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6 A SURVEY OF NAVY COST
MODEL INPUT VARIABLES
AND THEIR DATA SOURCES

by

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EXECUTIVE SUMMARY

This survey of cost model input variables and their data sources is part of a series of tasks, sponsored by the U.S. Navy HARDMAN Development Office (OPNAV 112C), aimed toward the development of cost models which will be used by the Navy and industry to facilitate design/cost tradeoff analysis during the Weapon Systems Acquisition Process (WSAP). The survey was undertaken to determine whether the input data requirements of proposed HARDMAN cost models are consistent with and can be met by existing Navy data sources.

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We concluded that the required source data are available for almost all input variables to the cost models. However, the data are widely dispersed, thus difficult and time consuming to obtain. Further, since most data bases are not originally intended to be used as source data for cost analysis, the information in the bases is often not in the form required for input to cost models. To convert the data into an appropriate form requires additional analysis. The problems this analysis must overcome include inappropriate level of detail, the inclusion of undesired additional cost elements, and the use of average cost data when marginal data are required. The time and effort required to assemble a complete data set is likely to discourage the use of HARDMAN models during the early phases of the WSAP.

To overcome these problems, we recommend that the HARDMAN Development Office be able to convert source data into a form appropriate for HARDMAN cost models. This information would be made available to model users, and would be specifically geared to the needs of individual projects. This approach assures that model inputs will be accurate, appropriate, up-to-date, and available when needed. It will also add authority to the models and encourage their use.

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1.0 INTRODUCTION

This survey of input variables and their data sources is part of a series of tasks, sponsored by the U.S. Navy HARDMAN Development Office (OPNAV 112C), aimed toward the development of mathematical cost models which will be used by the Navy and hardware manufacturers to facilitate design/cost tradeoff analysis during the Weapon Systems Acquisition Process (WSAP). The original HARDMAN Study Report recognized that the incorporation of design/cost tradeoff analysis--and in particular hardware/manpower tradeoff analysis--in the WSAP is an essential step in reducing the life cycle cost of a proposed weapon system.* In an earlier report for HARDMAN, The Assessment Group proposed a system of "linked and graded" computer life-cycle cost models as a tool to effect such tradeoffs, and developed a set of methodological guidelines to construct these models.** A Demonstration Model System (DMS) was then developed to test the feasibility of the guidelines and to extend some of the concepts introduced there.*** To remain open to other techniques in cost analysis,

* Military Manpower Versus Hardware Procurement (HARDMAN) Study Report, Office of the Chief of Naval Operations, Washington, D.C., 1977.

** Neches, T. and R. Butler, "Guidelines for Hardware/Manpower Cost Analysis," PR-A100-2, The Assessment Group, Santa Monica, 1978 (for OPNAV 112C, contract number N00014-77-C-0809).

*** Neches, T., et al., "Demonstration Model System." Vols. I-V, PR-A101, The Assessment Group, Santa Monica, 1979 (for OPNAV 112C, contract number N00014-78-C-0465).

a review of current cost and manpower estimation techniques was undertaken in the hope of finding other useful approaches to design/cost tradeoff analysis.* This review of Navy data sources was then undertaken to determine whether the input data requirements of the DMS are consistent with and can be met by existing Navy data sources. The results of this survey were largely positive, as we discuss in the next section.

This review is keyed very closely to the DMS: our starting point was a list of input variables used in the models. For each variable we attempted to answer the question: Where would one go and what must one do to obtain the best estimate of the actual value of this variable? ** The main advantage of this approach is that it provided a focus for the survey; otherwise the list of potential inputs to a hypothetical Navy model would be inexhaustibly long. The DMS provides good coverage of potential cost model input variables because it includes a wide variety of cost elements at differing levels of complexity. *** However, we make no claim to have considered every input element used

* Neches, T., et al., "A Review of Current Manpower and Cost Estimation Methodologies," PR-A103, The Assessment Group, Santa Monica, 1979 (for OPNAV 112C, contract number N00014-79-C-0216).

** For clarity's sake, throughout this report we will deliberately blur the technical distinction between the actual value of a variable, which is in many cases unknowable (in a statistical sense), and a good or best estimate (again in the statistical sense) of the value of that variable.

*** The DMS has three levels of complexity. Level I, the most simple, requires a limited number of aggregate average input values, while Level III requires a great deal of detailed, system specific data.

in most cost models--even our own. The list of variables included here should be considered to be representative, not exhaustive.

With one exception, we do not provide separate descriptions of the individual data sources referenced in this report. Rather, for each variable we discuss how an existing data source could be exploited to provide a value for that variable. The single exception is the 3-M (Maintenance and Material Management) Data System. This system is the data source for so many different variables (and the data base for other data sources) that we felt it was important to pass on our understanding of the system, achieved during the course of performing this study. We must emphasize that all descriptions are in no way meant to be critical reviews of the data sources.

The variables themselves break down into three major categories: Navy environment, system operating environment, and system design. Navy environment variables describe the Navy as a whole, and do not depend on a particular system or individual system design. Example Navy environment variables include personnel attrition rates, billet costs, and available work hours. System operating environment variables depend on the type of system, but usually do not depend on individual system designs. They include such variables as the number of ships on which a system may be deployed, annual system operating hours, or the number of years in the system life cycle. The last group of variables could be further divided into two groups--system

support policy and system design variables. We prefer, however, to consider the two groups as one because of our philosophy that the support policy is an integral part of the system design.

Support policy variables include such inputs as the desired confidence level against stockout, the fraction of equipment components coded local repair, or the number of training days required for maintenance personnel. System design variables, of course, describe individual system configurations and include such variables as system unit production cost, mean time between failure, required number of operators, or number of repairable components.*

Values for Navy environment and some system operating environment variables can be derived based on analysis on historical data and can be applied to a wide range of potential systems. In contrast, values for system design variables are dictated directly by design, and must be estimated by the designer based on his judgment and experience. In some cases, however, historical data can provide guidance for the designer.

There is a large body of Navy data sources that can be tapped to provide historical values for input variables. A major source for maintenance data, for example, is the Navy Maintenance Support Office (NAMSO), located in Mechanicsburg, Pa. NAMSO is the central data bank for Navy maintenance data and

* The division of input variables into these three groups is somewhat arbitrary, of course. It is often not clear-cut--or important--to assign a given variable to a particular variable class.

is responsible for the preparation and distribution of all 3-M Data System reports. Training cost data are available through the Chief of Naval Education and Training (CNET), located at Pensacola, Fl. CNET maintains extensive data on every training course given by the Navy. Personnel cost data are available in the various billet cost model reports produced by the Naval Personnel Research and Development Center (NPRDC), San Diego. Other major data sources include NAVWESA (Naval Weapons Engineering Support Activity), located in Washington, D.C., NODAC (Naval Occupational Development and Analysis Center), located in Washington, D.C., the NALCOMIS-O&S (Naval Aviation Logistics Command Management Information System--Operating and Support), under the direction of the Naval Aviation Logistics Center (NALC) located at Patuxent River, Md., and the VAMOSC-AIR and VAMOSC-SHIPS Reporting System (Visibility and Management of Operating and Support Costs), under the direction of NALC for AIR and NAVSEA for SHIPS. A complete list of data sources is provided in an appendix to this report.

The remainder of this report is organized as follows. We present our research findings in Section 2, and recommendations in Section 3. Appendix A is divided into three sections corresponding to the three types of input variables. For each variable a brief description of the variable, its use in the DMS, and a source and method for obtaining an input value is provided. Appendix B provides a complete list of agency and document data

sources referenced in this report. Finally, Appendix C provides a brief description of the 3-M Data System. We emphasize again that this description is in no way intended to be a critical review.

2.0 FINDINGS

The main finding of this study is positive: the data are available to meet cost model input requirements. This does not mean, however, that the data are always easy to obtain or are always in the form we would like. In fact, considerable time and effort would be required to assemble a complete input data set to run the DMS, starting from scratch. The time constraint in particular would be detrimental to the use of the DMS during the early phases of the WSAP: it would defeat the purpose of the tradeoff model systems to have the models up, running and ready, only to lie idle as model users generate the required non-design-related input data. We believe that the solution to this problem is that the HARDMAN Development Office be able to provide timely and accurate input values to model users. We discuss this in greater detail in Section 3.

In attempting to assemble a data set for a model, there are two main tasks--data collection and data analysis. Each task presents its own problems in connection with the input data for the DMS. We discuss these in Sections 2.1 and 2.2.

2.1 DATA COLLECTION

Historical Navy data need be collected and provided to model users only for the Navy environment variables and to some extent the system operating environment variables. In the first case

users must be provided with a wide range of input values. For example, designers must know the annual billet costs and attrition rates of potential system maintenance personnel; the need for and the choice of a particular rate/rating/NEC is then determined by the system design and support philosophy. The input data requirements for system operating environment variables, on the other hand, tend to be more specific. For example, designers working on a modification to an existing equipment may need to know the number of ships on which the system is deployed, average system operating hours or the length of a typical deployment period. In this case accurate, timely, and system-specific data must be provided to the designer.

Unlike the first two variable categories, system design data must be generated by the design team. However, historical data from similar systems may still be very useful to system designers. For example, the voluminous records the Navy maintains in the 3-M Data System on the mean time to repair or mean time between failure of radar systems may be of great value as a guide to the designer of a new radar system--if the designer is sufficiently familiar with the 3-M reports to interpret the information presented in them properly. For all system design variables the information provided would only be a guide to the input values, not the actual values themselves.

One need only review the list of major data sources presented in the previous section to understand the difficulty of obtaining

values of all the Navy environment and system operating environment input variables to the DMS. The data are widely dispersed: practically every corner of the continental United States appears to be represented. Since there is no single, central location to which one can go to obtain input data values, the time, effort and expense necessary to assemble a complete data set for a new system could be considerable. In addition, the information desired is not always available through a regularly published report, but rather must be obtained through special request. Naturally, there is considerable delay and effort involved in processing such requests. By the time the information is available, it may be too late for it to be useful.

In spite of the difficulties in data collection, the data are available for most input variables of the DMS. There were, however, elements of two variables for which we could not find information. The first was the average cost of ship's modifications to accommodate an additional crew member on a platform. This cost is part of the input variable Z_s , the total cost of adding personnel to a ship. There is ample data on the other major element of Z_s , Permanent Change of Station (PCS) costs. The variable Z_s is used in the DMS to convey to the designer the cost difference between utilizing personnel already onboard ship and requiring that new personnel be added to the platform. Since the PCS element of Z_s is significant (approximately \$1300 per person), the variable will still fulfill its function without

the additional information on the cost of ships' modifications. Therefore, the lack of these data as input to the DMS should not significantly hamper the models' usefulness as a design/cost tradeoff tool.

Another input for which data could not be located was LRT_s , the average shipboard response time for non-aviation equipments.* There are ample data on local response times for aviation equipments: these values may be used as a substitute for LRT_s . Another substitute is a policy variable representing the minimum required days of stockage for an assembly. (The DMS uses response times in the calculation of stockage levels--spares must be purchased to cover potential failures during repair lead times. Often, if a shipboard assembly is stocked at all, it is required to be stocked to a minimum lead time set by Navy policy.) These substitutes make the absence of LRT_s data less important than it otherwise might be.

