calculations are shown. For any valid comparison of expenditures/appropriations, the values should be the same for both data sets. If not, the user should analyze one of the data sets again using the shipbuilding tool so that the values match. Last, a check box is shown indicating whether or not the calculations are up to date for a particular data set. If the box is not checked, the calculations are *not* up to date. Again, the analyst should redo the calculations for the data set using the shipbuilding tool. In Figure F.1, you can see that the second data set, “Change Data Set,” does not have up-to-date calculations.¹

SELECT DATA SETS

Choosing **Select Data Sets** from the main menu brings up a screen where the user is able to select a new baseline or change the data set. Selecting one of the menu options to change either the baseline or change data set causes a standard Windows **Open File** pop-up to appear, allowing the user to select a new data set.

UPDATE YEAR LIST

When the analyst selects this option, two pop-up windows appear asking for the starting year and ending year for the analysis. These two values set the range for the output for all the comparison analysis. Therefore, if the user selects 2003 as a starting year and 2020 as an ending year, the output will cover fiscal years 2003 through 2020 (provided that data exist for those years).

LABOR DIFFERENCES

This menu option opens a pop-up window that lets analysts examine the differences in labor at the shipyards between the two data sets. The pop-up is shown in Figure F.2.

¹An important qualification is that the tool is only able to track changes and determine whether the calculations are up-to-date when data changes are made through the interface windows and forms. The tool will not recognize any changes made directly in the Access tables.

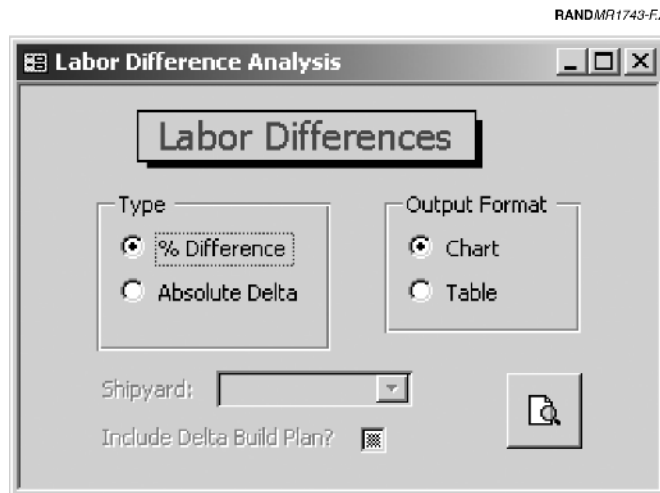


Figure F.2—Labor Differences Pop-Up Window

From this window, the user can choose to examine the labor differences as **% Differences** or **Absolute Delta**. The percentage differences are relative changes from the baseline. All shipyards are shown on one graph or table. For the absolute delta, one shipyard is shown (and must be selected before displaying). With the absolute delta option, the user can optionally select to display the relative change in the build plan (delta build plan) on the chart. This table displays where work starts have been changed for the yard in question. Figure F.3 shows an example of such a chart—this one in which the start for a ship has been delayed one year.

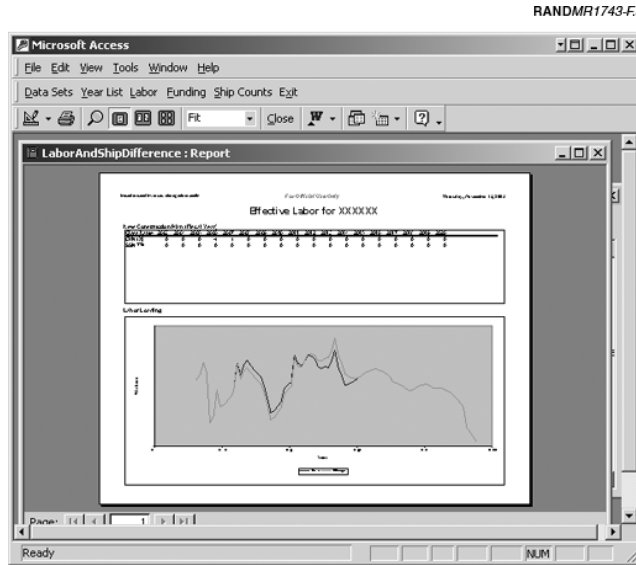


Figure F.3—Example Absolute Delta Labor Graph with Delta Build Plan

FUNDING DIFFERENCES

The **Funding Differences** option from the main menu opens a sub-screen of the switchboard, shown in Figure F.4. The user is given the option to produce a chart, table, or report of the funding differences between the two data sets. Figure F.5 shows a highlight of the funding difference table.