There were three sets of variables for which further conceptual work is required. While in all three cases source data are available, the data may turn out to be inadequate once the variable definitions are refined. The first variables are the cost of item entry and management in the National Stock System. The nature of this system makes it a difficult task to determine how costs should be allocated to individual items. The second set

* The term "aviation equipment" refers to all aircraft, drone, and missile components and related ground support equipment. It is often confused with "avionics equipments," a subclass of aviation equipments.

represents the sizes of the pools of available manpower onboard ships. Findings on the distributions of the pool sizes indicate that modifications to the manpower cost equations used in the DMS, in which the manpower pools play an essential role, may be required. Finally, in the course of our research on the labor utilization rate (the fraction of work time actually spent on productive labor) we were led to the conclusion that this variable should be dropped from the DMS.

Summary

The required source data for almost all input variables to the DMS are available. However, the data are widely dispersed and sometimes difficult to obtain. Appropriate substitutes can be found for most inputs lacking source data, while some variables require further conceptual work.

2.2 DATA ANALYSIS

Few Navy data bases were originally designed to be used as input data sources for life cycle cost models. Rather, they were intended for management and planning applications, and their outputs are directed toward this goal. For example, the 3-M Data System was developed as a management tool to pinpoint problem areas in the use of maintenance manpower and material resources. As a by-product, 3-M can provide a great deal of data useful to cost models like the DMS. However, the format of 3-M outputs does not always coincide with DMS input re-

quirements. After the data are obtained, additional processing and analysis are often required to transform the data into a form suitable for cost models.

A good example of what is involved in this analysis is provided by the input variable Repair Materials Cost (RP), the average cost of materials associated with the repair of a single assembly. While data for this variable are readily available through the 3-M Data System, some analysis is required to extract a value for RP. One must utilize two separate reports: the first presents a total repair materials cost per reporting period and the second provides the total number of repair actions during that period. Dividing the first value by the second yields RP. However, great care must be taken in doing this.

In utilizing the two reports, one must be certain that the time periods represented in the two reports correspond, as well as the number of ships in the report, equipment types and so on. Further, one must be aware that since all maintenance actions are not reported through the 3-M System (while most material requisitions are) the value of RP using this approach is likely to be somewhat high. On the other hand, this overstatement will be offset by the fact that the reported materials cost does not include all purchases (e.g., items bought in bulk are excluded). This example highlights a general rule: to develop a reasonable estimate of an input data element, one must

be extremely familiar with the usage, formulation and basis of the data source used.*

The data available in many sources are often at an inappropriate level of detail to be of general application. Usually the data are too detailed rather than too general. For example, CNET provides detailed cost breakdowns of individual training courses and NAMS0 provides detailed information on the maintenance record of a particular piece part in a particular aircraft type/model/series (T/M/S). More aggregate, general values can only be obtained after additional analysis. It is possible--indeed, not even particularly difficult--to accomplish this processing: both CNET and NAMS0 can provide reports in almost any format requested to retrieve the desired data. However, to do so requires a special request entailing additional processing and delay.

Another problem is that data may be available only in a form including cost factors which the models treat as distinct elements. While in some cases it is not difficult to reformat the input requirements of the models to correspond to the form of the input data, in other cases this is not desirable. For example, the current values of annual personnel billet costs provided in the Enlisted Billet Cost Model (EBCM) include amortized portions of the cost of specialized training associated with each

* An excellent and very detailed example of the importance of this rule is provided in the discussion of the variables MTBF, MTRR and MTRR, in Appendix A.

billet. It is an essential element of the DMS tradeoff analysis approach that training be considered separately from other personnel compensation costs so that training costs can be linked directly to design. Therefore, the billet cost values from this model must be extensively modified to be used appropriately in the DMS.* Some other input variables have similar definitional problems, but they are usually much simpler to deal with.

Another way in which some data sources may not coincide with the DMS input requirements is in their use of average (versus marginal) costing. The basic purpose of the DMS is to provide comparative estimates of the marginal costs of alternative designs of a proposed weapon system. To this end, many of the variables used in the DMS are defined in terms of the cost of an additional unit of a good or service. Thus we may be interested in the cost of an additional man stationed aboard a platform or the additional cost to the Navy of providing "A" and "C" school to maintenance personnel for the system. Most data bases, on the other hand, present information in terms of the average cost of a given activity, which is a more useful measure for management and planning. The difference between marginal and average costs can be significant. Consider, for example, a capital intensive training course which has the capacity to expand to meet additional student demand (such is the case in

* Work on a study to better understand and to correct the differences between the EBCM and DMS has been initiated.

many courses utilizing a computer). While the average per student training cost, as presented in CNET reports, may be high, the marginal cost of adding additional students to the course may in fact be much less. Marginal cost information can be extracted from most data bases, but to do so is often a difficult task requiring extensive analysis.

Summary

Since most data bases are constructed for purposes other than cost analysis, the information contained in them is often not in the form required for inputs to cost models. The required information can usually be extracted from the data base, but to do so requires additional analysis and a detailed understanding of the original data source. Some of the problems which this data analysis must overcome are inappropriate level of detail, the inclusion of undesired additional cost elements, and the availability only of accounting data when marginal data are required.

3.0 RECOMMENDATIONS

In Section 2 we reported that, while data for most input variables to the DMS are available, the information is widely dispersed, requiring considerable time and effort for initial data collection. Further, in many cases additional processing is required to convert the data to a form appropriate for cost models. These considerations may hamper the utilization of HARDMAN models during the early phases of the WSAP.

To overcome these problems, we recommend that the HARDMAN Development Office initiate an ongoing data analysis capability, which will act as a central source of input data for all HARDMAN models. We further recommend that only existing data bases be utilized; it is not necessary for the HARDMAN Office to initiate new source data collection efforts. The second recommendation is based on our finding that current sources can meet HARDMAN model input data requirements and our appreciation, gained during the course of this study, that Navy data collection requirements have reached the saturation point.

The HARDMAN data analysis capability (which we shall abbreviate DAC) should work in parallel with the model builders. Each time a HARDMAN model is used on a project, an input data guide should also be provided. The guide would be similar in structure to the Mod-III Default Data Guide provided by NAEC for users of the 1390B Avionics Level of Repair Model, but will

have greater scope.* The guide will provide not only the best current estimates of all Navy environmental variables used in the model, but values of system-specific operating environment variables and possibly historical guides to some system design parameters as well. In addition to providing the guides, the DAC should be able to respond quickly to requests for additional information from government and industrial users of HARDMAN models.

The main function of the DAC would be to collect data from existing data sources (e.g., the 3-M Data System, CNET Training Cost Reports, NPRDC Personnel Billet Cost Reports) and to transform the data into a form appropriate for use as inputs to HARDMAN cost models. In many cases little or no processing would be required: the DAC would utilize existing reports to the greatest extent possible. In other cases the DAC would process source data provided to the DAC from Navy data bases. (Two major data sources, NAMSO and CNET, have already expressed a willingness to provide the HARDMAN Development Office with copies of their master data tapes. In fact, they consider it an essential part of their task to provide such service.)

* See, "Naval Air Systems Command Avionics Level of Repair Model, MOD-III Default Data Guide," U.S. Naval Weapons Engineering Support Activity, Washington, D.C. (Responsibility for the production of the Default Data Guide has recently been transferred from NAVWESA to the Naval Air Engineering Center (NAEC). Due to the difficulties of transfer, the next update of the Guide will not be available before late 1980. The most recent guide was published by NAVWESA in November 1978.)

The processing of the data need not require a major level of effort. For example, HARDMAN can utilize an existing data network, AMPAS (Analytical Maintenance Program Analysis Support), specifically designed for the analysis of 3-M maintenance data. For avionics data, AMPAS will soon be superseded by a more powerful system, NALDA (Naval Air Logistics Data Analysis), which will allow interactive processing and analysis of 3-M data from terminal hookups. For other data sources, HARDMAN can take advantage of recent advances in computer technology which make it possible to process extremely large data banks using inexpensive micro- and mini-computers. Thus, expensive computational facilities will not be required.

We feel that this approach offers several advantages. It assures that inputs to the model will be accurate, appropriate, up-to-date, and available when needed. In addition, model users will know exactly where to obtain system-specific information. This will add an air of authority to the models, and will encourage their use. Finally, it will provide a brake to the dangerous "mad-modeler syndrome": model builders will be required to provide data sources and default values for all inputs, assuring that models will not be constructed for which input data are not available.

APPENDIX A: INPUT VARIABLE REVIEWS

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A.1 NAVY ENVIRONMENT VARIABLES

- DC: Average daily cost per student of attending a "C" School training course. This value includes student and instructor salaries, administrative overhead, travel and daily expenses, and some portion of the amortized costs of equipment used in the training course.
- TA_m: Cost per student of an "A" School training course for maintenance technicians.
- TA_o: Cost per student of an "A" School course for operators.
- Data Sources: Chief of Naval Education and Training, NAS Pensacola; Mod-III Default Data Guide.

The two "A" school variables in the DMS represent the cost to the Navy of providing "A" school to a maintenance technician or an operator. These are input variables in the Levels II and III models, while in Level I a single average "A" school training cost is used. DC, the daily cost of "C" school training is a single input in the Level II model, while in Level III "C" school costs are determined as a function of overhead costs for the school, travel costs, temporary duty costs and salaries.

The Chief of Naval Education and Training (CNET), located at NAS, Pensacola, is the major repository for information regarding the costs of Naval training. Statistical reports periodically produced by this office break down Navy training costs by total cost per graduate, cost per student per week, total course cost and costs per training activity. Each of these aggregation levels is also broken down by major accounting category (e.g., MPN, OMN, PCS). CNET does not cover non-Navy courses, such as those

given by other services, other government agencies, or private contractors. Data on the costs of such training courses must be obtained directly from the training activity.

A major problem in training cost estimation is the proper allocation of cost of the capital assets associated with a training course. As the training cost variables are presently defined in the DMS, the appropriate portion of the amortized value of capital assets used in training must be included in the value of these variables. For example, if a flight training course requires the exclusive use of an airplane, then clearly the entire cost to the Navy of that aircraft must be considered as a part of the per-student training cost. Unfortunately, such neat usage divisions of capital stock seldom exist. Whenever a capital resource is shared among two or more activities, the method of allocating portions of the cost of the asset among the activities is always somewhat arbitrary. The proposed VTXTS Undergraduate Jet Flight Training System provides a good example of the problems involved. Questions to be resolved include the fraction of the cost of the proposed aircraft to be allocated to its secondary role as a light attack fighter and the fraction of the costs to be allocated to the different courses (e.g., ECM, instrumentation, Radar) utilizing the VTXTS.

CNET's approach to capital cost allocations is straightforward: the depreciated cost of capital equipment is prorated to individual training courses based on utilization ratios. In addi-

tion, a general overhead and administrative cost is allocated equally to all courses.

The average per-student training costs presented in CNET reports is computed by dividing the total course costs (including capital costs) by the number of students in the course. To obtain a proxy for the marginal cost of training an additional student, the cost of capital equipment should be removed from the total training cost before dividing by the number of students, then be treated separately.*

The training cost breakdown in the Level III model is not congruent with that provided in CNET reports. The Level III model defines the daily "C" school training in terms of a one-time travel cost plus a daily per diem, a school overhead figure, and a daily course cost (salaries of students and teachers). CNET produces statistics which aggregate the daily per diem costs with the cost of travel to and from the course. Thus, in CNET reports the costs which vary with the number of days of the course are not distinguished from those whose magnitude depends only on the existence of the course (i.e., travel costs may not increase because the course is longer, while TDA [Temporary Duty Allowance] costs do). CNET data can meet DMS training cost input requirements. However, because of the distinction

* The Level I and II models of the DMS do not provide for this distinction between the fixed capital costs of resulting from the existence of a training course and the marginal costs of increasing the number of students in the course. Future versions of the DMS should be modified to incorporate this distinction.

between marginal and average costing, and the differences in training cost breakdown structures, additional processing would be required to modify CNET reports to coincide with DMS needs.

Finally, we note that the MOD-III Default Data guide has used CNET data to derive an average training cost of \$16.64/hour/student.

- BN_m: The undiscounted annual billet cost for a maintenance technician required to service the system.
- BN_o: The undiscounted annual billet cost for a system operator.
- BG: The undiscounted annual billet cost for a general labor NEC billet.
- BD: The undiscounted annual billet cost for a maintenance technician at a military operated depot.
- BO: Undiscounted annual billet cost for an officer required to supervise system operation.

Data Sources: Koehler, E. Life Cycle Navy Enlisted Billet Costs--FY 79. NPRDC Special Report 79-13, March 1979.

Koehler, E. Life Cycle Navy Officer Billet Costs--FY 79: An Interim Report. NPRDC Special Report 79-20, May 1979.

Butler, R. and S. Cylke, "The Civilian Billet Cost Model," AG-PR-A102, The Assessment Group, Santa Monica, 1979.

The DMS breaks manpower costs down into three categories: compensation, training, and other costs. In all three levels of the DMS, the variables above represent the compensation costs of the billet categories employed by the DMS.

The output of the Navy's Enlisted Billet Cost Model (EBCM) is the best available data source for the variables BG, BN_m, BN_o, and BD. The EBCM user should be aware, however, of certain problem areas when using the models. Cost definitions, amortization techniques used, and average versus marginal cost analysis represent some of the differences between the DMS and EBCM approach to personnel costing. Work is currently underway

to better understand and to correct these differences. For the variable BO, the Officers Billet Cost Model is recommended. For civilian counterparts to military billets, the Civilian Billet Cost Model (CBCM) is recommended. CBCM outputs should be released as an NPRDC Special Report in early 1980.

- WH_m: Number of hours available per week for assigned work for maintenance personnel.
- WH_o: Number of hours available per week for assigned work for operators.
- WH_d: Number of hours available per week for assigned work for depot maintenance personnel.
- Data Sources: OPNAVINST 1000.16D, OPNAV 10P-23, NAVMACLANT/PAC

These three variables help determine the total demand for maintenance and operating personnel generated by a particular hardware system. An important source of data on Navy personnel is provided by two major field components of the Navy Manpower Requirements System, the Naval Manpower and Material Analysis Centers, Atlantic and Pacific (NAVMACLANT/PAC). Other Navy organizations which play an important role in the measurement, determination and documentation of Navy manpower requirements are: the Naval Aviation Integrated Logistics Support Center (NAILSC), the Personnel and Training Analysis Office (PATAO) of the Naval Sea Systems Command, and the Naval Ship Engineering Center (NAVSEC). Available work hours for Navy personnel are utilized in the Ship Manpower Documents (SMD), Squadron Manpower Documents (SQMD) and the Shore Manpower Documents (SHMD), which serve as the basis for Manpower Authorizations (MPA).

The Navy guidelines for calculation of these three variables are contained in OPNAVINST 1000.16D, Manual of Navy Officer

and Enlisted Manpower: Policies and Procedures. The Navy Standard Workweeks are defined in Article 509. Navy workweeks indicate criteria for sustained personnel utilization. They are not necessarily an expression of the maximum weekly workhours which may be expended by an individual, but rather the average weekly workhours expended during an extended period. As an example, consider the sea portion of the Navy Standard Workweek Afloat. In assigning values, OPNAVINST 1000.16D assumes a war-time environment with the unit steaming in Condition III (Wartime Cruising Readiness) on a three section watch basis.* The values are:

Maximum Objective Workweeks at Sea

	Watchstander	Non-Watchstander
<u>Total</u>	<u>74</u>	<u>66</u>
Watch	56	--
Service Diversions and Training	4.5	6.0
Scheduled Work	13.5	60.0

Total hours are obtained by subtracting from the number of hours in the week time for sleep, messing, personal needs and free

* The DMS also may require information on manhours availability during Manning Readiness Conditions I-V: Battle Readiness; Battle Readiness-Limited Action; Wartime Cruising Readiness; Peacetime Cruising Readiness; and In-Port Readiness. This information is available in OPNAV 10P-23, "Guide to the Preparation of Ship Manpower Documents," currently under revision.

time. Service diversion and training hours are usually significantly greater in Condition IV (Peacetime Cruising Readiness).*

From this point, available workhours are further diminished by a productivity allowance to account for time lost due to fatigue, environmental effects, personal needs, make ready/put away time and unavoidable interruptions. Some of these factors may already be included in the values of the variables MTTR (mean time to repair) and U (labor utilization rate). It is important to be aware of this to avoid double counting.

* OPNAVINST 1000.16D, pg. 5-20.

U: Labor utilization rate.

Data Source: NALCOMIS-O&S/VAMOSC-AIR System Description Manual, Volume II.

The Level II and III models of the DMS contain a number of variables which deal with the allocation of a maintenance technician's time into various activities. The variable U describes the fraction of direct work time actually spent performing maintenance actions, and is used in the calculation of maintenance manpower demands. In the Level III model, the distinction is made between local and depot utilization rates. In the Level II model no such distinction is made.

Detailed in the VAMOSC-AIR System Manual,^{*} is the method used to determine for aviation maintenance technicians the fraction of a work shift during which productive labor is performed.

The U variable is defined in VAMOSC-AIR (MS) in terms similar to the U_m of the Level III model. The value of U is calculated using the following equation:

$$U = \frac{\text{documented direct maintenance manhours (DMMH)}}{\text{available maintenance manhours (MMH)}_{av}}$$

where DMMH = the sum of manhours reported through the 3-M system for a given month including scheduled and unscheduled maintenance and support actions and scheduled TDC actions at the organizational level, and a lump sum figure for hours reported at the intermediate level.

^{*} NALCOMIS-O&S/VAMOSC-AIR System Description Manual, Volume II, Maintenance Subsystem (MS), NALC, November 1977.

MMH_{av} = The number of technicians on-board for a given month multiplied by the number of hours worked per month.

VAMOSC-AIR MS then establishes these values for MMH_{av} :

$MMH_{av}(\text{afloat}) = 210 \text{ hrs/month,}$

$MMH_{av}(\text{ashore}) = 168 \text{ hours/month.}$

The utilization rate in the DMS is used to convert net hours on the job to net hours of delivered labor. The first is a personnel concept obtained by starting with a number like those above and removing a variety of factors which take workers away from their stations: service diversions, leaves, transient, prisoner and patient status and training duty are the major influences. What is left tells us how much the average worker is actually available to the job. It still doesn't tell us how much work he performs in terms consistent with the performance measurement called mean time to repair. MTTR is a sort of, "On your marks, . . ." concept used in the computation of operational availability. In order to use it as a legitimate reference for computation of labor demand, we have to adjust the number of hours spent on the job in the manner described. This means further deleting such things as coffee breaks, daydreaming, latrine calls and so on. We were able to find no data regularly collected by the Navy which addressed this rather difficult point.

In thinking about the utilization rate, however, we have concluded that U should be dropped from the model. U helps

to determine how many men are required to serve a given equipment, a capacity concept. The capacity of the support system, predicated on the labor demand rate, is made a function of peak operating hours. But under peak conditions, utilization rates tend to go up. That is, the amount of work delivered follows, quite usefully, a sort of Peter Principle: the rate at which labor is delivered expands to meet the amount required. What this means is that the notion of utilization rates is in error: once we have determined how many hours are available to the job, we are done. The amount of work that actually gets done (i.e., the utilization rate) will tend to rise or fall, depending on what is needed. The result of dropping U is the same as setting it to one. So by dropping it, the model makes the implicit assumption that every hour spent on the job is an hour worked. While this won't be true when average work loads are experienced, it will be true exactly when necessary--during peak loads. Therefore, we recommend deletion of the utilization rate from the HARDMAN models, retaining only a conversion from potential labor hours to net hours on the job.

TOR: Annual billet turnover rate.

Data Sources: NMPC 40; OP 135D; Force Analysis Simulation Model;
NAVPERS 15909.C.

Interbillet turnover rates are used in the DMS to determine replacement training requirements. Depending on the level of detail of the model, turnover values can be general, Navy wide averages, or tied to a specific rate/rating/NEC.

The standard proxy for billet turnover rates has been personnel attrition rates. Attrition values for each rate, rating and LOS (length of service) in the Navy can be obtained from the Loss Forecasting Branch, DCNO Manpower Personnel and Training (OP 135D). The values are obtained from outputs of the Force Structure Projection Model (FAST), developed by NPRDC.

Unfortunately, attrition rates are a very poor substitute for billet turnover rates. Personnel transfer from billets for many reasons other than leaving the Navy; thus billet turnover rates will be much higher than attrition rates would indicate. A better estimate of TOR can be obtained from NAVPERS 15909.C, "Enlisted Transfer Manual." This document provides the proscribed duration of sea and shore tours for each rating in the Navy. For example, sea and shore tours for electronics technicians are presently set at 39 months and 24 months respectively. These values translate to annual billet turnover values of .308 and .5. The Enlisted Transfer Manual is produced by the Naval

Military Personnel Command and is available through the Enlisted Assignment Division (NMPC 40).

A still more accurate estimate of TOR for a particular billet can be obtained by combining personnel attrition rates with sea and shore tour durations. This will provide a very good approximation of the actual number of replacement trainees required over the life cycle of a system.* The algorithm for accomplishing these is somewhat complex, and was not incorporated in the DMS. It is described in "Guidelines for Hardware/Manpower Cost Analysis," Section 6.

* One source of error is the Navy policy of not transferring billets for personnel with less than one year (in practice, six months) remaining in their present tour of duty.

Z_s : The average total cost of adding personnel to a ship, including administration, ship's modifications, support and other costs.

Data Sources: Enlisted PCS Step 1 Table; Navy Program Factors Manual; DCNO Logistics for Planning, Programming, Budgeting and Appraisal (OP 04J); Military Personnel Budget and Accounting Division, PCS Budget Development and Costing Branch (NMPC 712).

The DMS makes the distinction between three possible sources (pools) of Navy personnel--two of which are already aboard ship (called the AG and AN pool) and one (called the AS pool) in which personnel are transferred from ashore specifically for the equipment in question (either as an operator or a maintainer). For the third pool, certain costs are anticipated relating to a Permanent Change of Station (PCS) move and any alteration which must be made to the ship as a result of the addition of one or more new personnel. These costs are designated Z_s . They appear in both the Level III and Level II models, but are not considered directly in Level I models. Z is a linear cost factor applied to the number of personnel drawn from the AS pool.

Discussions with DCNO Logistics for Planning, Programming, Budgeting and Appraisal (OP 04J) indicated that data on the costs of marginal modifications to a ship caused by the addition of a new crew member do not presently exist. In most cases, it was suggested, the cost of adding one additional crew member (not of senior grade) is likely to be small. Beyond that point, additional costs will be incurred as personnel are added to the

ship. The non-PCS elements of these costs are likely to have the nature of a step function--no marginal costs are incurred up to the point that an existing underutilized resource is used up, then a sudden cost jump. The nature of these costs requires additional investigation.

There are, however, data available on PCS costs. The Head, PCS Budget Development and Costing Branch, Military Personnel Budget and Accounting Division (NMPC 712) indicates that individual PCS moves are generally costed in terms of several dimensions: Officer/Enlisted status, length of move, and number of dependents to be moved. The Enlisted PCS Step 1 Table, maintained by this office, provides both specific PCS estimates (e.g., Washington to Norfolk for an E-5 with 2 dependents is \$370 for the E-5 and \$1099 for the dependents) and more general estimates of the costs to transport personnel to a vessel already deployed. The overall average for an enlisted PCS move is currently \$1311.