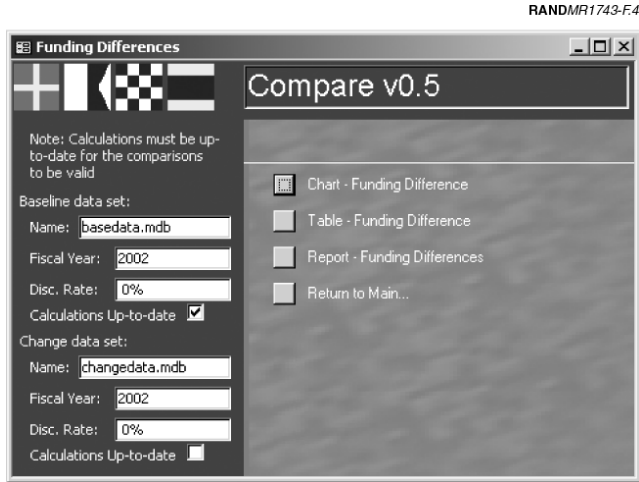


Figure F.4—Funding Differences Menu

Year	deltaShips	deltaSCN	deltaOMN	deltaMPN	Total
2003	0	(\$0.095)	\$0.000	\$0.000	(\$0.10)
2004	0	(\$0.943)	\$0.000	\$0.000	(\$0.94)
2005	0	\$0.666	(\$0.143)	\$0.000	\$0.52
2006	0	(\$2,302.551)	\$0.000	\$0.000	(\$2,302.55)
2007	0	\$2,312.356	\$1.043	\$0.000	\$2,313.40
2008	0	\$4.166	\$0.000	\$0.000	\$4.17
2009	0	(\$0.938)	\$0.000	\$0.000	(\$0.94)
2010	0	\$0.168	\$0.620	\$0.000	\$0.79
2011	0	(\$7.975)	\$0.000	\$0.000	(\$7.98)
2012	0	(\$2.651)	\$0.437	\$0.000	(\$2.21)
2013	0	(\$2.118)	\$0.000	\$0.000	(\$2.12)
2014	0	(\$1.777)	\$0.000	\$0.000	(\$1.78)
2015	-1	(\$0.565)	\$0.000	\$0.000	(\$0.57)
2016	0	(\$0.226)	\$0.000	\$0.000	(\$0.23)
2017	0	\$0.000	\$0.000	\$0.000	\$0.00
2018	0	\$0.000	\$0.000	\$0.000	\$0.00

Figure F.5—Funding Differences Table

SHIP COUNTS

The last major menu item allows the analyst to examine differences in the number of active ships or produced ships based on the changes between the two data sets. Figure F.6 shows the pop-up window that opens when this switchboard option is selected.

The first selection option on the window, Delta, lets the user choose between differences in production (i.e., the number of production starts) and the number of active ships. Next, Group Results By allows the user to summarize the results based on the various ship categories based on the various ship categories (see Appendix G). Last, the analyst is given the choice of the output format: either a table or a chart. Figure F.7 shows a table of the delta number of active ship by role.

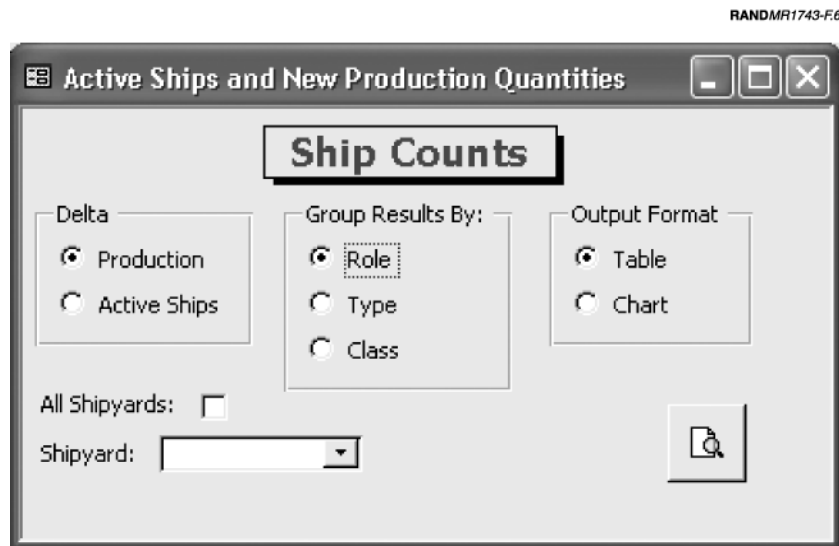


Figure F.6—Ship Counts Pop-Up Window

RANDMR1743-F7

ShipRoleType	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aircraft Carrier	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
Amphibious	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
Auxiliary / Support	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
Mine Warfare	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
Submarine	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
Surface Combatant	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0

Record: 1 of 6

Datasheet View

Figure F.7—Delta Ship Production by Ship Role

SHIP ROLES, HULL TYPES, AND CLASSES

Table G.1 on the next page provides a list of ship roles, hull types, and classes.

Table G.1
Ship Roles, Hull Types, and Classes

Ship Role	Hull Type	Ship Class
Aircraft Carrier	Aircraft Carrier	CV 63, CVN 65, CV 67, CVN 68, CVN (X)
Amphibious	Tank Landing Ship Dock Landing Ship Amphibious Assault Ship Amphibious Transport Dock	LST 1179 LSD (X), LSD 36, LSD 41, LSD 49 LH (X), LHA 1, LHD 1 LPD 1, LPD 14, LPD 17, LPD 7
Auxiliary/Support	Auxiliary Fast Combat Support Ship Research Vessel Salvage Ship Submarine Tender Ocean Surveillance Ship Surveying Ship Vehicle Cargo Ship Misc. Command Ship	ADC (X), AO (X), ATF AOE (X), AOE 1, AOE 6 AGER 2, AGSS 555 ARS 50 AS 39 AGOS 23 AGS 60, AGS 65 AKR 300, AKR 310 AGF 11, AGF 3, JCC (X)
Mine Warfare	Mine Hunter Coastal Mine Countermeasures Ship Mine Countermeasures Support Ship	MHC 51 MCM (X), MCM 1, MCS (X) MCS 12
Patrol	Patrol Coastal	PC 1
Submarine	Attack Submarine Ballistic Missile Submarine	SSN 21, SSN 637, SSN 640, SSN 688, SSN 774 SSBN 726
Surface Combatant	Destroyer Guided Missile Cruiser Guided Missile Destroyer Guided Missile Frigate	DD 21, DD 963 CG 21, CG 47 DDG 51 FFG 7
Unclassified		

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