Estimates for Navy PCS costs are commonly taken from the Navy Program Factors Manual, which classifies these costs by ship type (total annual cost of PCS moves for enlisted and officers), by fleet (Atlantic, Pacific), by Naval Aircraft class, Naval Reserve units and Marine Corps Units. It is possible to disaggregate these figures using information on the number of PCS moves assumed per year for each type of unit.

Unit moves (where an entire military unit changes home port) are not included in the Navy Program Factors Manual's PCS cost

estimates. NMPC 712 suggests that, from a budgeting standpoint, these costs are likely to be less expensive per person for the Navy than individual PCS moves because unit moves frequently involve military transport, so that it is not necessary to budget for civilian transport. In addition, unit moves do not necessarily require a PCS for all personnel in the unit. Further work would be required to estimate this difference more accurately.

AG: Number of general labor personnel on board ship capable of receiving the "A" and "C" school training required for operating or maintaining the system.

Data Sources: DCNO MPT, Enlisted Programs Implimentation Branch (OP-135).

The DMS approach to manpower modeling assumes three sources of manpower to operate and maintain a proposed system: an AN manpower pool, consisting of those on board who have already taken the appropriate "A" school; an AG pool of those on board without the "A" school, but who are capable of receiving "A" and "C" training; and an AS pool, consisting of all general duty ashore personnel capable of receiving advanced training. The AN pool is the least costly to draw from, requiring only "C" training; personnel from the AG pool require both "A" and "C" training; AS personnel require both "A" and "C" training, as well as potential additional costs associated with joining the ship's company (see the discussion of Z_s).

According to Head, Enlisted Programs Implimentation Branch, Military Personnel and Training Division, DCNO Manpower (OP 135), definition of the AG pool is possible using the results of the Armed Services Vocation Ability Battery (ASVAB), given to each Navy enlisted entrant. These tests result in a classification of entrants into one of six aptitude classes: 1 (highest) 2, 3a, 3b, 4 and 5 (lowest). Those with scores of 3a and above are considered capable of advanced schooling--such as "C" schools.

Current Navy policy requires that 74% of all Navy enlistees must be 3a and above. Because of the shortage of trained personnel in the Navy, virtually all such people will receive advanced training. The remainder (approximately 26,000 people in 1979) are virtually all assigned to ships as General Detail Personnel (GENDET).

Of the shipboard personnel who are not classified as eligible for advanced training, about 22% (5,720 in 1979) will receive such training on waivers of various sorts. This is another result of the Navy shortage of trained personnel, as well as the desire of Navy training institutions to maintain full class schedules. These factors indicate, and OP 135 concurs, that the AG pool is likely to be small, in that considerable effort is expended to assure that anyone who can benefit from training, and thereby become more valuable to the Navy, is trained.* A high proportion of the General Detail Personnel who do not receive advanced training qualify for on the job training (OJT). Equipment operators and to a lesser extent equipment maintainers are occasionally produced as a result of such OJT programs. To the extent that maintenance or operating requirements are made sufficiently simple by the hardware designer, there is a greater probability

* The make-up of the AG pool aboard ship is likely to be affected by cyclical factors in recruitment as well. Most of the high school graduates who join the Navy do so shortly after graduation. Hence the fall training courses are likely to be composed of relatively well educated recruits--and the AG pool aboard ship will consequently contain a larger number of persons who will later qualify for training with an ASVAB waiver.

that such needs may be met through this less formal OJT training process, thereby effectively increasing the size of the AG pool.

It should also be noted that, in addition to the Navy wide policies which define the capability of recruits to benefit from advanced training, there are also requirements for specific schools, in terms of specific background and experience as well as general vocational ability. This information is available in the Catalog of Navy Training Courses.

OP 135 has suggested that the AS pool is likely to be small as well: there are few GENDET's ashore because of the tendency to use civilian personnel at Navy shore facilities for lower skill level jobs.* Because of the important roles the AG and AS pools play in the manpower cost formulations used in the DMS, these findings concerning the size of the pools indicate that a reexamination of the equations may be called for.

* See, OPNAVINST 1000.16, pg. 5-7, "Shore billets/positions which have been documented by SHORTSTAMPS and coded for either military or civilian incumbents may be classified as military requirements if they are needed to achieve CNO sea/shore rotation goals. Otherwise, these billets/positions will normally be classified as civilian requirements."

AN_m, AN_o : The real number of maintenance (AN_m) or operator (AN_o) personnel available on a ship for use by the system.

Data Sources: NODAC; NAVMMACLANT/PAC.

The AN pool of available shipboard labor is defined as those persons who have completed the appropriate "A" school, as dictated by system requirements (see the discussion of AG). This is the least expensive source of personnel for a proposed new system and therefore the first chosen. It is assumed that personnel may be perfectly cross utilized. This means that four existing billets each with 25% of their work time spent in general duties (the assumed alternative to their specialized tasks), are equated to one man available 100% of the time. This is reasonable in most maintenance activities (where the work may be scheduled to fit available time), and somewhat less so in operator situations (where physical presence is required).

The Naval Occupational Development and Analysis Center (NODAC) compiles empirical data on the actual allocation of time among various Navy occupational categories. These data consist of detailed tabulations of the activities of various Naval ratings during their work week. NODAC's objective is a continuous refinement of position descriptions for Naval service. For the DMS, however, such data could be used to estimate the amount of "underutilized" time (time spent on work not requiring advanced training) for various occupational specialties. Necessary, and

not currently produced by NODAC, is a standard listing of the activity designators which are considered to be part of these "unskilled" tasks. Given the development of such a listing, Navy wide information on AN_m and AN_o could be developed for a wide range of ratings.

Another source of data on the size of underutilized trained manpower pools aboard ship, from a prescriptive rather than descriptive point of view, is the Navy Manpower and Material Analysis Centers, Atlantic and Pacific (NAVMMACLANT/PAC). This agency produces the Ship Manpower Documents (SMD), which define and justify the billet requirements for every ship in the Navy and serve as the basis for Manpower Authorizations (MPA). Required system manning levels, both for maintenance and operation, are determined by Navy policy and industrial engineering analysis. Individual system requirements are then aggregated to create a set of skill level requirements for entire ships. To the extent that planned manning policies result in underutilized personnel, they will be visible from these documents. It should be noted that the method of calculating ship manpower requirements is currently undergoing thorough revision; the factors used in estimating manpower requirements may be significantly changed in the near future.

ρ : Annual Discount Rate.

Data Source: Office of Management and Budget.

Discounting is used to find the present value (the current dollar amount) of a dollar to be paid or received in the future. The present discount rate of 10% per annum was mandated by the OMB in Memo A-94 (March 1972). This rate is by fiat and may be changed at any time.

COND: Fraction of items coded repair which are beyond capability to repair and must be condemned.

Data Sources: Local Repair--Mod III Default Data Guide; 3-M Aviation reports MSOD 4790.A2245-01 & A2245-03.

Depot repair--SPCC; ASO; Mod III Default Data Guide.

This variable is used in the Level I-III models in the computation of replenishment spares for items which are ultimately unrepairable at either the local or depot level.

Average historical rates values of COND for avionics equipment may be obtained using the Mod-III Default Data Guide. The "Scrap Rate" data element listed in this guide sets condemnation rates for WRA's (Weapon Replaceable Assemblies) and SRA's (Shop Replaceable Assemblies) at both the intermediate and depot repair levels. These rates are intended for use with all avionics equipment. The November 1978 Guide lists the following values:

Intermediate repair (WRA)	.024
Depot repair (WRA)	.0012
Intermediate repair (SRA)	.008
Depot repair (SRA)	.0009

Sources used in the derivation of these figures include the 3-M Aviation Type Equipment Work Unit Code Report for the period of January 1975 through December 1977, and information obtained through contact with the Naval Air Rework Facilities (NARF's).

If more specific condemnation rates are desired for components making up a particular aviation equipment, either the 3-M

Aviation MSOD 4790.A2245-01 or A2245-03 Reports may be utilized. The first breaks down equipment to a five-digit work unit code (WUC) representative of different equipment categories at the WRA level. The second report specifies equipment by its part number listing--enabling the user to inspect data concerning a particular issue of a WUC item. Attention should be focused on two headings contained in both reports titled "Total Items Processed," and "ATC 9 Items." The first presents a total of all actions made at an intermediate maintenance activity in the attempted repair of a WUC or part number item. All actions resulting in the scrapping or otherwise disposing of a component of the item are totaled under the second heading.

The ratio of ATC 9 Items to Total Items Processed yields an Intermediate-Level Beyond Capability of Maintenance (BCM) rate for the components making up a particular WUC or part number item. However, because some ATC-9 items are sent on to the depot, where they may or may not be condemned, BCM rates will overstate actual condemnation rates. Also, the 3-M Aviation System does not process information on items reporting less than six maintenance actions in the given report period. This information may, however, be extracted upon special request.

Both the A2245-01 and A2245-03 reports may be helpful to detail designers who wish to estimate, using historical data, the average condemnation rate of components used in existing systems similar to the system being designed. The reports are issued quarterly and cover a six month data base.

Rates for specific aviation components condemned at the depot level must be obtained through the Aviation Supply Office (ASO), located in Philadelphia, Pa. Items under consideration must be specified by stock number. Unfortunately, stock numbers describing similar items cannot be combined to derive rates for more general equipment categories.

For non-aviation equipment, useful data can be obtained through the Naval Ships Parts Control Center (SPCC) in Mechanicsburg, Pa. The SPCC computes depot level survival rates (one minus the condemnation rate) for equipment categories (e.g., ordnance, electronics). The SPCC does not publish its survival rate data, however. This information must be obtained by special request. We found no reports from which one could extract organizational condemnation rates. 3-M Ships reports include data on items locally deferred to a higher repair echelon, but as these items may eventually be repaired, these measurements will overstate actual condemnation rates.

m: Annual maintenance of support equipment rate--the ratio of average annual support of support equipment cost to support equipment initial purchase cost.

Data Sources: Avionics equipment--Mod-III Default Data Guide.

This maintenance rate of (external) support and test equipment (STE) is a convenient means of estimating a class of costs whose magnitudes do not merit more extensive analysis. As used in the DMS, m is applied to the initial procurement costs of both hardware and software elements of STE.

In general, the variable m is set between .10 and .30, depending on the nature of the system being designed. The Mod-III Default Data Guide provides an average value of m for avionics STE at .26 for the first year and .12 for succeeding years. These figures include the costs of document revisions, level of repair analysis, initial spares, replenishment parts, and engineering changes. Not included are calibration costs--an omission which detracts from the usefulness of these figures for many types of STE.

Discussion with representatives of NAVEX revealed that no general "ballpark" figures for m exist for either general or special purpose non-avionics STE. In fact, the initiation of a two-year study to determine support costs of STE is currently under consideration, emphasizing the complexity involved in estimating these costs explicitly.

The simplifying assumption of using the same value of m for both hardware and software elements of STE results in an understatement of software support costs. These costs are believed to increase over time as the program is revised and lengthened. In the DMS, software costs are included only as part of total STE cost. Though the application of m to software development cost may not adequately describe the nature of software support costs, the inclusion of some sort of support figure was deemed essential in the DMS. However, the model user should be aware of the inaccuracies in such use.

TDP: Cost per page of developing technical data.

ADC: Annual per page cost of maintaining technical data.

Data Sources: Mod III Default Data Guide; Naval Air Technical Services Facility.

The variables TDP and ADC are found in equations which predict the costs associated with the development and maintenance of system technical manuals. Required technical documentation costs vary widely with the type of equipment under consideration. As a result, data on these parameters should be obtained directly from the technical services facilities which oversee their production. As a general guide, the Mod III Default Data Guide provides average per-page documentation cost estimates for avionics equipment. For initial documentation costs, figures are grouped by equipment complexity, equipment type, and geographic location of the contractor. For average maintenance of data cost, the break-out is by equipment type and contractor location. Listed in the November 1978 publication are the average figures over all three categories of \$315.00/page for a new basic manual (an approximation of TDP), and \$268.03/page for a set of changes or revision pages for an equipment (ADC). The Naval Air Technical Services Facility is listed as the data source of all documentation figures shown.

- IEC: The Cost of Entering a New National Stock Number into the National Stock System.
- IMC: The Annual Cost of Maintaining one National Stock Number item at a site.
- Data Sources: DLA, Executive Director, Technical and Logistic Services, Defense Logistics Service Center, Directorate of Item Identification.

The task of the National Stock System (NSS) is to identify each part, assembly and system used in the federal government for which federal supply support is required. Of the approximately 4.5 million numbers currently active, about four million are military. Approximately 100,000 new numbers are created each year, and the same quantity are retired to non-active status. Within the Department of Defense, management of the NSS is divided between the Defense Logistics Agency (DLA) and the various supply branches of the individual services. For the Navy, the primary supply activities are the SPCC, the ASO, NARF's and military operated depots.

The measurement of the cost to enter a particular National Stock Number (NSN) is made difficult by the nature of many of the costs of the NSS. Discussions with the Executive Director, Technical and Logistic Services in the DLA indicated that a definitive investigation of this question has never occurred, although various informal estimates have been made and are used. A major barrier to a more exact estimate of this cost are the high overhead costs attributable to the existence of the system but

not directly allocable to the individual stock numbers. For example, consider the process of item entry for Navy stock items. Items directly related to a new Navy procurement are defined in a Procurement Conference attended by representatives of the DLA, the Navy, and the contractor. The Defense Logistics Service Center, Battle Creek, Michigan, then attempts to determine which among the proposed listing of new items are identical to items already in the NSS. This effort alone results in 30-40 million searches per year--a significant cost. About 40% of these searches find an item identical to the proposed new addition to the NSS. In these cases, then, there is no additional stock number created. However, certain costs have been generated in determining that such an addition is not necessary.

Another method of generation for a NSN occurs when the Navy requests an item from the NSS. In this case, there is no formal process in which manufacturer submits a list of parts and assemblies required by a planned system. Items requested more than three times per six month period are generally assigned a NSN and added to the system. The cost of adding such a number is significantly higher than in the larger scale procurement conference situation.

Accurate estimates of the cost of retention of an item in the system at individual sites are also difficult to obtain. Virtually all NSN's are related to hardware produced by the civilian economy. Hence, for each stock number a description is provided

as to where the item may be procured and, usually, how the item may be precisely identified to the supplier. Frequently, through mergers or administrative decisions, civilian stock numbering systems are modified or replaced. In this case, the NSS is required to modify all their records relating to all items from that particular source. If the source is a large company, this can be a significant expense. Such expenses may either be considered as an overall overhead item attributable to the existence of the NSS system itself or, perhaps less realistically, as a specific retention cost for the items whose civilian stock numbers have changed.

Pricing policies at the DLA do not provide significant insights into the cost of item entry and retention. The cataloging activity, which is perhaps the most directly related to individual NSS entry costs, is direct budget funded. Thus it is difficult to allocate costs to the specific numbers cataloged. To stock an item at a given supply center, the NSS charges the services the cost of the item plus an overhead charge of about 2%. In a sense one could consider this 2% fee as part of the item retention cost. However, the DLA and the Defense Logistics Service Center both suggest that such an interpretation is probably not justified. Rather, retention costs appear to be most strongly influenced by the number of items retained at a given site, and the number retained in the system as a whole.

Finally, it should be noted that the National Stock System is used by all of the services for a great variety of management information purposes which are unrelated to its primary purpose-- that is, providing an unambiguous identification for all those pieces of hardware used by the federal government. Any serious attempt to investigate the costs of item entry or retention would need to take the value of these associated benefits into consideration when allocating shares of the total cost of the system.

Although the conceptual issues raised above appear to preclude an accurate estimate of a single, Navy wide cost figure for either IEC or IMC, the existence of certain more limited estimates should be noted. The Mod-III, Default Data Guide suggests a range of \$409 to \$501 per item entered, with a \$455 expected value. Item retention (in the NSS) is estimated to cost between \$202-\$248 per item per year. This same source includes an estimate of the Field Administrative Cost of maintaining one item at one site each year. This estimate includes data processing costs, labor and administration, but not warehousing, and is put at \$17.63 per year per item per site.

In summary, considerable research and analysis is required to provide accurate, theoretically sound values for item entry and management costs.

CC: Cost of Transportation.

Data Sources: Commander, Military Sealift Command, Air Force Regulation 76-11; Mod-III Default Data Guide; NAVSUP, Fleet Support and Supply Operations, Fleet Support Section.

In the Level II and Level III models, CC, the cost per pound per mile for insured freight, is used in conjunction with average distance between repair and supply points to determine transportation costs. In the Level I models this variable is not used. For depot repair items destined for contractor operated depots, the cost of transportation is usually included in a single repair cost, hence CC refers only to military operated depot destinations. In general, transportation costs are an extremely complex issue. These costs have been intentionally dealt with in a very simplified fashion in the DMS because of the small cost of transportation compared to other cost elements.

There are several Navy controlled transport activities: the Military Sealift Command (MSC), a non-combat transportation service utilizing civilian, licensed crews, the Transportation Section of the Naval Supply Systems Command (NAVSUP), which utilizes military vessels operated by military personnel, and the QUICKTRANS Service, a contract commercial agreement providing primarily air cargo service on fixed schedules for destinations within the continental United States. Government rates charged by the Military Sealift Command are set by the Depart-

ment of Defense, and are available from the Commander, Military Sealift Command. The MSC operates as part of the Mobile Logistics Support Fleet (MLSF) in both combat and non-combat environments. As the MSC is a part of the Navy, it does not charge other Navy units for its services. However, in terms of cost (rather than price), it should be noted that certain aspects of transportation costs may be high for MLSF ships, due to potential combat service. For example, certain components are required to be shock mounted when shipped via MLSF in order to withstand specified levels of attack vibrations. Rates charged for the QUICKTRANS Service are negotiated periodically with the air carriers concerned, and are available from the NAVSUP Fleet Support Section.

Transportation costs for military parts are greatly affected by the priority level attached to the shipment. Some parts may be essential to the mission of the equipment, and thus justify the unusual transportation expense of QUICKTRANS. However, for most parts being shipped to military depots for repair, priority will be relatively low, and a least-cost combination of military and commercial transportation modes will be used. Average transport cost default values have been computed for particular types of equipment: the Mod-III Default Data Guide suggests a value of \$.0001245 per pound per mile, based on the rates charged by the Military Airlift Command, provided in Air Force Regulation 76-11. These rates are updated frequently.

The distinction between transportation costs and transportation prices is an important one. For example, while the price of the QUICKTRANS service is easily known--and subject to some concern within the Navy--the actual cost of utilizing military operated transport activities, which do not price their services, is a much more difficult question. The cost may be entirely an opportunity cost. If a tender makes a scheduled trip to a deployed fleet, for example, there may be few or no marginal costs involved in transporting additional parts, since all expenses would occur whether or not the parts were aboard. Another consideration is the difference between the administered price charged by government transportation agencies to other government agencies, and the actual cost of the transport. For example, the administered prices charged by the Military Airlift and Sealift Commands reflect only a portion of the real costs involved in the transport services. Other costs are direct budget funded. These issues should be considered in developing more accurate average transportation cost estimates.

A.2 SYSTEM OPERATING ENVIRONMENTAL VARIABLES

- N: The number of ships on which the system is
 deployed.
- Q: The number of systems deployed per ship.
- Data Sources: Determined by Program Manager; Inventory listings
 from SPCC and ASO.

These variables are determined by the system operating environment and as such will be most likely determined by the program manager or system designer. The values obtained for these variables may be based on policy decisions regarding the distribution of a new and independent system within the Navy. If the new system is intended to augment an already existing system, a trackdown of the number and locations of the existing system may produce the desired values.

Inventory listings for specific equipment types already in the Navy inventory--the number and locations of their use--may be obtained through the Navy Aviation Supply Office (ASO) for aviation equipment and the Navy Ships Parts Control Center (SPCC) for shipboard equipment. Point of contact at the ASO would be the Weapons Logistics or Stock Control divisions. At the SPCC, the Weapons Systems Support Group maintains a Ships History File report which, for equipment identified by its Allowance Parts Listing (APL), gives the number of ships on which the equipment is deployed, and a total count of the equipment on a Navy-wide basis.

AHR: Average annual system operating hours.

Data Sources: Aircraft equipment--3-M Aviation report MSOD
4790.A2142-02.

Shipboard equipment--3-M Ships report NAMSO
4790.S5763.

The variable AHR is used in all levels of the DMS. It is highly system-specific, determined to a great extent by the system operating environment and perhaps by system design as well. For aircraft equipment, AHR may be the total average annual flight hours of the aircraft it is installed on, while hours underway may be the determining factor for certain types of shipboard equipment. Two reports yield historical figures for these time periods. 3-M Aviation report A2142-02 gives, for different aircraft, total flight hours over a three month data base. 3-M Ships report S5763 lists, by ship or ship type, the total hours underway, not underway (at sea or in port), and hours cold iron. The time period covered in this report must be specified by the report user.

h: Average annual number of ship deployments.

D: Average length of a ship deployment.

Data Sources: OP-64 (Deputy Chief of Naval Operations, Fleet Operations Readiness & Navy Command Center Division); Mod-III Default Data Guide; 3-M Ships NAMS0 4790.55763.

The variables h and D are used to calculate manpower demand and spare stockage levels in the DMS. Their product is used to estimate total steaming time. The variable D is also sometimes used as the lead time for a ship to obtain spares from the depot.

OP-64 (Fleet Operations Readiness & Navy Command Center Division) can provide information regarding average historical figures for D and h. Projected figures for upcoming years may also be obtained from this source. (Note: this information is classified.)

Historical averages for D may be obtained through two unclassified sources. The Mod-III Data Guide gives a CV deployment factor of .3012, which represents the average percentage of time a carrier is deployed.* Multiplication of this factor by a given period of time (in days) would yield a D value for that time period. For ship types other than carriers, the 3-M Ships report S5763 lists total steaming hours (broken-down into "hours underway" and "hours not underway") against total hours by

* Recent political developments have rendered this figure obsolete.

ship or ship type. Time range is specified by the report user, and average steaming hours must be calculated over the desired time range.

RRATE: System Production Cost learning curve rate.

Data Sources: Individual contractors.

The idea of a learning curve is simple: as production continues, producers will "learn" how to produce more efficiently, leading to a decrease in unit cost. The concept is especially useful when it is not known beforehand exactly how many units will be produced (for example, the production lot size of an item may depend on its as yet unknown support philosophy). The learning curves are used in the DMS to determine the unit cost of equipments as a function of production and initial spares lot sizes. There has been significant discussion in the literature as to how long this reduction in unit cost continues after production start-up.* In the DMS, the assumption is made that production cost reductions from learning occur only in the first year.

Because the Navy produces very little hardware itself, the Navy does not calculate rates of cost reduction over production runs. Individual contractors' learning curve rates are generally determined by each manufacturer for a proposed project, based on past experience (the values are usually considered to be proprietary information). It should be noted that the RRATE is distinct and separate from the economies of scale resulting from changes in the lot size.

* See Alchain, A., Economic Forces at Work, Liberty Press, 1977, pg. 335 ff.

RP: The average repair material cost for the repair of an assembly.

Data Sources: Aviation equipment -- VAMOSC-AIR Maintenance Subsystem Report.

Shipboard equipment -- 3-M Ships Reports NAMSO 4790.95660 and S6271; SPCC.

In the Level II and III models, the variable RP defines the average cost of parts replaced during the repair of an assembly. This cost is computed as the average price of a repair part multiplied by the average number of repair parts per repair. The same RP value is used for both local and military-operated depot level repairs. In the Level I model, RP retains the same definition, but only local repairs are costed.

Historical repair material costs for aviation equipment at either the subsystem or WRA level may be computed using the VAMOSC-AIR Maintenance Subsystem Report. This report is aircraft-specific; reports may be obtained for different aircraft type/model/series. Included in this report are the Total Component Maintenance Cost and Component Maintenance Action reports for both scheduled and unscheduled maintenance actions. In the Component Maintenance Cost report, total material costs for all repairs over a given fiscal year for various aviation equipment are listed. The Component Maintenance Action report lists the number of repairs of these items over the same time period. One can therefore obtain an average repair material cost value by dividing the total material cost by the total number of

repairs. Figures are given in both reports for the organizational, intermediate, and depot repair levels. Listings of scheduled and unscheduled maintenance actions are shown separately, and the depot figures are broken down into Naval Air Rework Facility (NARF) and commercial depot classifications.

For non-aviation shipboard WRA's, NAMS0 4790.S5660, a reliability and maintainability report, displays a total count of corrective maintenance actions performed on the assembly, which is specified by its Equipment Identification Code (EIC). This report summarizes maintenance actions by individual ship, and for all ships reporting maintenance actions on the given EIC. The data cover a year's activity, with the beginning month specified by the report user. NAMS0 4790.S6271, a parts report, provides data concerning National Stock Number (NSN) parts utilized in support of equipment maintenance. The key element in this report is the extended price listing total, which gives the total cost of NSN items used in the maintenance of an EIC item. Again, this report covers a year-long period, with the beginning month selected by the user.

Given a certain EIC item, the total cost of those parts used in its maintenance may be divided by the total number of corrective maintenance actions performed to produce the desired value for RP. Caution must be exercised when using these two reports so as to not confuse data totals for one ship as opposed to all ships reporting actions, and a knowledge of the EIC equipment

listing is essential. In addition, items which the Navy buys in bulk (e.g., nuts, bolts, rags) are not included among parts costed in the repair of an LRA.

The 3-M Ships reports cover organizational (shipboard) and intermediate (tender/base) maintenance only. Depot cost of repair for component-level items may be obtained from the Navy Ships Parts Control Center (SPCC). Equipment must be referenced through its individual stock number. For end-items, NAVSEA can retrieve depot information by special request. The equipment is grouped in broad categories (e.g., electronics, ordnance), and low-cost and high-cost items are combined within these categories.

Use of these data sources both slightly redefines and supplements the variable RP. The average price of a repair part and the average number of repair parts are not calculated. Instead, gross amounts for cost and number of repairs are divided to determine the average cost per repair. However, this method may be better than the one originally used to define the computation of RP. In effect, the focus is on the total number of repairs rather than the total number of parts making up a repair. Also, as data sources are available on military-operated depot repair costs, RP may potentially be made both local and depot-specific in the Level II and III models.

COD: The average cost of repair at a contractor-operated depot.

Data Sources: SPCC; ASO; VAMOSC-AIR Maintenance Subsystem reports.

The variable COD is used in the DMS to account for average repair costs of an item at a contractor-operated depot. The value includes all costs associated with repair: labor, training, STE, transportation, insurance, technical data, etc.

For certain types of equipment, contracts setting repair costs may be negotiated between either the Navy Aviation Supply Office (ASO) or the Navy Ships Parts Control Center (SPCC) and a contractor-operated depot. Reference to the individual contractor's policies regarding price of repair may yield the best value for COD.

Historical data for this variable may be obtained directly from the ASO, SPCC and the VAMOSC-AIR Maintenance Subsystem reports. At the SPCC, equipment is referenced by stock number, but the only statistic kept is the average percentage of the original cost needed for repair. G&A is added into cost, but not the cost of any government transportation. See the discussion of the variable RP for information regarding the relevant VAMOSC-AIR Maintenance Subsystem reports. The labor costs shown in these reports should be added to the material costs, and it should be noted that VAMOSC-AIR assumes all components sent to the vendor are repaired. In general, care must be taken in determining precisely what repair costs are included in the figures obtained from these data sources.

LRT: Local Response Time.

Data Sources: 3-M Aviation report MSOD 4790.A225-01; Mod-III Default Data Guide.

Local Response time (LRT) is defined as the time between the failure of an item coded local repair and the time it is restored to ready for issue status. Response or lead times play a crucial role in the determination of spares stockage levels--these levels must be sufficiently high to cover any demands made during the lead time.

Two reports may be utilized to arrive at an average historical figure of LRT for aviation equipment: the 3-M Aviation report MSOD 4790.A2245-01, and the Mod-III Default Data Guide. The more general of these two reports, the Mod-III Default Data Guide, lists an average response time for all avionics equipment. This value, as of the November 1978 publication, is given as three days for both carrier and land-based aircraft, based on ASOINST P4423.32 dated March 1974.

MSOD 4790.A2245-01, the Component Repair Report, is geared to the analysis of a particular aircraft weapon system deployed on a particular type/model/series of aircraft. As such, all reported totals are aircraft-specific. Equipment indenture-level and identity must be specified by a work unit code (WUC). A five-digit code represents a WRA, the only option available for this report. The heading "ATC B/C/K/Z Items" identifies data on turnaround time for carrier Intermediate Maintenance Activities

(IMA). Under this heading are two separate columns labeled "AVG DAYS TAT," and "TAT LESS AWP." The first of these provides the total elapsed time from component removal to the completion of IMA repair. This turnaround figure includes the time spent awaiting parts (AWP). If isolation of pure maintenance time is desired, this quantity is broken-out under the "TAT LESS AWP" column. All figures represent averages, and may be taken directly from the report. Reports may be requested for any number of aircraft types. However, averaging between aircraft types must be done by the report user. An average response time for all systems onboard a particular aircraft is given in this report by major command and Navy-wide. The report is published quarterly and has a six month data base.

We were unable to obtain specific data on the average response time for non-aviation shipboard equipments (LRT_s). Lacking a better estimate, the value for aviation equipments should be used in its place. In many cases, however, the value of LRT in spare stockage calculations is overridden by a much larger value representing the minimum required days (usually 90) to which an item must be stocked. That is, Navy policy often dictates that a critical item be stocked to a ninety-day safety level regardless of the repair lead time. In these instances the value of LRT is replaced by a policy variable representing this required minimum. These two potential replacements for LRT_s make the lack of specific data on the variable less important than it otherwise might be.

DRT: Depot Response Time.

Data Sources: Mod-III Default Data Guide; NAVSUP 034.

The depot response time (DRT) is defined as the time between the failure of an item coded depot repair and the time it is returned from the depot to ready-for-issue status at the operational site.

For avionics equipment, the Mod-III Default Data Guide provides historically-based average rates of repair cycle time. Distinctions are made between the recycling of an item which originates from a carrier-based or land-based location, and the forwarding of that item either to a primary inventory maintenance activity (PIMA--supply depots located on Naval Air Stations) or a Naval Air Rework Facility (NARF--a repair depot for avionic equipment). The average repair cycle time for a land based depot is given as 93 days, which includes IMA processing, transportation and depot repair times. The Default Data Guide utilized 3-M Aviation data and records in various NARF's, Intermediate Maintenance Activities, and the NAVAIRSYSCOM Material Management Division to derive these values.

NAVSUP, Fleet Support and Supply Operations, Repairables (SUP 034) manages data on depot response times for specific stock numbers. Aggregate values are not available, therefore considerable processing would be required to derive average DRT values for broad ranges of equipment. Work is currently underway,

under the direction of NAVSUP, to create a Repairables Management Data System, which would automate repairables maintenance data processing. Aggregation of item-specific DRT values would be considerably easier using this system. Unfortunately, the Data System will not be ready for use before FY82, at the earliest.

- d_r : The number of repair depots in the repair system.
- d : The number of stockage depots in the repair system.
- DIS: Average distance between repair and supply depots.
- Data Sources: Naval Supply Systems Command (NAVSUP), Fleet Support & Supply Operations Division.

The variable d_r is used in both the Level II and III models of the DMS to estimate total manpower, support and test equipment, inventory management, and technical data costs. These costs are calculated over the network of military repair depots utilized in the repair of the system. The variable d is used in all levels of the DMS to calculate spare stockage demand at the supply centers serving the d_r repair depots. The variable DIS is found in transportation cost equations at the second and third levels of the DMS.

The number of military repair and supply depots appropriate to the repair of a system or assembly is determined by the type of system and its geographic location. Depot repair of avionics equipment is performed at Naval Air Rework Facilities (NARF). Electronic, non-avionic equipment is sent to either shipyards or Naval Electronic Systems Engineering Centers (NESEC). Ordnance systems are repaired at Weapons Stations and a few shipyards. Any other category of shipboard equipment will be sent to the shipyards for repair.

There are six NARF's: Pensacola, Jacksonville, North Island, Alameda, Cherry Point, and Norfolk. The supply centers for these depots are located on the NAS. The two main NESEC's are found in San Diego and Portsmouth. There are also two minor NESEC's at Charleston, South Carolina and Del Leo, California. NESEC's make use of supply centers located on nearby shipyards. Most weapons stations are located near shipyards, in which case they make use of the supply centers located there. If it is not near a shipyard, a Weapons Station will have a supply center on its own grounds. There are six shipyards, each with its own supply center. In addition, supply centers not associated with repair depots may be found in various locations around the world.

To obtain values for the variables d_r , d , and DIS, the design team must first determine the locations in which the system is to be deployed. Given a knowledge of the category of equipment into which the system falls, contact with the Naval Supply Systems Command (NAVSUP) Fleet Support and Supply Operations Division will yield appropriate values for d_r and d . DIS may be calculated through inspection of distances between the depots numbered by d_r and d . In most cases, the distance between supply centers and repair depots will be small.

A.3 SYSTEM DESIGN VARIABLES

SM: System weekly scheduled maintenance requirement.

Data Sources: Shipboard equipment--Maintenance Index Pages.

Aviation equipment--Maintenance Requirement Cards

The variable SM is used in equations determining maintenance manpower demand. It is multiplied by the number of systems deployed per ship to yield the total system planned maintenance manhour requirements. In most cases, the system designer will determine SM based on the reliability measure designed into the system.

If the designer wishes to base an estimate for SM on manhour requirements for similar systems, the Navy documented maintenance periodicity for such equipment may be obtained. According to the Ship's 3-M Manual, the Departmental Master Planned Maintenance Subsystem (PMS) Record contains information on the planned maintenance requirements for the components, subsystems, and systems in each department of a ship.* This Master Record provides a listing of Maintenance Index Pages (MIP) prepared for each installed equipment. The MIP's list maintenance requirements with associated periodicity, and recommended manhours (which do not include time spent on tool preparation, removal and replacement, and clean-up). Special maintenance concepts during ship overhauls, activations, strikes, or transfers to foreign navies are also included.

* OPNAVINST 4790.4, "Ships' 3-M Manual, Volume 1," pg. 5-1, June 1973.

For each maintenance task the MIP's provide a reference to a corresponding Maintenance Requirement Card (MRC), which details the specific requirements for each task. For modeling purposes, however, data contained in the MRC are more detailed than necessary. Information obtained from the MIP's should suffice.

For aviation equipment, an analogue to the MIP is the Periodic Maintenance Information Card (PMIC). This card lists the periodicity or planned maintenance tasks and a reference to each task's MRC. Aviation MRC's, conceptually similar to the ship MRC's, provide recommended maintenance manhours.

MTBF: Mean time between failure (average number of operating hours between failure).

MTRR: Mean time to fault isolate, remove and replace an assembly.

MTTR: Mean time to repair an assembly.

Data Sources: Aviation equipment--MSOD 4790.A2142-01, A2107-04, and A2245-01; ASO; Naval Air Rework Facilities.

Shipboard equipment--NAMS0 4790.S5660; Shipyards.

These three reliability and maintainability (R&M) variables are highly system-specific. In the DMS, they are used in calculating manpower and spare stockage demand. The judgement of the detail designer is the best source of information for these three variables. Durability and ease of repair are qualities which the designer builds into a component. The designer may wish, however, to use historical figures for similar systems as a guide to his own estimates.

R&M information for aviation equipment may be found in the following 3-M Aviation reports: MSOD 4790.A2142-01, A2107-04, and A2245-01. The Fleet Weapon System Reliability and Maintainability Summary, report A2142-01, documents mean flight hours between failure (MFHBF) and MTTR for equipment to the WRA level. Report A2107-04, the Flight Hours Per Failure for Aircraft Electric Power and Engine Starting Items, provides MFHBF data for specific WRA items selected by NAVAIR. The Component Repair Report, A2245-01, yields MTTR and MTRR information at the WRA level. All reports are by particular aircraft type/model/series

with totals by major command and total Navy. A2142-01 and A2245-01 are produced quarterly; A2107-04 is a monthly report with a six month data base.

Not all equipment listed in report A2142-01 have operating hours which correspond to flight hours, therefore MFHBF for some equipment would not be a representative measure of MTBF. However, only equipments whose actual measure of use is flight time are included in report A2107-04. Both average manhours and Elapsed Maintenance Time (EMT) are presented in reports A2142-01 and A2245-01. Thus both reports can be used to measure MTTR.

In report A2142-01, average times are reported per maintenance action. Maintenance actions at both the organizational (ML1) and intermediate (ML2) repair levels are combined for a given WRA. Report A2245-01 separates average time for ML1 and ML2 repair levels, and these averages are defined per repaired item. A repaired item may be one which has merely been calibrated or had a corrosion treatment. In A2245-01, EMT at the organizational level is essentially a measure of MTRR. The 3-M Aviation system defines the primary function of organizational-level repair to be that of locating, removing, and replacing a defective part.

The designer or report user should be aware of some data limitations. Total maintenance actions shown are understated, because 3-M Aviation requires a minimum of six maintenance actions per reporting period in order for data on any given piece

of equipment to be processed. The total number of failures are understated as well. Finally, the degree of equipment indenture is limited to the WRA level. Effectively, data on equipment of lower indenture level making-up the WRA are combined to yield the report averages. The detail designer may not be able to isolate pertinent information at the component level.

For non-aviation shipboard equipment, 3-M Ships report NAMS0 4790.S5660, the Reliability/Maintainability report, may be used. Equipment is specified by a four position Equipment Identification Code (EIC). This represents equipment at one indenture level lower than the subassembly level. The three report measures which roughly correspond to the R&M variables in the model are the following: Mean Time to Trouble Isolate (Mean TI Time); Mean Active Maintenance Time (Mean AM Time); and Mean Time Between Corrective Maintenance Actions (Mean Time BCM Actions). Analysis of these data for a given EIC may be made at either an organizational (shipboard) or intermediate (tender/base) level of repair. Ship type and hull number or activity Unit Identification Code (UIC) must be specified when requesting this report. A ship-specific report includes summary data for all ships reporting maintenance actions on the EIC. Report time range must also be specified by the report user.

Matching the data of S5660 with the R&M variables of the model presents certain problems. As a gauge of MTRR, Mean TI Time is limited. Only time spent in fault isolation is inclu-

ded. The definition of a corrective maintenance action, used in determining Mean Time BCM Actions, includes adjustment and alteration actions as well as the repair of a true failure. However, by special request, the number of true failures and the active maintenance time spent on their repair may be isolated. Mean Time BCM Actions would then correspond closely with MTBF. Active maintenance time used in formulating Mean AM Time includes removal and replacement time. No isolation of this time from actual repair time is possible. Thus, total Mean TI Time and Mean AM Time used in conjunction represent a combined value for MTRR and MTTR in the model.

Other limitations to the usefulness of this report are similar to those noted for the 3-M Aviation reports. 3-M Ships defines equipment operating hours as equal to the ship's steaming hours. Equipments not using steaming hours as a measure of use are included in report S5660. Problems with equipment indenture level are the same as those pertaining to the 3-M Aviation reports. Also, maintenance personnel are required to report trouble isolation and active maintenance time for certain select equipment only. Report S5660, then, does not cover all types of shipboard equipment.

Both the 3-M Ships and Aviation Systems do not report data for depot-level repairs. This information can be obtained through either the Navy Ships Parts Control Center (SPCC), the Navy Aviation Supply Office (ASO), or contact with individual Naval Air Rework Facilities and Shipyards.

Other System Design Variables

These variables are examples of DMS system design inputs whose values must be estimated by the design team.

FIH:	Hardware cost of system fault isolation hardware.
CS:	Cost of system fault isolation test equipment software development.
CH:	Cost of common system repair support and test equipment hardware.
STE _i :	Cost of WRA specific support and test equipment.
P:	The number of technical documentation pages required for a system overview (maintenance and operation).
P _f :	The number of pages of technical documentation required for system repair.
P _r :	The number of pages required for the repair of a typical assembly.
K:	Desired system confidence level against stockout.
OP:	Required number of operators per system.
OF:	Number of officers assigned to each ship to supervise the system.
OTC:	Required number of "C" school days for system operator training.
TS:	Required days of maintenance "C" school training for system repair.
TR:	Required days of maintenance "C" school training for one repair of a typical assembly.
λ:	Estimated system production lot size.
UC _λ :	Estimated unit production cost at production lot size λ.
PT _λ :	Estimated system assembly, or put together, cost at lot size λ.

- q_i : Number of appearances of an assembly type in the system.
- n : Number of different assembly types in the system.
- PP: Number of new piece parts in the system which will have to be entered into the National Stock System.
- WP: Average assembly weight, including shipping container weight.
- δ_i : Item duty cycle (the ratio of item operating hours to system operating hours).

APPENDIX B: DATA SOURCES

Table B.1. Naval Data Sources

<u>Acronym/Name</u>	<u>Location/Phone Number</u>
ASO (Navy Aviation Supply Office)	700 Robbins Avenue Philadelphia, PA 19111 (215) 697-2000
CNET (Chief of Naval Education & Training)	NAS Pensacola, FL 32508 (904) 452-4543
COMSC (Commander, Military Sealift Command)	4228 Wisconsin Ave., N.W. Washington, DC 20016 (202) 282-2800
DCNO MPT (Deputy Chief of Naval Operations, Manpower Personnel Training Division)	Washington, DC 20370 (202) 694-5571
DLA (Defense Logistics Agency), Executive Director, Technical and Logistics Services	Cameron Station Alexandria, VA 22314 (202) 274-6771
DLSC-C (Defense Logistics Service Center, Directorate of Item Identification)	Federal Center Battle Creek, MI 49016 (616) 962-6511, ext. 6444
NAEC (Naval Air Engineering Center)	Lakehurst, NJ 08733 (201) 323-2190
NAVMACLANT (Naval Manpower & Material Analysis Center, Atlantic)	Naval Station Building X12 Norfolk, VA 23511 (804) 444-2444
NAVMACPAC (Naval Manpower & Material Analysis Center, Pacific)	1200 Pacific Highway San Diego, CA 92132 (714) 235-3185
NALC (Naval Aviation Logistics Center)	NAS Patuxent River, MD 20670 (301) 863-4295
NATSF (Naval Air Technical Services Facility)	700 Robbins Avenue Philadelphia, PA 19111 (215) 697-2926

NAVSEA Support Center, Maintenance Management Division	Pacific: 4297 Pacific Highway San Diego, CA (714) 225-5263 Atlantic: 3321 East Princess Anne Rd. Norfolk, VA (804) 857-0121
NAMSO (Navy Maintenance Support Office)	Mechanicsburg, PA 17055 (717) 790-2014
NMPC (Naval Military Personnel Command)	Washington, DC 20370 (202) 694-2243
NODAC (Naval Occupational Development & Analysis Center)	Building 150 Washington Navy Yard (Anacostia) Washington, DC 20374 (202) 433-4620
NPRDC (Navy Personnel Research & Development Center)	San Diego, CA 92152 (714) 225-6617
NAVSEA (Naval Sea Systems Command)	2531 Jefferson Davis Hwy. Arlington, VA (202) 692-3381
NAVSUP (Naval Supply Systems Command), Fleet Support & Supply Operations, Repairables (SUP 034)	Crystal Mall Bldg. 3 1931 Jefferson Davis Hwy. Arlington, VA (202) 695-9099
DCNO (Deputy Chief of Naval Operations), Logistics for Planning, Programming, Budgeting, and Appraisal (OP-04J)	Washington, DC 20350 (202) 695-4823
DCNO (Deputy Chief of Naval Operations), Fleet Operations Readiness & Navy Command Center Division (OP-64)	Washington, DC 20350 (202) 697-6033
OMB (Office of the Management & Budget), Executive Office of the President	Washington, DC 20503 (202) 395-3000
SECNAV OASN (MRA&L)(SAS) (Office of the Secretary of the Navy, Manpower, Reserve Affairs and Logistics, System Acquisition & Support)	Room 244 CP 5 Washington, DC (202) 692-7860
SPCC (Navy Ships Parts Control Center)	P.O. Box 2020 Mechanicsburg, PA 17055 (717) 790-2000

Table B.2. Data Source Documents

<u>Document</u>	<u>Data</u>	<u>Contact</u>
Air Force Regulation 76-11	Military Airlift Command Intra Governmental Charge Schedule	H.Q. USAF, LETT Washington, DC 20330 (202) 697-4742
Civilian Billet Cost Model	Civilian Billet Costs	NPRDC San Diego, CA 92152 (714) 225-6617
Enlisted PCS Step I Table	PCS costs	NMPC 712 (PCS Budget) Washington, DC 20370 (202) 694-4520
Maintenance Index Pages	Shipboard scheduled maintenance procedures	NAVSEA Support Center Pacific: San Diego, CA (714) 225-5263 Atlantic: Norfolk, VA (804) 857-0121
NALCOMIS-O&S/VAMOSC-AIR MS reports	Aircraft equipment operating & support costs	NALC NAS Patuxent River, MD 20670 (301) 863-4295
NALCOMIS-O&S/VAMOSC-AIR System Description Manual, Vol. II, Maintenance Subsystem (MS)	Derivation of utilization rate for avionics technicians	NALC NAS Patuxent River, MD 20670 (301) 863-4295
NAVAIR Avionics Level of Repair Model, Mod-III Default Data Guide	Various default data values for avionics equipment	NAEC Lakehurst, NJ 08733 (201) 323-2190
NAVPERS 15909.C: Enlisted Transfer Manual	Sea and shore tour lengths	NMPC 40 Washington, DC 20370 (202) 427-5630
Navy Program Factors Manual	PCS costs	OP-901M (Data Management) (202) 695-5038
OPNAV 10P-23: Guide to the Preparation of Ship Manpower Documents	Navy ship manpower requirements	OP-111 C1 (Ship Manpower Requirements) Washington, DC (202) 694-4894

OPNAVINST 1000.16D Manual of Navy Officer and Enlisted Manpower Policies and Procedures	Official guide to work hours available for Navy Enlisted personnel	OP-111 C1 (Ship Manpower Requirements) Washington, DC (202) 694-4894
Periodic Maintenance Information Card	Aircraft scheduled maintenance procedures	NALC NAS Patuxent River, MD 20670 (301) 863-4295
Ships Manpower Documents	Defines the billet requirements to every ship in the Navy	OP-111 C1 (Ship Manpower Requirements) Washington, DC (202) 694-4894
3-M Aviation & Ships reports	A wide variety of maintenance data	NAMSO Mechanicsburg, PA 17055 Air: (717) 790-2031 Ships: (717) 790-2043
Ships Manpower Documents	Defines the billet requirements to every ship in the Navy	OP-111 C1 (Ship Manpower Requirements) Washington, DC (202) 694-4894

Note: Copies of documents produced by the Navy are usually available through:

Navy Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

APPENDIX C: THE 3-M DATA SYSTEM

For data on many of the DMS variables, the design team must rely on information obtained from sources outside their company. This search involves contact with several different Navy agencies. For maintenance-related data variables, however, information is available through one centralized source: the 3-M (Maintenance and Material Management) Data System. The 3-M Data System reports are issued by the Navy Maintenance Support Office (NAMS0) located in Mechanicsburg, Pennsylvania. These reports provide a wide variety of historical maintenance measurements.

Since so many of the input variable reviews in Appendix A reference 3-M reports, the following descriptive overview of the 3-M System is provided. It is in no way intended to be an exhaustive examination or critical review of 3-M. Its basic objective is merely to relay our understanding of this data system, obtained during the course of this study.

Background and Purpose of the 3-M System

The 3-M System was formed in the mid-sixties in response to concern about the upkeep and readiness of expensive Naval weapons systems. It was decided to standardize maintenance manpower and material resources. To achieve these ends, the 3-M System was developed. It has since become the major source of Navy maintenance data.

3-M System Organization

The 3-M system is sponsored by the Chief of Naval Operations and managed by the Chief of Naval Material. It is composed of two main elements: the Planned Maintenance System (PMS), and the Maintenance Data System (MDS). The PMS establishes the scheduling and procedural requirements for planned maintenance at the shipboard/squadron level. The MDS is a management information system which controls the production of all 3-M Data System reports. These reports are divided into two categories: those pertaining to aviation maintenance only (Aviation 3-M reports), and those covering maintenance on most other non-aviation shipboard Navy equipment (Ships 3-M reports). NAMSO is the central data bank to which all maintenance documentation is sent. It is tasked with the preparation and distribution of all 3-M Aviation and Ships reports.

3-M Aviation and Ships Reports

Although both the 3-M Aviation and Ships reports are intended for similar managerial purposes, the emphasis and scope of each varies significantly. For instance, report users should not assume that a particular Aviation report will have an analogous Ships report.

The 3-M Aviation reports tend to be more comprehensive than the Ships. This is due in part to the relative difficulties in coordinating the flow of maintenance data and in generating an appropriate statistical base from which measurements may

be drawn. Aviation equipment is relatively standardized among different aircraft types, easily transportable, produced in large quantities, and for the most part is repaired in areas close to the squadron. Shipboard non-aviation equipment, however, is highly diversified and spread out among numerous ship types. In addition, while most ships equipments are repaired on board by removing and replacing defective items, the great majority of these items are deferred to offship repair. In general, aviation equipment is more easily categorized, monitored, and its data more readily available than is non-aviation equipment.

3-M Aviation Reports

The 3-M Aviation reports interpret maintenance data collected on aircraft, missiles, drones and associated ground support equipment.* Most of the standard reports issued are aircraft-specific. Information given for a certain category of aviation equipment usually relates to work done and data collected on a particular type/model/series (T/M/S) of aircraft, summed over the entire Navy or by major command. Generally, the report user must specify the type of aircraft as well as equipment to be covered. Through special request, however, report users may obtain data on common types of aviation equipment without reference to any specific aircraft T/M/S. Also, special reports exist which detail maintenance information specific to aviation

* NAMSOINST 4790.1, Catalog of 3-M Aviation Information Reports, Navy Maintenance Support Office, 1978.

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ground support equipment. The majority of 3-M Aviation reports are distributed regularly and are based on data collected over a three or six month period.

In 3-M Aviation reports, data on different makes and issues of similar categories of equipment are identified by and totaled under a single work unit code (WUC). The WUC listing is simply an index which defines and assigns an alphanumeric code to standard categories of aviation equipment. Subassemblies of major components correspond to seven-position WUC's and represent the lowest indenture level to which 3-M Aviation reports aggregate data. For some variables, however, seven position WUC data are available only by special request, if at all. Maintenance measurements given for a specific WUC represent accumulated data for all components making up the WUC item. Copies of the WUC listing may be obtained through the Naval Air Technical Services Facility.

The data presented in 3-M Aviation reports are accumulated by maintenance technicians on standardized forms. Called the visual information display system/maintenance action forms (VIDS/MAF), these forms are the primary source documents from which NAMS0 extracts maintenance data. As an item is processed through different repair levels, information is added to its VIDS/MAF until a full account of its maintenance is chronicled. Explicit rules govern the way in which a VIDS/MAF must be filled-out.

3-M Aviation recognizes three different repair levels--organizational, intermediate, and depot--but processes information for only the first two. Organizational maintenance actions are those performed directly on the aircraft. For the most part, these actions consist of simple removals and replacements. A "black box" removed at the organizational level is sent to an intermediate maintenance activity (IMA) for actual repair. Most of the 3-M Aviation data are generated from actions taken at the IMA. Emphasis is on the collection of unscheduled maintenance data.

The 3-M Aviation reports are divided into four groups: Readiness and Utilization; Reliability and Maintainability; Service and Support; and Control and Administrative. Readiness and Utilization reports convey current and six month trend analysis of aircraft readiness. The percentage of time a particular aircraft is described in a certain readiness condition (e.g., not operationally ready, operationally ready-reduced material condition), and the rankings of those items contributing most highly to the degradation of the aircraft (e.g., high failures, beyond capacity to maintain, and no defect found items) are listed. Also, graphical representations of aircraft readiness over periods of time are given. Most of these reports are confidential.

The Reliability and Maintainability reports give information regarding total aircraft flight hours over a period of time and

reliability measures based on that time (e.g., mean flight hours between failure) for aircraft equipment. Also, the total number of failures of a WUC item and the average manhours of elapsed time per maintenance action on that item are listed.

In the Service and Support reports, maintenance actions on WUC items are broken down into different categories. Here we find the total number of repairs completed, the total number of condemnations, and the amount sent on to the depot for repair. The manhours associated with these actions at the organizational and intermediate levels are included, as well as local repair cycle times.

Finally, the Control and Administrative reports contain data discrepancy measures used as a control mechanism to monitor the efficiency of data flow, and the data accuracy of 3-M Aviation reports. Individual work supervisors and NAMS0 representatives make use of these reports to insure that maintenance information is properly collected.

The 3-M Aviation reports are numerous and detailed. As was noted earlier, the standardization of aviation equipment among different aircraft, and the relative ease of their transportation and repair greatly aids in the attempt to document and process aviation maintenance data. The 3-M Aviation Data System takes full advantage of this to present reports whose emphasis is on comprehensive data measurements taken over the full range of aviation equipments.

3-M Ships Reports

The 3-M Ships reports cover maintenance data on most non-aviation equipment installed on ships, service craft, and small boats.* Medical equipment, fleet ballistic missiles, nuclear power plants, and associated test equipment are not included. Equipment data are totaled by specific ship, and are summarized for all ships reporting data on the equipment. The time period covered by the reports must be specified by the report user.

Shipboard equipment is referenced through its Equipment Identification Code (EIC). This categorization of equipment is conceptually similar to the aviation WUC listing. Although seven position EIC's are listed, information at this level is difficult to obtain. 3-M Ships reports are usually limited to four position EIC's, which represent items at one indenture level lower than the subsystem level. If analysis of components at a lower indenture level is desired, the report user must specify the stock number of individual items and have information retrieved for those items specifically. As is the case with the Aviation reports, data given for a particular EIC represent all the components in the equipment categorized by the EIC.

Ships and certain offboard maintenance activities are referenced by a unique Unit Identification Code (UIC). Ships are further identified by their type and hull number. The EIC list-

* OPNAVINST 4790.4, OP-4330, "Ships' 3-M Manual, Vol. 1," 1973.

ing may be obtained through reference to the EIC Master Index, while UIC and ship types and hull number listings are found in the Ships Status Report. Both can be requested through NAMSO.

The primary data source for 3-M Ships reports is a standardized Maintenance Action Form (MAF), filled out by the maintenance technician. The technician must classify each maintenance action in one of three categories: a completed action, a deferral, or a completed deferral. A completed action describes "maintenance not previously deferred that was completed within a reasonable length of time." A deferred action is one in which "maintenance must be completed at some other time" due to the lack of parts, or the need for outside assistance. Completed deferrals describe "maintenance that has been completed after it was deferred."*

Maintenance actions defined in one of these three ways are processed by 3-M Ships at both the organizational (shipboard) and intermediate (tender/base) repair levels. No depot repair data are processed. The great majority of shipboard maintenance actions are classified as deferrals. In fact, non-deferred maintenance documentation is required for only certain select equipment onboard certain select ships. These "select"

* Trainee's Guide: Documenting Maintenance for 3-M: MDCS Documentation Identification, Naval Education and Training Support Center, Pacific, 1975, p.3.

equipments are those which are new, modified, or have proven unreliable in the past.

There are seven families of 3-M Ships reports, with much report overlap between families. The seven families and representative data measures are as follows:

Monitoring reports: Listings of total deferrals; completed deferrals; reported maintenance actions; and ships force manhours for a particular ship or EIC item.

Analytic reports: Total manhours and parts cost expended in reported maintenance actions; rankings of high failure items; and ship steaming hours.

Reliability and Maintainability reports: For selected equipment only: mean active maintenance time; mean time between failure; and other R&M measures.

Parts Usage reports: Detailed counts of parts issued in the support of maintenance.

Configuration Changes reports: The number of and time spent on ship/equipment alterations.

Manning reports: Total manhours expended at given ships/IMA's; average manhours per EIC item.

INSURV reports: The number of and time spent in performing required Board of Inspection and Survey actions.

The 3-M Ships data are not exhaustive; the system does not emphasize the collection of detailed information on all equipments. In addition, the large number of deferrals at the organizational level complicates repair cycle measurements, and the lack of documentation for certain items leaves gaps in the data base.

Obtaining Reports

NAMSO recommends that potential 3-M Data System report users contact representatives at NAMSO to discuss their data requirements. In many cases, data files may be manipulated to extract information not shown as part of standard reports. General catalogues are available through NAMSO which describe the most widely-used Aviation and Ships reports. For further information contact:

3-M Ships reports: (717) 790-2043/3124/3695/3558

3-M Aviation reports: (717) 790-2031